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GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

PAPER 73-1
Part A

REPORT OF ACTIVITIES, Part A: April to October 1972

Price, $2.00

1973

CANADA

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PAPER 73-1
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Part A: April to October 1972

DEPARTMENT OF ENERGY, MINES AND RESOURCES

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CONTENTS

Page

INTRODUCTION 1

APPALACHIAN GEOLOGY

1. F.D. ANDERSON: Central mineral belt of Newfoundland 2

2. H.H. BOSTOCK: Belle Isle, Newfoundland 2

3. L.M. CUMMING: Geology of the proposed Gros Morne National Park, western Newfoundland 5

4. HAROLD WILLIAMS, W.R. SMYTH, and R.K. STEVENS: Hare Bay allochthon, northern Newfoundland 8

COAL RESEARCH

5. P.A. HACQUEBARD: Studies by the Coal Petrology Section 15

6. S.H. WHITAKER, P. BROUGHTON, and J.A. IRVINE: Joint Federal-Provincial coal evaluation program in Saskatchewan . 15

CORDILLERAN GEOLOGY

7. S.L. BLUSSON: Operation Stewart Yukon Territory and District of Mackenzie 17

8. B.E.B. CAMERON: Tertiary stratigraphy and microfaunas from the Pacific Margin, west coast Vancouver Island 19

9. R.B. CAMPBELL and A.V. OKULITCH: Stratigraphy and structure of the Mount Ida Group, Vernon, Adams Lake, and Bonaparte map-areas 21

10. G.H. EISBACHER: Tectonic framework of Sustut and Sifton Basins, British Columbia 24

11. J.W.H. MONGER: Upper Paleozoic rocks of the western Canadian Cardillera 27

12. J.E. MULLER: Geology of Pacific Rim National Park 29

13. J.E. REESOR: Blanket Mountain area, British Columbia 38

14. T.A. RICHARDS and C.J. DODDS: Hazelton (east-half) map-area British Columbia 38

15. J.A. RODDICK, W.W. HUTCHISON, and G.J. WOODWORTH: Coast Mountains Project 42

16. J.G. SOUTHER: Cordilleran volcanic project, Spectrum Range .. 46

17. D.J. TEMPELMAN-KLUIT: Operation Snag-Yukon 48

Page

GEOCHEMISTRY

18. R. J. ALLAN, E. M. CAMERON and C. C. DURHAM: Bear-Slave Operation 50

19. Q. BRISTON: Development of geochemical instrumentation...... 53

20. W. DYCK: The use of volatile compounds in mineral exploration. 54

21. E. H. W. HORNBROOK: Canada-Newfoundland Mineral Development Program, Project 6; Geochemical-Glacial Geological Survey (Geochemical Phase).. 56

22. JEAN-PIERRE LALONDE: Dispersion of fluorine in the vicinity of fluorite deposits.. 57

23. M. H. TIMPERLEY, I. R. JONASSON and R. J. ALLAN: Sub-aquatic organic gels: A medium for geochemical prospecting in the southern Canadian Shield 58

24. M. H. TIMPERLEY, R. E. HORTON and J. J. LYNCH: The analysis of metals in geological materials by D. C. ARC direct reading emission spectrometry 63

GEOCHRONOLOGY

25. R. K. WANLESS and R. D. STEVENS: Collection of samples from the Kaminak Group for zircon age determination (Kaminak Lake area, District of Keewatin) 65

GEOPHYSICS

26. A. BECKER and A. K. SINHA: Airborne resistivity electro-magnetic system.. 67

27. B. W. CHARBONNEAU: Ground investigations of the Mont Laurier airborne radioactivity survey...................... 67

28. A. G. DARNLEY: The use of total radioactivity measurements for reconnaissance airborne surveys...................... 79

29. A. V. DYCK: Airborne INPUT surveys 81

30. R. L. GRASTY: Gamma-ray scattering corrections for the air-borne measurements of uranium.......................... 82

31. G. D. HOBSON: Seismic refraction-Sverdrup Basin............ 83

32. P. J. HOOD and MARGARET E. BOWER: Davis Strait: Low-level aeromagnetic profiles obtained in 1972 84

Page

33. J.A. HUNTER and L. ROSNUK: Shallow seismic surveys, Yukon coast 86

34. J.A. HUNTER, L. ROSNUK and K. KEELER: Shallow seismic refraction surveys, New Brunswick 86

35. J.A. HUNTER, R.A. BURNS, R. GOOD and P. BAZELEY: Shallow seismic refraction survey Mackenzie River Valley 86

36. T.J. KATSUBE: Electrical rock properties 87

37. P.G. KILLEEN and G.D. HOBSON: EGMA seismic survey 88

38. L.J. KORNIK and P.H. McGRATH: Magnetic test range near Timmins, Ontario 90

39. A. LAROCHELLE: Federal-Provincial aeromagnetic surveys 93

40. K.A. RICHARDSON: Airborne radioactivity measurements over the Canadian Shield 94

41. P. SAWATZKY, D.W. OLSON, and PETER J. HOOD: Experimental high-resolution aeromagnetic surveys: 1972 95

42. W.J. SCOTT: VLF mapping 97

43. V.R. SLANEY: Colour aerial photography east of Great Bear Lake, District of Mackenzie 98

44. S. WASHKURAK: Weather satellite pictures 98

45. S. WASHKURAK: Optical data processing 101

MARINE GEOSCIENCE

46. D.E. BUCKLEY: Geochemical interactions between water and particulate solids and models for the mechanisms of metal dispersion and accumulation in marine environments 104

47. R.E. CRANSTON: Development of shipboard methods for marine geochemical analyses 107

48. I.M. HARRIS: Under-water, diamond drill trial and support survey northeast of Belle Isle, Newfoundland 109

49. R.T. HAWORTH: Natural resource charts 109

50. R.T. HAWORTH: Geophysical investigation of the Laurentian Channel and southern Grand Banks of Newfoundland 112

Page

51. C. E. KEEN: Continental margin of eastern Canada 112

52. LEWIS H. KING, BRIAN MacLEAN and GORDON B. FADER: Marine activities of the Grand Banks 113

53. B.R. PELLETIER: Bottom studies of the Beaufort Sea 115

54. D. I. ROSS: Geophysical studies of Baffin Bay and adjacent continental margins 116

55. C. T. SCHAFER: Studies of Benthonic Faraminifera in the Restigouche Estuary, Quebec 117

56. S. P. SRIVASTAVA: Magnetic variations 118

57. S. P. SRIVASTAVA: Geophysical studies of the continental margin and of the deep sea off the west coast of Canada............. 119

58. D. L. TIFFIN: Magnetometer survey west of Baillie Islands 120

59. D. L. TIFFIN: Marine geophysical activities on the Pacific margin 121

60. W. J. VAN DER LINDEN: The Labrador Shelf 121

61. G. VILKS: Ecology of recent planktonic foraminifera in the surface waters of the Beaufort Sea 122

62. D. A. WALKER: Test surface ultrastructure of benthonic foraminifera and applications of scanning electron microscopy 123

63. D. A. WALKER: Field and laboratory investigations of the life cycles, microecology and species succession of the tide pool foraminifera of Nova Scotia.......................... 124

MINERAL DEPOSITS

64. O. R. ECKSTRAND and A. R. MILLER: A study of sulphide and spinifex distribution of the Texmont nickel deposit 125

65. R. V. KIRKHAM: Geology of copper and molybdenum deposits in Canada.. 126

66. R. MULLIGAN: Geology of lithophile elements 127

67. E. R. ROSE: A note on rare-earth occurrences in eastern Canada 128

68. D. F. SANGSTER: Geology of Canadian lead and zinc deposits ... 129

Page

MINEROLOGY

69. J. Y. H. RIMSAITE: Mica group minerals and related silicates in Canadian mineral deposits 131

PALEOMAGNETISM

70. K. W. CHRISTIE: Paleomagnetism of the Hopedale diabase dykes.. 135

71. W. F. FAHRIG: Paleomagnetism of the dykes of west Greenland . 135

72. W. F. FAHRIG: Paleomagnetism of the Lac St-Jean anorthosite . 135

73. J. FOSTER: Paleomagentic reversals in the Paleozoic of the St. Lawrence platform 136

74. J. C. McGLYNN: Paleomagnetic study of the Proterozoic red beds of western Canadian Shield........................... 136

75. E. J. SCHWARZ: Thermomagnetics of single minerals and rocks . 137

PETROLOGY

76. K. L CURRIE: The Red Wine - Letitia alkaline province of Labrador 138

77. R. F. EMSLIE: Harp Lake intrusive complex 139

78. E. FROESE and I. HUTCHEON: Petrological studies in the vicinity of the Kisseynew Front 139

PRECAMBRIAN GEOLOGY

79. F. H. A. CAMPBELL: Sedimentary rocks of the Prince Albert Group, District of Keewatin 141

80. I. F. ERMANOVICS and ANTON BROWN: Geological studies in southeastern Manitoba 143

81. THOMAS FRISCH: Granitic and associated rocks of the Committee Bay area, Districts of Keewatin and Franklin 145

82. R. A. FRITH: The geology of the Bear-Slave boundary in the Indian Lake area, District of Mackenzie 146

83. JOHN B. HENDERSON, M. B. LAMBERT and G. R. PEELING: Yellowknife and Hearne Lake map-areas, District of Mackenzie 148

Page

84. P. F. HOFFMAN: Aphebian supercrustal rocks of the Athapuscow aulacogen, East Arm of Great Slave Lake, District of Mackenzie . 151

85. I. KNIGHT: The Ramah Group between Nachvak Fjord and Bears Gut, Labrador.................................... 156

86. W. C. MORGAN: Ramah Group and the contact between Archean and Proterozoic in north Labrador.......................... 162

87. E. W. REINHARDT, and F. W. CHANDLER: Gibson-MacQuoid Lakes map-area, District of Keewatin 162

88. R.H. RIDLER: Volcanic stratigraphy and metallogeny; Rankin Inlet-Ennadai Belt, District of Keewatin 165

89. MIKKEL SCHAU: Volcanic rocks of the Prince Albert Group 175

QUATERNARY GEOCHRONOLOGY AND PALEONTOGY

90. T. W. ANDERSON: Historical evidence of land use in a pollen profile from Osoyoos Lake, British Columbia................ 178

91. R. J. MOTT: Quaternary palynology, Manitoba and Quebec 180

QUATERNARY GEOLOGY: ENVIRONMENTAL AND ENGINEERING GEOLOGY STUDIES

92. D. M. BARNETT and D. L. FORBES: Terrain performance, Melville Island, District of Franklin........................ 182

93. N. R. GADD: Distribution of marine deposits, Ottawa - St. Lawrence Basin.................................... 183

94. J. E. HARRISON: Environmental geology - mountain coal mining, Alberta and British Columbia 184

95. D. A. HODGSON: Terrain performance, central Ellesmere Island, District of Franklin.............................. 185

96. D. A. ST-ONGE: Geoscientific studies, New Montreal International Airport region 185

97. J. S. SCOTT: Environmental geology prototype study, – Ottawa – Hull region 186

QUATERNARY GEOLOGY: INVENTORY MAPPING AND STRATIGRAPHIC STUDIES

98. N. V. ALLEY, and R. J. FULTON: Co-operative terrain mapping south-central British Columbia 188

		Page
99.	D.M. BARNETT and D.L. FORBES: Surficial geology and geomorphology of Melville Island	189
100.	LYNDA DREDGE: Surficial geology, Sept-Iles – Cap Chat, Quebec	192
101.	M.M. FENTON: Quaternary geology, Winnipeg map-area	194
102.	R.J. FULTON: Terrain mapping in mountainous areas	194
103.	D.R. GRANT: Canada – Newfoundland and Labrador Mineral Development Program Project 6	196
104.	M.G. GROSSWALD: Reconnaissance glacial geology, southwestern Grinnell Penninsula, Devon Island, District of Franklin	199
105.	E.P. HENDERSON: Quaternary geology, Haliburton – Burleigh Falls area, Ontario	200
106.	L.V. HILLS: Beaufort Formation, western Queen Elizabeth Islands	202
107.	D.A. HODGSON: Surficial geology and geomorphology of central Ellesmere Island	203
108.	R.W. KLASSEN and J.A. NETTERVILLE: Quaternary geology inventory Lower Nelson River Basin	204
109.	C.F.M. LEWIS, A.E. WOOTTON and J.B. DAVIS: Stratigraphic and engineering studies of unconsolidated sediments in central Lake Erie near Erieau, Ontario	205
110.	W.H. MATHEWS: Quaternary geology, Charlie Lake, British Columbia	210
111.	J.M. RYDER and R.J. FULTON: Terrain inventory and Quaternary geology of the Ashcroft map-area, British Columbia	212
	QUATERNARY GEOLOGY: TRACING MINERAL DEPOSITS	
112.	W.W. SHILTS: Till indicator train formed by glacial transport of nickel and other ultrabasic components: a model for drift prospecting	213
113.	R.G. SKINNER: Prospecting for diamonds in northern Ontario – a suggestion	218

Page

QUATERNARY SEDIMENTOLOGY AND GEOMORPHOLOGY

114. H. M. FRENCH: Geomorphological processes and terrain sensitivity, Banks Island, District of Franklin 220

QUATERNARY GEOLOGY: SURVEYS AND TERRAIN PERFORMANCE – MACKENZIE VALLEY

These projects are part of the Environmental Social Program Northern Pipelines, of the Task Force on Northern Oil Development, Government of Canada

115. J. A. CODE: The stability of natural slopes in the Mackenzie Valley 224

116. J. A. HEGINBOTTOM: Erosion in a permafrost environment 225

117. J. A. HEGINBOTTOM and P. J. KURFURST: Terrain sensitivity and mapping Mackenzie Valley transportation corridor 226

118. O. L. HUGHES, J. PILON, and J. VEILLETTE: Surficial geology and land classification, Mackenzie Valley transportation corridor 229

119. RALPH M. ISAACS: Engineering geology Mackenzie Valley transportation corridor 230

120. D. E. LAWRENCE: Granular resource inventory - Mackenzie Valley 231

121. J. ROSS MacKAY: Some aspects of permafrost growth, Mackenzie delta area 232

122. B. C. McDONALD and C. P. LEWIS: Sedimentary and geomorphic processes, Yukon Coastal Plain 233

123. GRETCHEN MINNING, J. A. RENNIE, and J. L. DOMANSKY: Granular material inventory – Southern Mackenzie Valley 236

124. E. B. OWEN: Dam site investigations, Yukon and District of Mackenzie 236

125. V. N. RAMPTON: Surficial deposits of Yukon Coastal Plain and adjacent areas 237

126. N. W. RUTTER and A. N. BOYDELL: Surficial geology and land classificiation, Mackenzie Valley transportation corridor 239

127. J. M. SHEARER: Surficial geology and geomorphology, Mackenzie Bay – Continental Shelf 242

Page

STRATIGRAPHY and PALEONTOLOGY

128. J.D. AITKEN, R.W. MAQUEEN, A.E. FOSCOLOS: A Proterozoic sedimentary succession with traces of copper mineralization, Cap Mountain, Southern Franklin Mountains, District of Mackenzie 243

129. H.R. BALKWILL: Structure and stratigraphy, Ringnes Islands and nearby smaller islands, District of Franklin 247

130. K.P. BENDER: Pennsylvanian and Permain conodonts from Arctic Canada 251

131. W.W. BRIDEAUX: Taxonomy, biostratigraphy and paleoecology of Mesozoic miospore and microplankton assemblages from District of Mackenzie 252

132. W.W. BRIDEAUX: Monograph of miospore assemblages from the Lower Colorado Group and comparative studies of assemblages from southwestern Alberta and adjacent British Columbia 252

133. T. POTTER CHAMNEY: Tertiary and Mesozoic micropaleontology sampling, west flank of the Mackenzie River Delta, District of Mackenzie 253

134. W.T. DEAN: Lower and Middle Paleozoic biostratigraphy Gaspé, Québec and Maritime region 253

135. W.H. FRITZ: Cambrian biostratigraphy Mackenzie Mountains and Labrador 254

136. J.A. JELETZKY: Cretaceous and Jurassic stratigraphy of northern Vancouver Island and Manning Park area, British Columbia 259

137. J.Wm. KERR, D.W. MORROW, and K.W. SAVIGNY: Grinnell Peninsula, Devon Island, District of Franklin 262

138. W.S. MacKENZIE: Devonian and older Paleozoic rocks, southern and central District of Mackenzie 263

139. GRANT D. MOSSOP: Lower Ordovician evaporites of the Baumann Fiord Formation, Ellesmere Island 264

140. T.P. POULTON: Jurassic trigoniidae of western British Columbia 268

141. K.J. ROY: Isachsen Formation, Amund Ringnes Island, District of Franklin 269

Page

142. H.P. TRETTIN: Stratigraphy and sedimentology of Upper Ordovician to Lower Devonian clastic formations, Canon Fiord region, Ellesmere Island 273

143. T.T. UYENO: Conodont biostratigraphy of Silurian and Devonian rocks of Canada 277

144. F.G. YOUNG: Jurassic and Cretaceous stratigraphy between Babbage and Blow Rivers, Yukon Territory 277

GENERAL

145. R.W. BOYLE and H.R. STEACY: An auriferous radioactive hydrocarbon from the Richardson Mine, Eldorado, Ontario.... 282

146. R.L. GRASTY, B.W. CHARBONNEAU, and H.R. STEACY: A Uranium occurrence in Paleozoic rocks west of Ottawa 286

147. J.M. LAROSE: Preparation of collections of Canadian rocks and minerals for distribution to the public 289

148. S. LEAMING: Mineral occurrences, British Columbia and Yukon 290

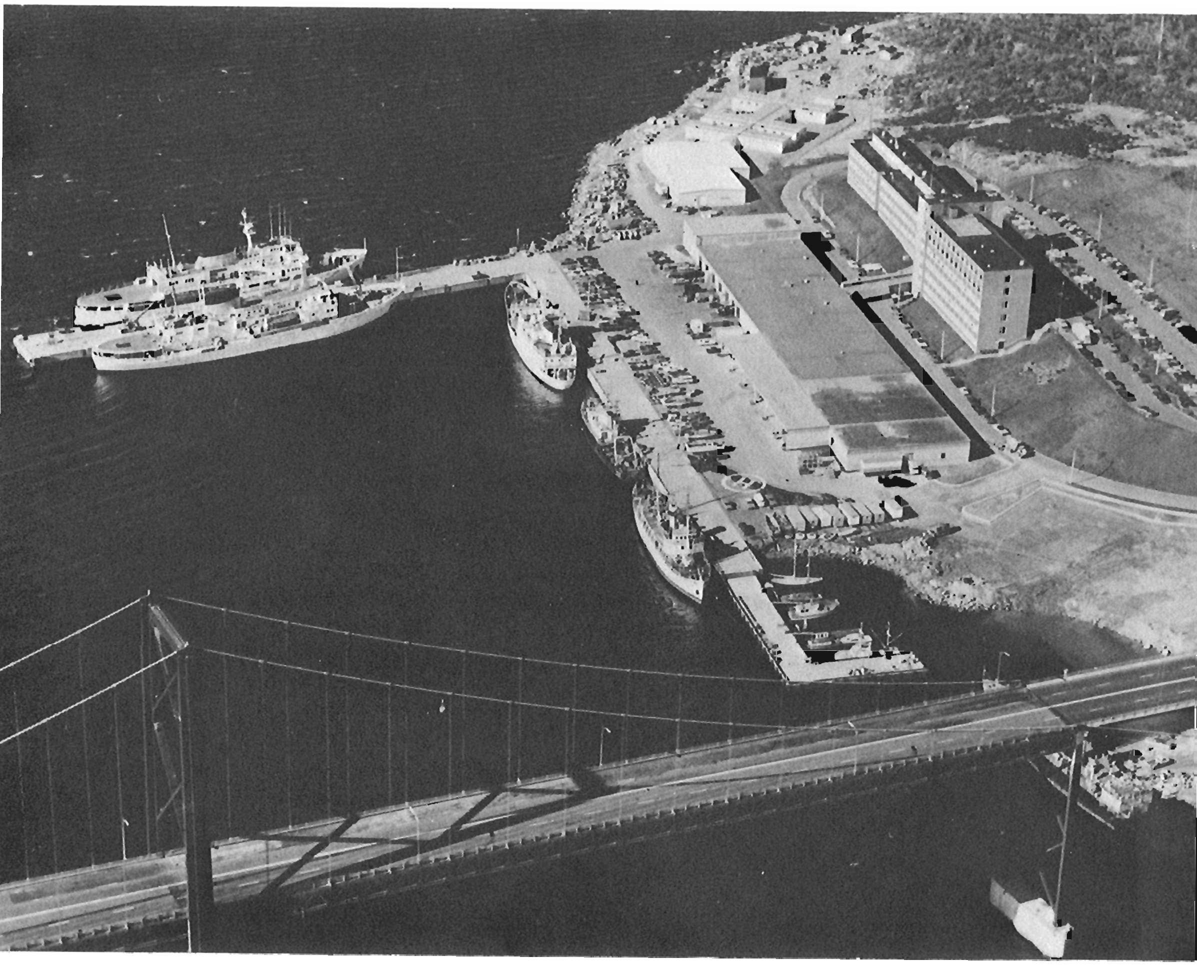
149. A.P. SABINA: Study of mineral collecting areas of interest to collectors and tourists 291

150. H.R. STEACY: National mineral collection 291

AUTHOR INDEX 293
LOCATION INDEX.. 295
PROJECTS NUMBER INDEX 296

ABSTRACT

This report, containing 150 short papers, many illustrated by page-size maps and figures, presents the preliminary results of field work undertaken by members of the Geological Survey of Canada in 1972.



Bedford Institute, Dartmouth, Nova Scotia.

The Atlantic Geoscience Centre, which on April 1, 1972 became a division of the Geological Survey, shares these quarters with branches of the Department of the Environment.

Institut Bedford, Dartmouth, Nouvelle-Écosse

Le Centre géoscientifique de l'Atlantique devient le 1[er] avril 1972 une division de la Commission géologique du Canada et partage ses locaux avec des services du ministère de l'Environnement.

INTRODUCTION

The Geological Survey of Canada, a branch of the Department of Energy, Mines and Resources, was founded in 1842 and is the principal geological agency of the federal government. Its primary role is to provide an overview of all facets of Canadian geology as a basis for national policy, for government and industrial planning and for public information.

In addition to data derived from its own field and laboratory projects, the Geological Survey receives information from provincial agencies and private companies. These results are integrated to provide the geological basis for national policy in all fields affected by geology; for the search and evaluation of Canada's potential mineral resources; for the planning by industries and governments concerned with regional and northern development; for land use and urban development; for conservation, recreation and engineering; for construction; indirectly for forestry, agriculture and water supply, and for national security.

The objectives of the Geological Survey comprise geological aspects of the objectives of the official Mineral and Energy Resources Program and the Earth Sciences Program of the Department. Current objectives of the Geological Survey are:

To provide a comprehensive inventory and understanding of the geological framework and processes in Canada as a basis for national policy and planning in all matters affected by geology, with special emphasis on:

- ascertaining our national energy and mineral resources;
- facilitating their exploration and development;
- promoting regional development in Canada;
- identifying and describing geological features and processes that affect environmental and ecological equilibrium, with particular emphasis on the effects of energy and mineral development;
- identification and inventory of Quaternary and Recent features and ongoing geomorphological processes that affect use of the terrain, engineering design, urban development and the renewable resource industries (forestry, agriculture, fisheries);
- identifying and assessing natural hazards;
- disseminating information on the Canadian landmass; and surrounding continental shelves and the resources they contain.

This report, the outgrowth of compilations of preliminary results of each year's field program, has expanded during the past decade to include a wide range of relatively brief papers. The addition on April 1, 1972 of the Atlantic Geoscience Centre as a division of the Geological Survey has further widened the scope. Submissions for inclusion in this report were accepted until November 17, 1972. Many of the conclusions presented are based on a preliminary assessment of the data collected and are therefore subject to confirmation or revision in the light of more detailed office and laboratory studies. To expedite publication, illustrations are reproduced directly from material submitted by the authors and the text has been given a minimum of editorial attention. The 150 papers that make up this publication are arranged in broad geoscientific categories. An index to geographic locations (arranged by province, territory or district) and an authors' index follow the text; for branch use, project numbers are included with each paper.

Format

APPALACHIAN GEOLOGY

1. CENTRAL MINERAL BELT OF NEWFOUNDLAND

Project 710045

F. D. Anderson
Regional and Economic Geology Division, Ottawa

The geology of the Lake Ambrose and Star Lake (east-half) map-areas was examined during the 1972 field season. This completes the field portion of a project started in 1971 by which mining exploration company geology maps and reports in the central mineral belt are compiled and lithology and formational contacts examined in the field. The co-operation of American Smelting and Refining Company - Buchans Unit is gratefully acknowledged. Maps, on a scale of 1:50,000 and an accompanying report will be published on the two areas.

The distribution of the major rock units as outlined by Williams[1] has been modified slightly. Possible Silurian rocks are probably more extensive than previously mapped. Brachiopods were found in a calcareous siltstone intercalated with volcanic rocks near the mouth of Victoria River. Carboniferous strata on the east shore of Red Indian Lake dip up to 75 degrees, indicating considerable post-depositional activity. Previous mapping portrayed the Carboniferous strata as essentially horizontal.

[1] Williams, Harold: Red Indian Lake (East Half), Newfoundland; Geol. Surv. Can., Map 1196A (1970).

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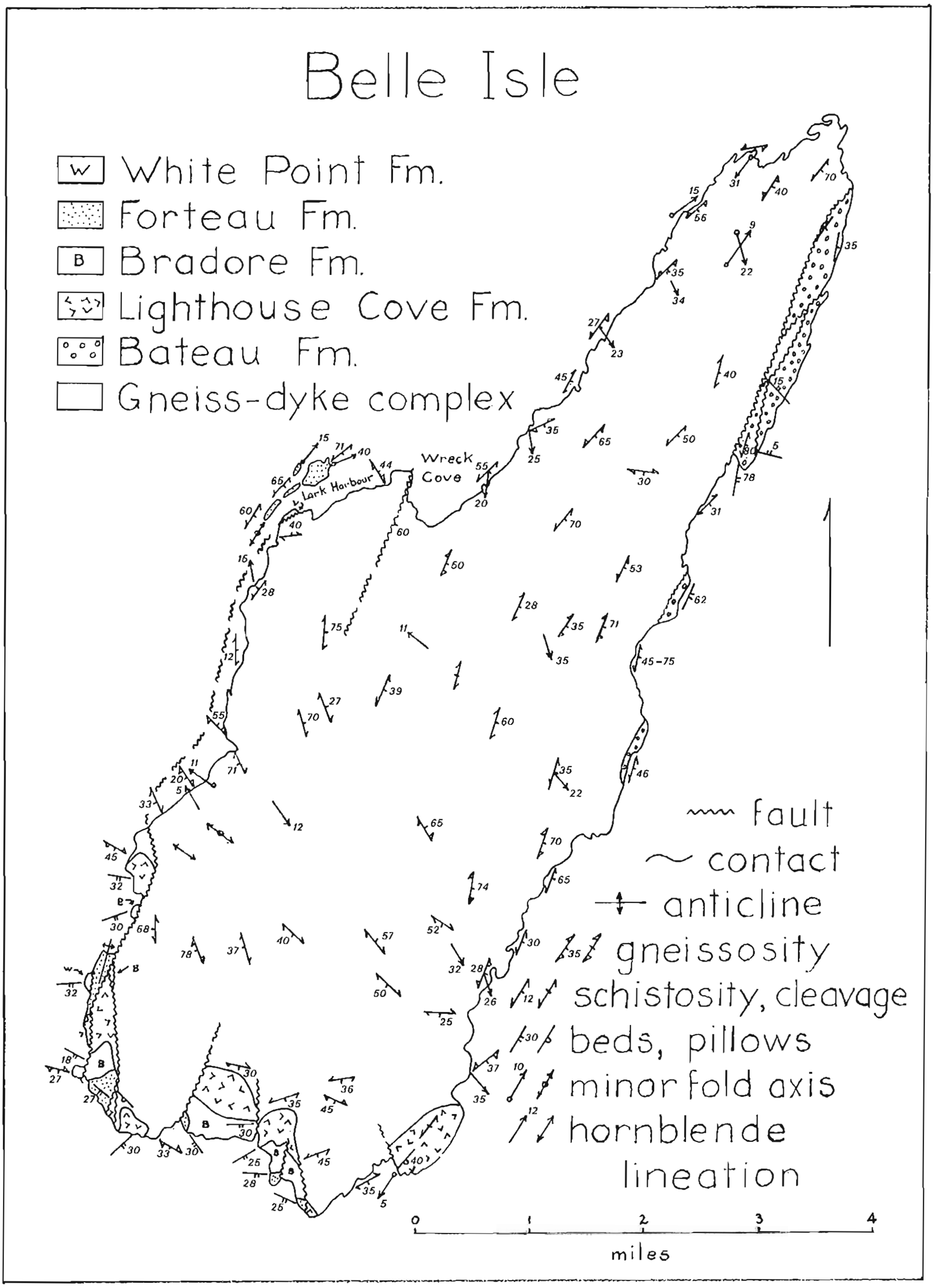
2. BELLE ISLE, NEWFOUNDLAND (2M/14 West)

Project 680130

H. H. Bostock
Regional and Economic Geology Division, Ottawa

The Precambrian rocks of Belle Isle were studied for two weeks, thus completing the mapping of Precambrian rocks of the Strait of Belle Isle region within Operation Strait of Belle Isle (Project 680130). The writer is indebted to Mr. Thomas O'Dell and Mr. George Thomas, lighthouse keepers, who landed the party with their boat during calm weather at numerous points around the island.

Belle Isle is surrounded by bluffs some of which reach more than 500 feet above the sea. Inland the surface rises to slightly over 800 feet above sea level. The west side of the island is covered by a veneer of drift that thins eastward. Glacial striae trend easterly about 110 degrees. Late, eastward ice movement is clearly indicated by an eastward diminishing train of erratics from the White Point Formation. The dominant physiographic features on the island are northeast-trending ridges underlain by doleritic dykes that probably make up from 30 to 50 per cent of the basement and form in excess of 90 per cent of exposure inland.


Belle Isle
W White Point Fm.
Forteau Fm.
B Bradore Fm.
Lighthouse Cove Fm.
Bateau Fm.
Gneiss-dyke complex
Wreck Cove
Lark Harbour
fault
contact
anticline
gneissosity
schistosity, cleavage
beds, pillows
minor fold axis
hornblende lineation
0 1 2 3 4
miles

The oldest rocks on Belle Isle are composed predominantly of medium-grained, grey to pink and greenish, schistose and banded, hornblende-quartz-feldspar gneiss with a colour index of 10 or greater. Lighter coloured gneiss, and biotite gneiss, in contrast to their abundance in the northern Long Range and southeast Labrador, are subordinate. Quartz-rich gneiss is uncommon and pelitic gneiss is apparently absent. Foliation (gneissosity, schistosity) in the gneisses in the southwest part of the island trends west to northwest and dips southwest. Minor folds and hornblende lineation, that trend parallel to the foliation, plunge gently. Foliation in the northern and eastern parts of the island trends northeast and dips southeast. Northeast-trending gently plunging minor folds, which were not observed in the southwest part of the island, are younger than the hornblende lineation.

The Bateau Formation[1] lies against the northeastern coast of the island and is composed of quartzite, conglomerate, siltstone, slate and minor volcanic rocks. In the south these rocks lie unconformably upon gneiss but farther north, where the underlying gneisses are sheared and shattered, the contact is probably a fault. There, the formation occupies at least three fault wedges, two of which are partly separated by a wedge of sheared basement gneiss. The attitude of bedding in the Bateau Formation differs by 60 to 75 degrees from one wedge to another, suggesting that the wedges have been rotated with respect to one another. Northeast-trending doleritic dykes were abundantly intruded into both basement gneiss and the Bateau Formation. These dykes show a southeastward dipping schistosity that is commonly pronounced in the eastern part of the island, but there is no evidence that the dykes have been rotated between wedges of the Bateau Formation. Thus the Bateau Formation has undergone at least two periods of deformation, one prior to, and one post-dating the emplacement of the dykes.

Apparently younger supracrustal rocks comprising the Lighthouse Cove (chiefly basalt), Bradore (chiefly arkose), Forteau (chiefly shale), and White Point (chiefly chert, siltstone, carbonate) Formations[1] overlie the gneiss along the southern and western coast of the island. Massive basalt, possibly a sill, lies at the base of the Lighthouse Cove basalts, and was fed by doleritic dykes, but the dykes do not penetrate the overlying Bradore and younger formations. The basic volcanic rocks are tholeiitic[2]. All these formations for the most part occupy two northerly trending grabens separated by horsts of gneiss and dyke rock overlain by remnants of the lowermost formation, the Lighthouse Cove basalts. The basalt on the horsts dips southeast whereas the sediments in the grabens dip predominantly south to southwest suggesting that faulting has resulted in a rotational movement between horsts and grabens. The western graben is truncated by a steeply dipping reverse fault that extends northward near the west shore of the island as far as Lark Harbour. The Forteau Formation west of this fault is tightly folded with east-dipping to vertical axial plane cleavage. Near White Point and at Lark Harbour the fold axes are nearly horizontal but on the northern islands north of Lark Harbour they plunge 15 to 40 degrees northeast.

[1] Williams, H. and Stevens, R.K.: Geology of Belle Isle-northern extremity of the deformed Appalachian miogeosynclinal belt; Can. J. Earth Sci., v. 6, p. 1145-1157 (1969).

[2] Strong, D.F. and Williams, H.: Early Paleozoic flood basalts of northwestern Newfoundland: their petrology and tectonic significance; Proc. Geol. Assoc. Can., v. 24, p. 43-54 (1972).

3. GEOLOGY OF THE PROPOSED GROS MORNE NATIONAL PARK, WESTERN NEWFOUNDLAND

Project 720076

L. M. Cumming
Regional and Economic Geology Division, Ottawa

This coastal area of approximately 550 square miles, originally surveyed by Capt. James Cook,[1,2] extends north from the ophiolitic rocks near Trout River[3,4] to the limestone megabreccias of Lower Head near Cow Head Harbour[5].

Four landscape areas occur within the park: -

1. The high plateau of the Long Range is composed of crystalline Precambrian rocks. Diabase dykes cut Grenvillian gneiss and are exposed in 2,000-foot vertical cliffs at Western Brook Pond.

2. The coastal lowlands are composed of autochthonous and allochthonous rocks including limestone (see Fig. 1), dolostone, shale, sandstone, greywacke and flysch[6]. These rocks display spectacular small-scale folds and distinctive lithologies, including various Cow Head "breccias".

3. The uplands north of Upper and Lower Trout River Ponds are made up of thrust sheets composed of volcanic, granitic and ultrabasic rocks[4,7]. The uppermost thrust slice is the layered igneous rocks of Table Mountain. These are believed to represent oceanic crust which has been thrust on top of continental crust.

4. The uplands around Bonne Bay are composed of faulted and folded lower Paleozoic strata. Gros Morne itself (2,644 feet, the second highest mountain in Newfoundland) is a down-faulted, pie-shaped wedge of Cambrian carbonates capped by quartzite (Fig. 2) of the Hawke Bay Formation.

The park area, situated on the western side of a large landmass and exposed to prevailing westerly winds, was the site of a Pleistocene ice cap. Valley and piedmont glaciers greatly modified the landscape[8]. Finger lakes (Fig. 3) and a fiord provide spectacular scenery near the western escarpment of the Long Range.

A geological and resource inventory map of the park was compiled on the scale 1:50,000. Stream sediments and tills were sampled to provide a reconnaissance geochemical survey of the area.

[1] Cook, James: A exact trigonometrical survey of the west coast of the island of Newfoundland taken by order of Commodore Palliser, Governor of Newfoundland, Labrador, etc., scale 6,000 feet to one inch; National Archives of Canada - English Charts, Ser. I, No. 1 (1767).

[2] Cook, James: James Cook, surveyor of Newfoundland. Being a collection of charts of the coast of Newfoundland and Labrador, etc., drawn from original surveys taken by James Cook and Michael Lane; London, Jefferys, 1769-1770. Facsimile with introductory essay by R. A. Seelton; San Francisco, David Magee (1965).

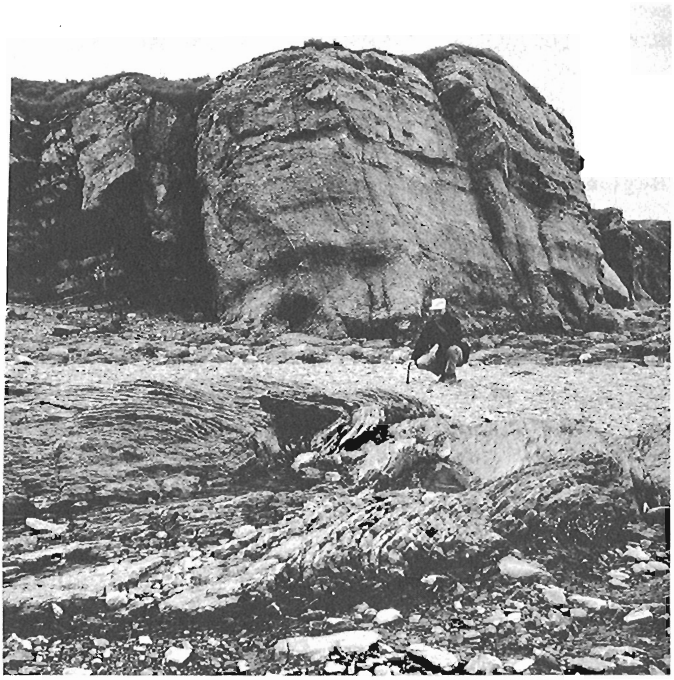


Figure 1. Massive limestone turbidite and underlying contorted thin-bedded limestones; north shore of Cow Head. GSC photo 201825-B

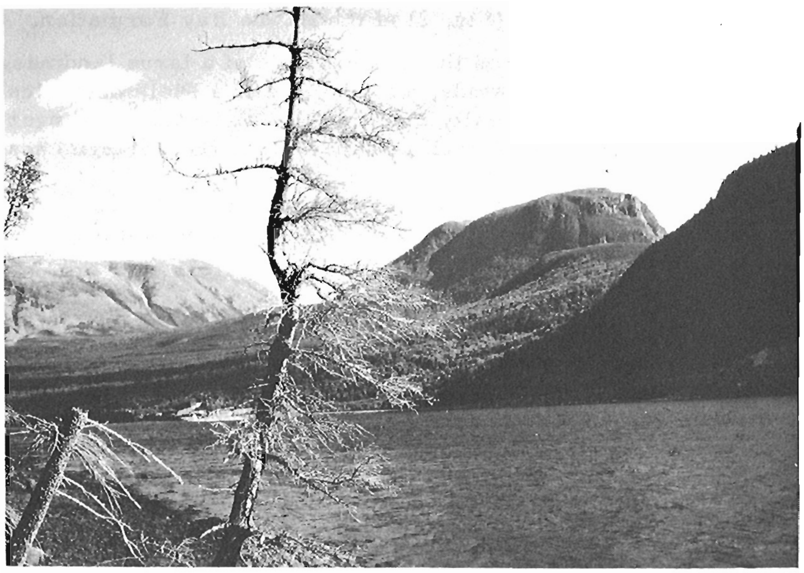


Figure 2. Gros Morne (2,644') is the barren ridge of quartzite on the left. These Cambrian strata are faulted against Precambrian gneiss, forming Old Crow Mountain (2,150') in the middle distance. View is to the northeast from Deer Arm. GSC 201825-N

Figure 3. View to the southeast, looking toward the entrance of glaciated valley at Western Brook Pond. GSC photo 201825-M

[3]Baird, D. M.: Sandy Lake, west half, Newfoundland; Geol. Surv. Can., Map 47-1959 (1960).

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[5]Kindle, C. H. and Whittington, H. B.: Some stratigraphic problems of the Cow Head area in western Newfoundland; N. Y. Acad. Sci. Trans., ser. 2, v. 22, p. 7-18 (1959).

[6]Stevens, R. K.: Cambro-Ordovician flysch sedimentation and tectonics in west Newfoundland and their possible bearing on a Proto-Atlantic Ocean; in Flysch Sedimentology in North America, J. Lajoie (ed), Geol. Assoc. Can., Spec. Paper no. 7, p. 165-177 (1970).

[7]Smith, C. H.: Geological Map 1086A (Trout River); Geol. Surv. Can., scale 1 inch to 1 mile (1960).

[8]Grant, D. R.: Late Pleistocene Re-advance of Piedmont Glaciers in Western Newfoundland; Mar. Sed., v. 5, no. 3, p. 126-128 (1961).

4. HARE BAY ALLOCHTHON, NORTHERN NEWFOUNDLAND

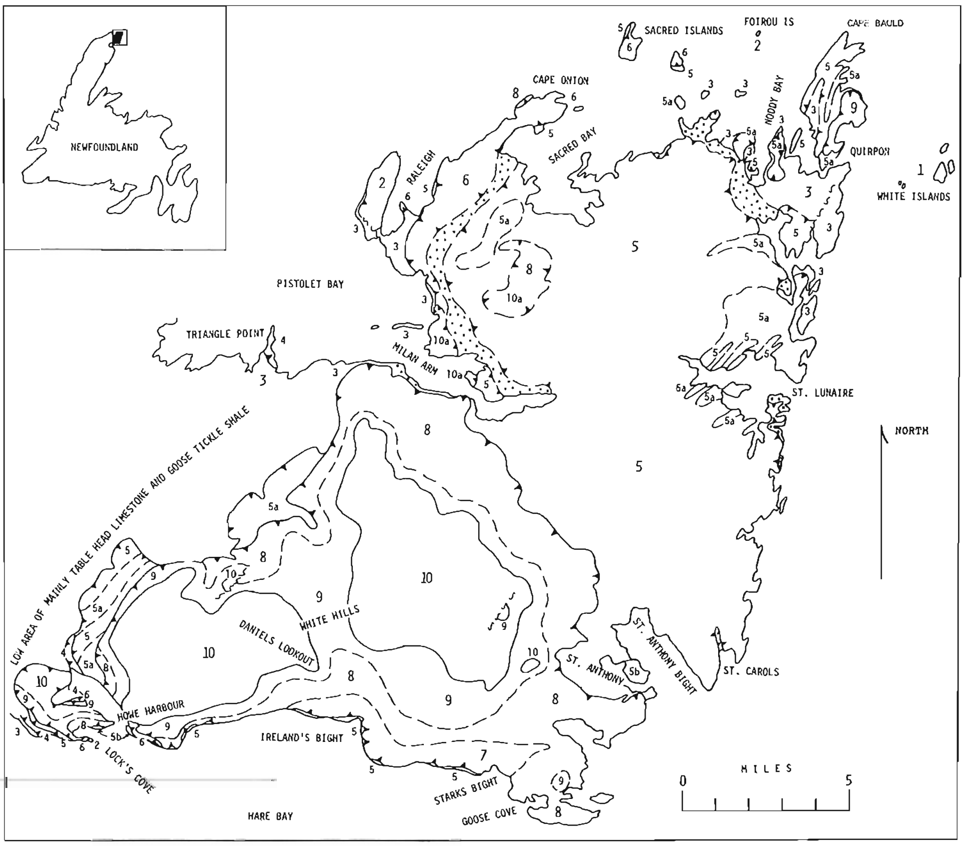
Project 720093

Harold Williams*, W.R. Smyth*, and R.K. Stevens*

Approximately 60 per cent of the Hare Bay allochthon north of Hare Bay was mapped for publication at a scale of 1 inch to 2 miles, and reconnaissance studies were carried out in the remainder of the area.

Autochthonous rocks below the allochthon are mainly Middle Ordovician flysch of the Goose Tickle Formation (3)[1,2], underlain by limestone of the Middle Ordovician Table Head Formation (2). The quartzite on White Islands is of unknown age and relationship but is correlated lithologically with the Bateau Formation (1) of Belle Isle[3].

Four lithologically distinct rock groups are recognized among the transported rocks. Each comprises one or more separate slices that occur in a definite and consistent stacking order with respect to structural slices of contrasting rock groups. Structural slices of the same rock group and at the same level within the structural succession are collectively referred to as a



*Memorial University, St. John's, Newfoundland

Legend for Figure 1 (opposite)

WHITE HILLS SLICE ASSEMBLAGE

LOWER ORDOVICIAN OR OLDER

10	Foliated peridotite and dunite; 10a, includes serpentinite, amphibolite, hornblendite, pyroxenite, and rhodingite
9	Amphibolite, garnetiferous amphibolite, and garnet-amphibole-biotite schist
8	GOOSE COVE FORMATION: green chloritic schist mainly of volcanic derivation, black phyllitic schist, grey schistose limestone, and minor psammitic schist
7	IRELAND POINT VOLCANICS: schistose to massive purple and green agglomerate, amygdaloidal (calcite) purple and green lava, and green pillow lava

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CAPE ONION SLICE ASSEMBLAGE

LOWER ORDOVICIAN

6	Dark grey to black amygdaloidal (calcite) pillow lava, agglomerate, tuff, minor black graphitic shale and diorite dykes

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MAIDEN POINT SLICE ASSEMBLAGE

LOWER CAMBRIAN (?) OR OLDER

5	MAIDEN POINT FORMATION: coarse greywacke to pebble conglomerate with blue quartz grains, grey siltstone and black and red argillite; 5a, green agglomerate, tuff, tuffaceous siltstone and sandstone, and pillow lava; 5b, medium- to coarse-grained massive diorite

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NORTHWEST ARM SLICE ASSEMBLAGE

LOWER ORDOVICIAN

4	NORTHWEST ARM FORMATION: black and green shale with boulders and blocks of buff-weathering limy siltstone, sandstone, and limestone. Locally includes limestone breccia beds and blocks of limestone breccia.

AUTOCHTHONOUS ROCKS

MIDDLE ORDOVICIAN

3	GOOSE TICKLE FORMATION: grey to dark grey sandstone, siltstone and shale with local conglomerate beds
2	TABLE HEAD FORMATION: grey nodular-weathering limestone

LOWER CAMBRIAN OR OLDER

1	BATEAU FORMATION: white quartzite, minor grey to purple shale

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∴	Mélange with black and green shale matrix and mainly sandstone (5) and volcanic (6) blocks.

'slice assemblage' (Fig. 1). Individual slices within an assemblage are locally superposed but more commonly they are widely separated, either as erosional remnants of a once continuous slice or as singly transported slices.

The transported slices in most places are separated by mélange zones that vary from a few feet to several tens of feet in thickness. These zones consist of a variety of boulders and larger blocks mainly of Maiden Point sandstone and volcanic rocks surrounded by black or black and green shale. In a few places where relatively high structural slices lie directly upon autochthonous flysch, mélange is sparse or absent, and the contact is a 'hard' thrust.

The four distinct rock groups comprise four slice assemblages as defined above. No continuous vertical section exhibits all four so that the order of structural stacking must be built up from observations throughout the map-area. Each slice assemblage is in contact with every other slice assemblage at least locally, and each in some place lies upon autochthonous flysch of the Goose Tickle Formation (Fig. 2). Ommisions in the stacking order are therefore commonplace, but reversals are unknown.

The four slice assemblages of the Hare Bay allochthon and their general geological features, from the structurally lowest to the structurally highest, are as follows:

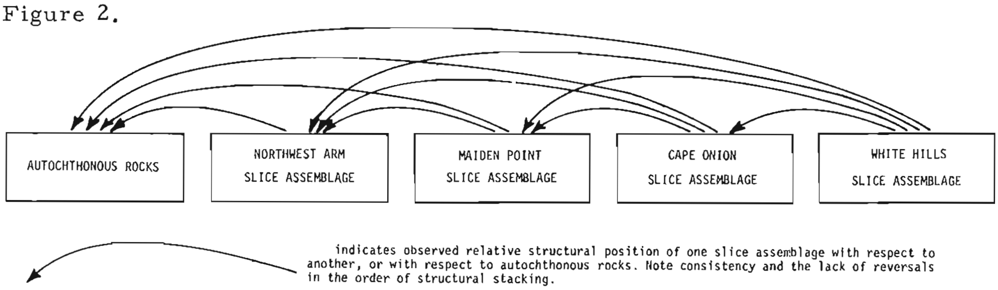
1. <u>The Northwest Arm slice assemblage</u> – composed of black and green shale with boulders and larger detached blocks of buff-weathering limy siltstone, grey sandstone, white to grey limestone, and limestone breccia (4) (the Northwest Arm Formation of Cooper)[1]. The rocks locally contain Lower Ordovician graptolites at Pistolet Bay[2, 4], and they are everywhere chaotic and rubbly. The Northwest Arm Formation (4) directly overlies the younger Goose Tickle Formation (3). Basal relationships are well exposed at Triangle Point and west of Lock's Cove, at the western extremity of the Hare Bay allochthon. The Northwest Arm Formation is of limited areal extent and occurs only at the western margin of the Hare Bay allochthon where its now widely separated occurrences may represent erosional remnants of a once much more continuous slice or slice assemblage.

2. <u>The Maiden Point slice assemblage</u> – composed of graded greywacke, pebble-conglomerate with blue quartz grains, and mainly dark grey to black shale (5). Agglomerate, tuff, and lesser pillow lava (5a) are prominent in the vicinity of St. Lunaire and Milan Arm. All these rocks are presently referred to the Maiden Point Formation[2]. Medium- to coarse-grained massive diorite (5b) also forms an integral part of the Maiden Point slice assemblage and is especially abundant in the greywacke in those places where the Maiden Point is overlain by structurally higher slice assemblages, i.e. at St. Anthony, Ireland's Bight, and Lock's Cove.

Black shaly mélange zones locally separate continuous sections of Maiden Point sandstone and suggest that the Maiden Point Formation is represented in several slices separated by mélange (e.g. Croque Head south of Hare Bay[5]). Other narrow outcrop belts of mélange within the Maiden Point terrane probably represent a basal mélange beneath a continuous slice that has been eroded across anticlinal crests to expose the basal mélange in elongate fold cores, e.g. St. Carols.

The Maiden Point slice assemblage is by far the most extensive within the Hare Bay allochthon. In general the Maiden Point slices lie directly upon autochthonous Goose Tickle flysch (3). Basal relations are well exposed at

Figure 2.



Noddy Cove, eastern Sacred Bay, Little Sacred Island, and Quirpon, all north of Hare Bay, and at Springs Inlet on the south side of Hare Bay. Locally at Lock's Cove and Howe Harbour, the Maiden Point overlies rubbly shale of the Northwest Arm slice assemblage.

3. The Cape Onion slice assemblage - composed mainly of basaltic pillowed lava and agglomerate with local black pyritic shale interlayers that contain Tremadocian graptolites at Onion Cove[6]. These rocks are informally referred to as the Cape Onion volcanics. The largest segment of the Cape Onion slice assemblage forms the Cape Onion Peninsula but similar rocks comprise the Sacred Islands and a small detached mass at Raleigh. These may be the remnants of a single slice or else represent several separate slices. Lithologically similar volcanic rocks above the Maiden Point Formation at Lock's Cove and two miles to the east may be correlatives. The Cape Onion volcanics directly overlie the Goose Tickle Formation (3) at Raleigh and lithologically similar rocks overlie minor unseparated Goose Tickle near the southern entrance to Lock's Cove. In addition a small slice of volcanic rocks, possibly correlative with the Cape Onion volcanics, overlies the Northwest Arm Formation (4) north of Lock's Cove on the west side of Howe Harbour. Elsewhere the Cape Onion slice assemblage overlies the Maiden Point slice assemblage. Clear relationships are evident on Sacred Islands, along the west shore of Sacred Bay, at the coast one mile north of Raleigh, and possibly east of Lock's Cove where amygdaloidal (calcite) pillowed lavas overlie the Maiden Point greywackes (5).

4. The White Hills slice assemblage - composed of mixed schistose volcanic rocks, greenschist, amphibolite, and ultramafic rocks north of Hare Bay; and including similar metamorphic rocks at Fishot Islands and Croque Head south of Hare Bay[5]. Polymictic conglomerate and arenaceous limestone at St. Julien Island, south of Hare Bay, are also considered part of the slice assemblage. The mixed volcanic rocks, greenschist, and amphibolite north of Hare Bay have been referred to the Goose Cove Formation (8)[2] and the ultramafic rocks are known as the White Hills Peridotite Sheet[1]. North of Hare Bay, these rocks constitute the White Hills in a large continuous slice. Similar greenschist and amphibolite occur at Quirpon above the Maiden Point Formation (5), and also south of Cape Onion where they overlie the Cape Onion volcanics. Other occurrences north of Hare Bay are along the north shore of Milan Arm and at the network of large ponds east of Raleigh. South of Hare Bay, similar greenschist and amphibolite, locally including psammitic units and conglomerate and arenaceous limestone have been referred to the Hare Bay Schist Group[5].

All of these rocks have a complex structural history that predates their final emplacement. The structural contrast with either allochthonous or autochthonous underlying rocks is everywhere pronounced and locally east of Ireland's Bight, boulders of foliated greenschist occur in black shale mélange below the White Hills slice assemblage.

Mixed volcanic rocks along the north shore of Hare Bay (Ireland Point Volcanics[1]) are gradational and infolded with Goose Cove greenschist at Starks Bight, although in places they are surprisingly unaltered and undeformed compared to the greenschists. The greenschist in turn grades into black amphibolite that is concordant and overlain in the White Hills by ultramafic rock. The ultramafic rock contains thin hard, amphibolite layers at its base overlain by mylonitized ultramafic rock, in turn overlain by banded cherzolite, hartzburgite and minor dunite. All contain a strong tectonic fabric that is generally parallel to the mineralogical banding. Orthopyroxenite bands of two generations are contained in the peridotites. The older are pre-tectonic and form the most conspicuous primary bands. The younger are post-tectonic and crosscut the banding and tectonic fabric in the peridotites.

Amphibolite and peridotite occur in isolated exposures and in superposed slices north of Milan Arm and east of Raleigh. In places the amphibolite has associated exceedingly coarse grained pyroxenite and hornblendite with single crystals up to one foot in length. Many of the amphibolite occurrences at Milan Arm are surrounded by a 1- to 2-foot-thick, hard, massive, light grey alteration halo followed outward by a thin 1-inch rind of serpentinite. The relationship indicates that these amphibolites were once surrounded by serpentinite and that the presently exposed surface is coincident with the tough alteration rind that formed as an alteration halo at an amphibolite-serpentinite contact.

The White Hills slice assemblage overlies each of the preceding slice assemblages and locally rests upon the Goose Tickle autochthonous flysch (3). In most places it rests upon the Maiden Point Formation (5) but locally south of Cape Onion it overlies the Cape Onion volcanics (6) and at Howe Harbour it locally overlies the Northwest Arm Formation (4).

Structural features related to at least three deformational episodes are recognized in the transported rocks of the Hare Bay allochthon. The earliest is represented only in the metamorphic rocks of the White Hills slice assemblage where the Goose Cove Formation (8) exhibits a penetrative schistosity and minor tectonic slides[5]. The second is evidenced by subhorizontal schistosity or cleavage and associated recumbent folds that are especially evident in the higher structural slices, e.g. Maiden Point and White Hills slice assemblages. Both early deformations are interpreted as penecontemporaneous with earliest transport of the allochthonous rocks. The latest penetrative deformational episode affects the transported rocks and underlying autochthonous rocks alike and is clearly post-emplacement. It increases in intensity from west to east across the map-area and it is expressed by a single steeply southeast-dipping cleavage and associated tight to open upright folds. It is probably Devonian (Acadian) in age and its effects are most apparent in the lowest structural slices, e.g. the Northwest Arm and Maiden Point slice assemblages. Higher structural slices are for the most part unaffected, except for mild warping and open folding. Mélange zones between structural slices are in most places cleaved as a result of post-emplacement deformation. Near the western extremity of the allochthon, westward directed low-angle thrusts along which have been emplaced Table Head limestone (2) above Goose Tickle shale (3) at Raleigh and Table Head limestone (2) above the Northwest Arm Formation (4) at Hare Island, are either related to or post-date the third deformational episode.

The Northwest Arm Formation (4) is everywhere dismembered and chaotic indicating emplacement in only a semi-consolidated condition. It has been deformed by post-emplacement deformation and its cleavage and intensity of deformation are analagous to those displayed in nearby outcrops of the underlying Goose Tickle Formation (3).

The Maiden Point Formation (5) is in places characterized by early recumbent folds with subhorizontal to gently-dipping axial plane cleavage. Excellent examples are apparent at St. Anthony Bight and their presence is inferred in other places by bedding-cleavage relationships. The early recumbent folds are clearly the result of deformation in well-indurated, competent rocks and their presence indicates that the Maiden Point Formation (5) was finally emplaced as a rigid and hard slice or slice assemblage. South of Hare Bay the early recumbent folds are upward-facing toward the northwest whereas north of Hare Bay they are of variable attitude with the best examples at St. Anthony Bight facing slightly downward toward the southwest. East of St. Anthony Bight the early recumbent folds are involved in post-emplacement steep upright structures near St. Carols.

The Cape Onion volcanics (6) for the most part consist of massive and relatively undeformed pillow lavas that show no indication of pre-emplacement deformation and most everywhere they have been only slightly affected by post-emplacement (Acadian) deformation. Where the Cape Onion volcanics (6) overlie the Goose Tickle slates (3) northeast of Raleigh, cleavage in the slates locally continues upward into the volcanic rocks, but nearby at Raleigh the the cleavage does not appear to penetrate the more competent overlying slice. Similarly at Cape Onion, fossiliferous black graphitic shales interlayered with the volcanic rocks are essentially uncleaved. The lack of post-emplacement deformation in the Cape Onion volcanics (6) is also in part due to their position at the western margin of the allochthon where the competent volcanic rocks are effectively outside the zone of intense Acadian deformation.

The White Hills slice assemblage is characterized by polyphase deformation that predated its final emplacement. The Goose Cove Formation (8) possesses a strong early schistose fabric that was refolded by flat-lying recumbent folds. The intensity of these deformations and grade of accompanying metamorphism increases structurally upwards within the formation towards the contact with the White Hills Peridotite Sheet.

The ultramafic rocks of the White Hills Peridotite Sheet exhibit a strong tectonic fabric defined by flattened orthopyroxene crystals. This fabric is axial planar to recumbent isoclinal folds that fold the primary lithologic banding. The folds are sparse, so that in most cases the tectonic fabric and the lithologic banding are parallel.

Late open upright folds and warps refold the earlier recumbent structures in the Goose Cove Formation (8) and in the White Hills Peridotite Sheet and are probably of post-emplacement age (Acadian). The base of the Peridotite Sheet in the vicinity of Daniels Lookout, northwest of Ireland's Bight, is cataclastically deformed. The tectonic fabric is brecciated and locally refolded on minor discontinuous flat-lying folds. The cataclastic effects die out upwards in about 250 feet from the base of the Peridotite Sheet. This cataclasis is interpreted as a late detachment feature that post-dated the main emplacement of the allochthon.

The stratigraphic and structural evolution of the map-area is interpreted to relate to the development of a continental margin that reached a climax by the obduction of oceanic crust and mantle westward upon the continent. This model fits well with the lithologies represented among the transported rocks and also the order of structural stacking of the slice assemblages, which indirectly suggests that the highest slices are the farthest travelled. The White Hills Peridotite Sheet is interpreted as oceanic mantle and its underlying metamorphic rocks, which now form an integral part of the same slice, are thought to represent supracrustal rocks that were deformed, metamorphosed, and structurally attached to the sole of the peridotite sheet at the time of its initial expulsion from an oceanic domain. The Cape Onion volcanics (6) probably originated in the same oceanic domain where at deposition they represented the upper volcanic layer of oceanic crust. The Maiden Point clastic sedimentary rocks (5) were derived from a metamorphic Precambrian terrane and the formation was probably deposited along a continental margin. Volcanic rocks within the Maiden Point possibly relate to rifting during the formation of such a margin. Finally, the Northwest Arm Formation (4), in the lowest slice assemblage, lay at a shelf edge immediately east of an evolving carbonate bank. There it represented a shaly deeper water facies of the Lower Ordovician carbonate bank that is so prominent and well developed in western Newfoundland[7]. Conglomerates in the autochthonous Middle Ordovician Goose Tickle Formation (3) consist mainly of Northwest Arm Formation detritus and the deposition of the Goose Tickle Formation is thought to be related to the emplacement of the Hare Bay allochthon.

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[2]Tuke, M.F.: Autochthonous and allochthonous rocks in the Pistolet Bay area in northernmost Newfoundland; Can. J. Earth Sci., v. 5, p. 501-513 (1968).

[3]Williams, Harold, and Stevens, R.K.: Geology of Belle Isle northern extremity of the deformed Appalachian miogeosynclinal belt; Can. J. Sci., v. 6, p. 1145-1157 (1969).

[4]Kay, Marshall: Thrust sheets and gravity slides of western Newfoundland; in Kay, Marshall (editor) North Atlantic - Geology and Continental Drift; Amer. Assoc. Petrol. Geol., Mem. 12, p. 665-669 (1969).

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[6]Williams, Harold: Mafic ultramafic complexes in western Newfoundland Appalachians and the evidence for their transportation: A review and interim report; Geol. Assoc. Can. Proc., v. 24, p. 9-25 (1971).

[7]Stevens, R.K.: Cambro-Ordovician flysch sedimentation and tectonics in west Newfoundland and their possible bearing on a proto-Atlantic ocean; Geol. Assoc. Can., Spec. Paper No. 7, p. 165-177 (1970).

5. COAL RESEARCH

STUDIES BY THE COAL PETROLOGY SECTION

Projects 610269, 680102, 710089,
710091, 720073

P.A. Hacquebard
Institute of Sedimentary and Petroleum Geology, Ottawa

Field work by the Coal Petrology Section in 1972 consisted of the collection of coal and rock samples from the Kootenay Formation in the Upper Elk River, Crowsnest and Flathead coal areas of British Columbia and Alberta. Whole seam and increment samples were taken from operating strip mines and exploration adits for the purpose of (1) a study of rank variations by measurements of vitrinite reflectance (project 680102), and (2) petrographic evaluations of coking coals (project 610269). A total of 95 samples from 14 different coal seams were collected by A.R. Cameron, P.A. Hacquebard, E. Mériaux and A.R. Sweet.

In conjunction with this program E. Mériaux completed his collection of "tonsteins" (clay bands) present in the Kootenay coals (project 710089) by obtaining 275 samples.

For the palynological studies of the Kootenay coal measures (project 710091) A.R. Sweet made systematic collections of both the clastic rocks and the coals of stratigraphic sequences at the following locations: Line Creek Ridge, Sparwood Ridge, Tent Mountain, Grassy Mountain, Adanac Strip mine area, Bryon Creek, Burmis, Beaver Mines, and Cabin Creek (Flathead area).

In addition, A.R. Cameron visited Estevan in connection with the joint Federal-Provincial drilling program carried out to evaluate the lignite deposits of Saskatchewan. From two wells he obtained 14 core samples from coals of the Ravenscrag Formation for a petrographic examination (project 720073)

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6. JOINT FEDERAL-PROVINCIAL COAL EVALUATION PROGRAM IN SASKATCHEWAN

S.H. Whitaker*, P. Broughton**, and J.A. Irvine***

This joint Federal-Provincial program is being carried out by three teams, each composed of a geologist and an assistant and each having available to it a rotary drill and a drill crew on a full-time basis. Two teams are provided by the Province of Saskatchewan, one under S.H. Whitaker, Saskatchewan Research Council and the other under P. Broughton, Department of Mineral Resources. The third team, under J.A. Irvine, is provided by the Geological Survey of Canada. S.H. Whitaker has been named as overall project co-ordinator.

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* Institute of Sedimentary and Petroleum Geology, Calgary
** Saskatchewan Research Council
*** Saskatchewan Department of Mineral Resources

Drilling has been done over a period of almost five months during which time 190 test holes totalling 120,000 feet were drilled into the Tertiary Ravenscrag Formation at sites across southern Saskatchewan. Most of these test holes penetrated the entire thickness of the formation. At each site, rotary cutting samples of lignite were collected from all lignite seams from which adequate samples could be obtained. These samples were forwarded to Mines Branch for analysis. A suite of geophysical logs was run in each hole, including spontaneous potential, resistance, natural gamma, gamma-gamma density, and caliper. In addition, most holes were side-wall sampled to obtain discrete samples of selected lithologic units within the hole.

The results of this drilling program will provide the geologic framework needed to delineate areas of significant seam development within the Ravenscrag Formation. These areas will be drilled in considerable detail (down to 1 mile centres) during 1973 in order to establish both energy reserve estimates by sample analysis and coal reserve estimates for the Ravenscrag Formation.

In addition to the test drilling, the seams in two holes in the Estevan area were cored to provide control samples for petrographic analysis by A. R. Cameron, Geological Survey of Canada. Some experimental drilling was conducted using reverse circulation rotary techniques to compare costs and effectiveness of this method to normal rotary method in the sediments of the Ravenscrag Formation.

7. CORDILLERAN GEOLOGY

OPERATION STEWART, YUKON TERRITORY AND DISTRICT OF MACKENZIE

Project 680119

S. L. Blusson
Regional and Economic Geology, Vancouver

As the final phase of Operation Stewart, field investigations were restricted to a number of specific problem areas in Niddery Lake (105 O), Lansing (105 N) and Nadaleen (106 C) map-areas. W.H. Fritz continued detailed biostratigraphic studies in several selected Cambrian sections in Sekwi (105 P) and Niddery map-areas (see elsewhere in this publication) and support was given to thesis projects carried out by R. Ludvigsen and D. Perry of the University of Western Ontario on Ordovician and Siluro-Devonian biostratigraphy.

In the eastern part of Selwyn shale basin only three broad divisions have been recognized. A lower monotonous slate unit of Lower Cambrian and (?) earlier age (Unit 2 of Nahanni map-area[1]), a middle unit of Ordovician to Middle Devonian age comprising block, commonly calcareous shale, minor limestone and chert, and an upper shale unit of Late Devonian and younger age distinguished by detrital chert and general absence of limestone and calcareous shale. Cambrian carbonates appear to be absent west of Sekwi map-area, due mainly to a facies change or, in part, to pre-Ordovician erosion. Basic volcanic rocks of Middle Ordovician age as noted elsewhere in Selwyn and Mackenzie mountains, were also discovered in the southeastern part of Niddery map-area within the shale basin.

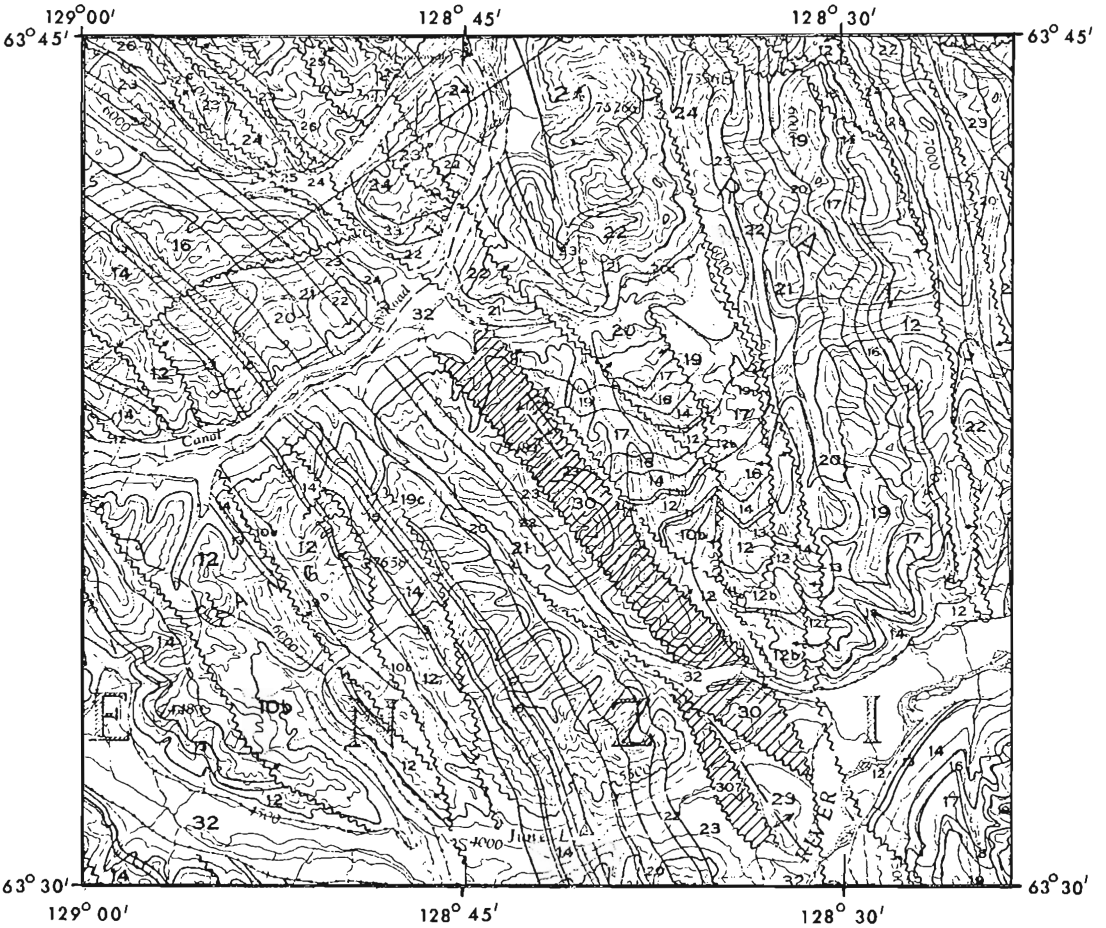
The Amax tungsten deposit in the MacMillan Pass area occurs in calcareous rocks of Ordovician age at the base of the middle unit noted above. The Hudson Bay Pb-Zn deposit in the same region is in finely laminated shales 2,000-3,000 feet above the base of the middle unit.

In northwestern Lansing and southwestern Nadaleen map-areas the upper shale unit is many thousands of feet thick and includes perhaps 1,000 feet of dark grey Triassic shale which is well dated in the adjoining Nash Creek map-area.[2] There the entire assemblage including (?) some middle unit strata is mapped as unit 14. Transitional lithologies at a well-exposed contact found recently on Rockla River strongly suggest a conformable relationship between fossiliferous Upper Triassic shales and massive quartzite of unit 17, a probable correlative of the Keno Hill quartzite.

A new coal deposit, probably unique in the Mackenzie Mountains, was discovered in a fault block of Upper (?) Cretaceous nonmarine strata in the central Sekwi map-area. The coal-bearing sequence, comprising at least 4,500 feet of interbedded shale, sandstone, and quartz-pebble conglomerate is everywhere fault-bounded and steeply dipping (Fig. 1). The entire section, where examined on ridge 3 1/2 miles southeast of Canol Road, contains minor amounts of coal, but the greater bulk, in seams ranging up to about 5 feet thick, appears restricted to the lower third of the sequence.

[1] Blusson, S.L.: Nahanni map-area; Geol. Surv. Can., Map 8-1967.

[2] Green, L.H. and Roddick, J.A.: Nash Creek map-area, Yukon Territory; Geol. Surv. Can., Map 15-1962.



Scale : 1 : 250,000

32	Unconsolidated glacial and alluvial deposits

CRETACEOUS

30	Dark grey and black shale, conglomerate and coal

MIDDLE DEVONIAN (units 21-25)

23	Landry Formation: well bedded light grey weathering crypto-grained limestone

L. CAMBRIAN and EARLIER

12	Orthoquartzite, brown siltstone and shale

Figure 1. Part of Sekwi map-area (105 P) showing coal-bearing strata, unit 30.

8. TERTIARY STRATIGRAPHY AND MICROFAUNAS FROM THE PACIFIC MARGIN, WEST COAST VANCOUVER ISLAND

Project 690075

B.E.B. Cameron
Regional and Economic Geology Division, Vancouver

1. Nootka Sound Area (92 E)

The Tertiary sequence exposed on the northwest side of Hesquiat Peninsula has been studied and sampled in detail for microfauna. This highly faulted sequence consists of mostly coarser clastic material than its more shaly, in part facies equivalent on Nootka Island[1]. Although foraminiferal faunas are sparse or specialized facies faunas, enough good assemblages have been recovered to effect correlations regionally and to indicate the great structural and stratigraphic problems within the sequence.

Analyses of the microfauna support the following tentative conclusions:

(a) The basal Tertiary, Escalante Formation (Division A, of Jeletzky[2], 1954), and the lower part of the overlying shale-sandstone sequence is older on Hesquiat Peninsula than on Nootka Island (Upper Eocene).

(b) The sequence on the northwest side of Hesquiat Peninsula is highly faulted and repeated by predominantly left lateral faults. It appears that a true stratigraphic thickness of Tertiary rocks from the base to the synclinal axis as mapped by Jeletzky[2] (1954) is in the order of 3,000 to 4,000 feet.

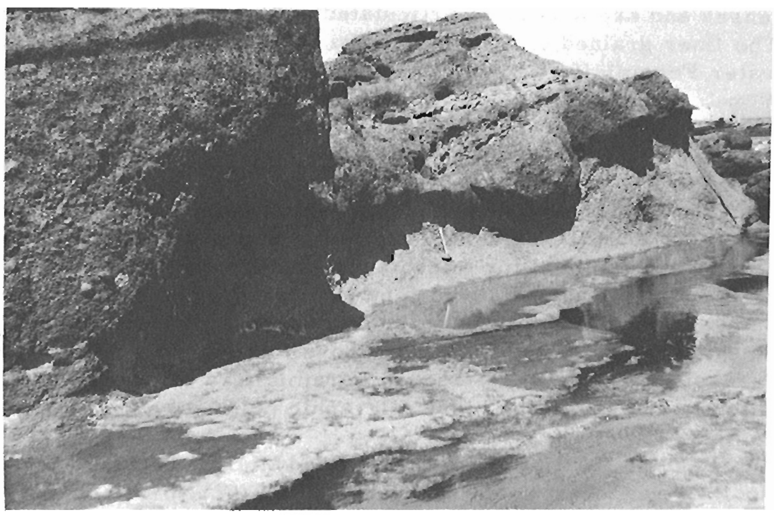
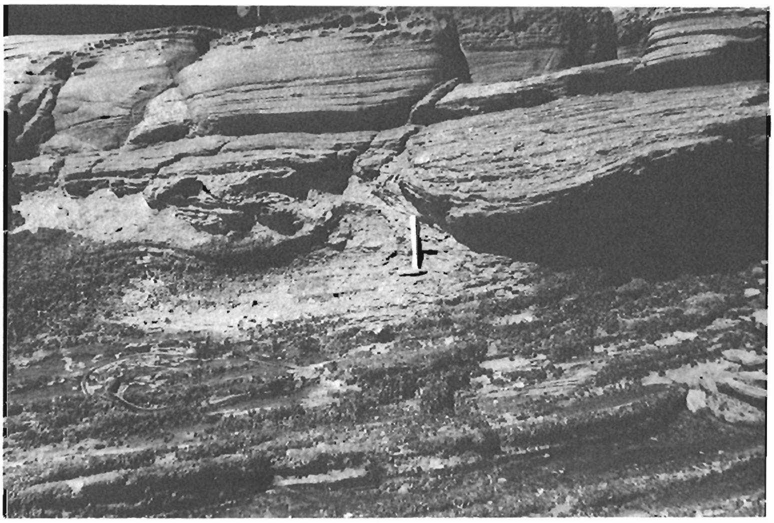


Figure 1. Mega-loadcasts in subsea channel deposits with bathyal-water Foraminifera. North side Barchester Bay, Hesquiat Peninsula.



392'

Figure 2. Penecontemporaneous soft sediment injection structure. North side Barchester Bay, Hesquiat Peninsula.

(c) Facies relationships are very complex in the Hesquiat sequence. All conglomerates encountered are lenticular and disappear abruptly along strike. The well developed loadcasts and other penecontemporaneous structures (Figs. 1, 2) lend further support to the bathyal water depositional environments as indicated by the Foraminifera.

(d) Shallow water molluscan faunas have been encountered in the Escalante Formation. In most cases, however, they are found in conglomerate lenses and are mostly disarticulated and commonly broken bivalves. The finer grained clastics of the Escalante Formation yield bathyal water Foraminifera.

2. Kyoquot Sound-Esperanza Inlet Area (92 E)

Reconnaissance studies of the Tertiary and Mesozoic rocks in this area, were carried out in 1972. Several sections of the Jurassic, Lower Cretaceous and Tertiary were sampled for microfauna. As in other areas of the west coast, the Mesozoic-Cenozoic boundary is marked by an erosional unconformity. Bathyal-water Foraminifera indicating an Upper Eocene to Lower Oligocene age were collected from just above this contact.

Jurassic and Lower Cretaceous Foraminifera although not abundant, are sufficiently diagnostic for biostratigraphic purposes.

[1] Cameron, B.E.B: Tertiary Stratigraphy and Microfaunas from the Hesquiat-Nootka Area, West Coast Vancouver Island (92 E); in Report of Activities, Part B, November 1970 to March 1971; Geol. Surv. Can., Paper 71-1, pt. B, p. 91-94 (1971).

[2] Jeletzky, J.A.: Tertiary rocks of Hesquiat-Nootka Area, west coast of Vancouver Island, British Columbia; Geol. Surv. Can., Paper 53-17 (1954).

9. STRATIGRAPHY AND STRUCTURE OF THE MOUNT IDA GROUP, VERNON (82L), ADAMS LAKE (82M W 1/2), AND BONAPARTE (92P) MAP-AREAS

Project 720037

R. B. Campbell and A. V. Okulitch*
Regional and Economic Geology Division, Vancouver

Introduction

A sequence of highly deformed low-grade metamorphic rocks, designated the Mount Ida Group[1] lies along the western margin of the Shuswap Metamorphic Complex in the Adams Lake–Shuswap Lake region. Three months were spent in this region in 1972; the work was concentrated mainly between Sicamous and Armstrong in the southeast and Barriere River in the northwest. Some general conclusions are reported herein, but much depends upon pending results of micropaleontological studies and further analysis of data.

Stratigraphy

In Table 1 the stratigraphic succession proposed by Jones[1] is compared to that tentatively suggested by the writers.

TABLE 1

STRATIGRAPHIC TABLE, MOUNT IDA GROUP (for lithology see Jones[1]).

Jones[1]	Present Study
Eagle Bay Formation	Eagle Bay Formation (may be older than some or all other units)
conformable	possible thrust fault
Sicamous Formation	Sicamous Formation
conformable	possible unconformity(?)
Mara Formation	no intervening unit
conformable	
Tsalkom Formation	Tsalkom Formation
conformable	possible unconformity(?)
Silver Creek Formation	Silver Creek/Mara Formation with Chase Formation
conformable	internally included
Chase Formation	type of contact uncertain
	Granitoid gneiss

At the deepest exposed level the rocks of the Silver Creek Formation interfinger with and lie above granodiorite and quartz monzonite gneiss (see Fyson[2]). On a broad scale the gneiss seems to have crosscutting relationships. It is not known if the gneiss represents an old basement complex or if it is the roof of a pre- or syn-tectonic granitic pluton.

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*University of British Columbia, Vancouver.

The Chase Formation seems to lie internally within rather than at the base of the Silver Creek Formation. The Tsalkom Formation lies directly above the Silver Creek and below the Sicamous Formation, hence the Mara Formation does not exist as a separable unit and rocks previously assigned to it[1] are mainly part of the Silver Creek and, less commonly, part of the Sicamous Formation. The Tsalkom Formation is commonly very thin and may be absent in places. It is highly folded where it appears to be unusually thick as at Tsalkom Mountain. Unconformities above and below the Tsalkom Formation cannot yet be proved but one or both are probable.

As suggested by Fyson[2] the total thickness of 60,000 feet indicated by Jones[1] for the Mount Ida Group is probably a gross over-estimate. At present the writers cannot provide any accurate thickness estimates of units of the Mount Ida Group.

Structure

Studies of macro- and mesoscopic structures by the writers confirm Fyson's[2] model of four phases of deformation. Earliest recognizable deformation produced small intrafolial folds and foliation subparallel with compositional layering. These structures do not appear to be related to megascopic folds or nappes (unless these possess limbs in excess of fifty miles long) but seem to have been produced by some mechanism akin to intrafolial flow. Second phase structures are tight, near isoclinal northerly- to northeasterly-trending folds overturned to the south and southeast. These have been folded about open northwesterly-trending folds. The interference of these two phases controls the areal distribution of the stratigraphic succession described above. Final deformation produced faults, open flexures and kink bands along northerly and northeasterly directions.

Tentative stratigraphic units within the Eagle Bay Formation appear to be truncated at a low angle along the contact with the Sicamous Formation and hence the contact is interpreted as a fault roughly parallel with the pervasive metamorphic foliation. The contact is remarkably planar and does not reflect mappable folds in the overlying and underlying rocks. This interpretation is speculative and requires additional study. At its northeastern or "upper" contact the Eagle Bay Formation is apparently in faulted contact with granitoid gneiss and metamorphic rocks of the Shuswap Metamorphic Complex that may include rocks of the Sicamous and older formations of the Mount Ida Group. Thus the Eagle Bay Formation may be confined to a large allochthonous mass.

Age and Regional Correlation

Fyson[2] pointed out that the limestone of the Sicamous Formation passes through a facies change west of Adams Lake and is coextensive with argillite included by Jones[1] with the Cache Creek Group. Fyson[2] concluded that the Silver Creek and Mara Formations as defined by Jones[1] are equivalents of the argillite (and hence the Sicamous Formation) and are distinct only because of higher metamorphic grade. The writers disagree; the Silver Creek Formation is more quartzose than the argillite, it is at least locally separated from it by the Tsalkom Formation and it is not everywhere of significantly higher metamorphic grade.

Pending results of micropaleontological studies some tentative regional correlations can be suggested. The Silver Creek (including Mara) and Chase Formations may be equivalent to or older than the Permo-Carboniferous Milford Group[3] on the eastern side of the Shuswap Metamorphic Complex.

Similarly the Tsalkom and Sicamous Formations (including the "Cache Creek Group" argillite) are thought to be equivalent to the Kaslo and Slocan Groups, respectively, and hence to be of Triassic and at least partly of Upper Triassic age. These two formations are also likely equivalents to the Fennell Formation and the Upper Triassic argillite-phyllite unit (map-unit 10) in the Bonaparte Lake map-area[4].

Poorly preserved macrofossils found previously in the northwestward extension of the Eagle Bay Formation in Adams Lake map-area[5] could only be determined as Paleozoic (G.S.C. loc. 58291). A collection from the same locality made during the present work (G.S.C. loc. 86349) has yielded Mississippian conodonts tentatively thought to be Lower Mississippian (B.E.B. Cameron, pers. comm.). If the Sicamous Formation, which structurally underlies the Eagle Bay, proves to be Upper Triassic, then a thrust relationship between the two formations is probable.

Preliminary reconnaissance suggests that rocks of the Sicamous and older formations of the Mount Ida Group extend directly into and are a part of the Shuswap Metamorphic Complex (Monashee Group of Jones[1]) as indicated by Fyson[2]. From east of Lumby dark argillaceous and carbonaceous limestone like that of the Sicamous Formation has yielded definite Upper Triassic (Upper Karnian or Lower Norian) conodonts (G.S.C. loc. 86351), (B.E.B. Cameron, pers. comm., 1972).

The four phases of deformation described above appear to have affected all formations of the Mount Ida Group and deformation presumably began in post-Upper Triassic time.

Conodonts were discovered in a sample of rocks (G.S.C. loc. 86350) mapped as Cache Creek Group by Jones[1] near the west border of Vernon map-area in Salmon River Valley. The rocks lie above the Salmon River unconformity and rest upon the Chapperon Group which, according to Jones[1], is possibly equivalent to the Eagle Bay Formation. The conodonts are Upper Triassic (Upper Karnian) (B.E.B. Cameron, pers. comm.).

Acknowledgments

The progress of the project was greatly aided by the enthusiastic support given by K.K. Daughtry of Derry, Michener and Booth, Geological Consultants, who generously provided field data from several years of mapping and exploration in the region.

[1] Jones, A.G.: Vernon map-area, British Columbia; Geol. Surv. Can., Mem. 296 (1959).

[2] Fyson, W.K.: Structural relations in metamorphic rocks, Shuswap Lake area, British Columbia; _in_ Structure of the Southern Canadian Cordilleran; J.O. Wheeler, ed.; Geol. Assoc. Can., Spec. Paper 6, p. 107-122 (1970).

[3] Wheeler, J.O.: Lardeau (west half) map-area, British Columbia; _in_ Rept. of Activities, Pt. A, April to October, 1967, Geol. Surv. Can., Paper 68-1, pt. A, p. 56-58 (1968).

[4] Campbell, R.B. and Tipper, H.W.: Bonaparte Lake map-area, British Columbia; Geol. Surv. Can., Mem. 363 (1971).

[5] Campbell, R.B.: Adams Lake, British Columbia; Geol. Surv. Can., map 48-1963 (1964).

10. TECTONIC FRAMEWORK OF SUSTUT AND SIFTON BASINS, BRITISH COLUMBIA

Project 690032

G.H. Eisbacher
Regional Economic Geology Division, Vancouver

Part of this season's activity was devoted to mapping the complex structural relationship between the Sustut Group and Bowser Assemblage near Sustut River (McConnell Creek west half map-area), and another part was spent on a helicopter-supported reconnaissance of the Bowser Assemblage within the Spatsizi map-area. A report on the stratigraphy and structure of the Sustut Group and a map of the Sustut Basin of north-central British Columbia is in preparation.

Sustut Group

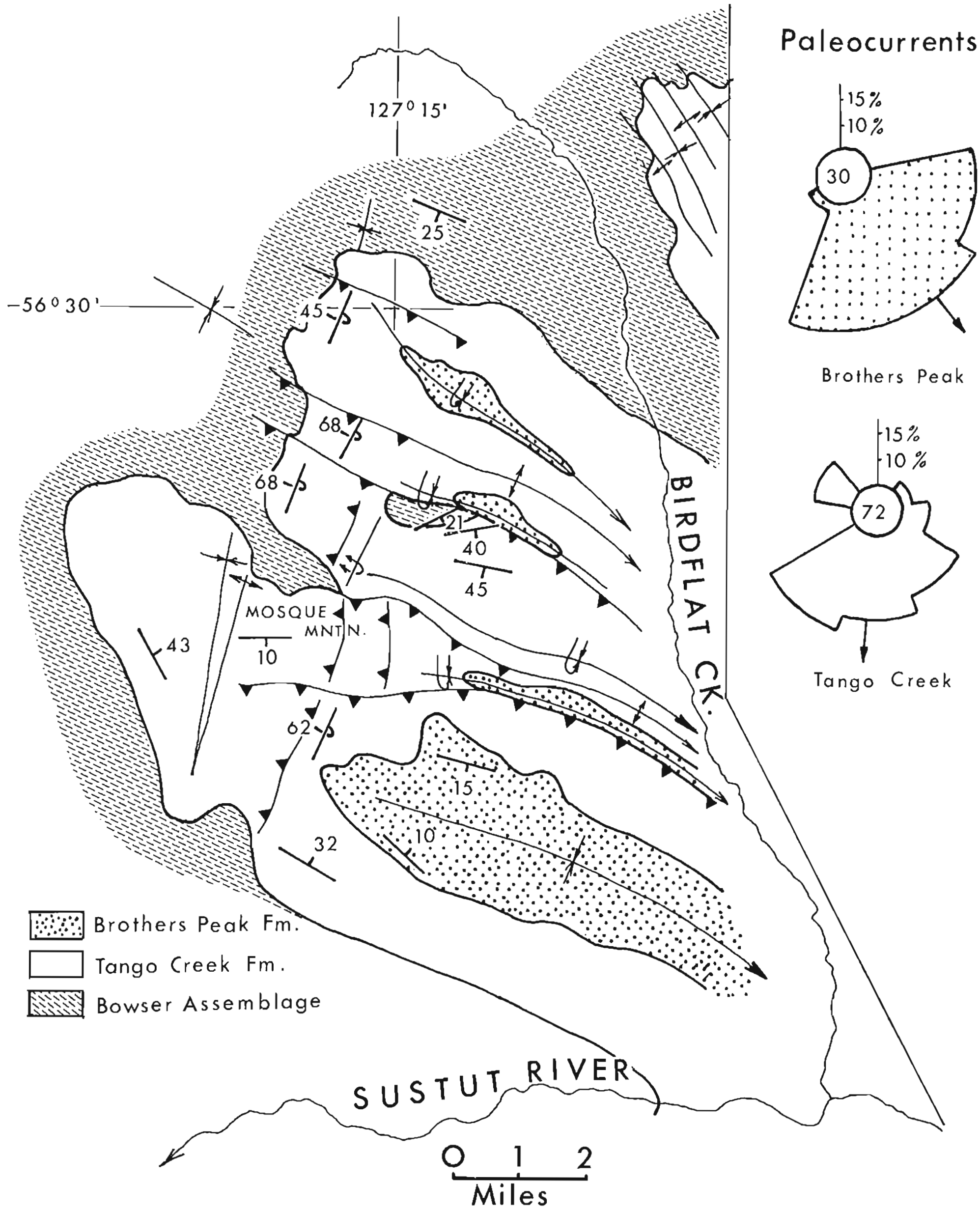
In the Mosque Mountain area north of Sustut River continental Tango Creek Formation of Late Cretaceous age (lower Sustut Group[1]) rests with angular unconformity of up to 25 degrees on marine, shallow-water Bowser Assemblage. Paleocurrents in the fluviatile sandstones of the Tango Creek Formation indicate a southerly flowing river system (Fig. 1). Subsequently Tango Creek rocks were deformed into northerly to north-northeasterly trending folds and thrust faults along the western margin of outcrop. The growth of strong northeast-southeast trending structures is expressed in southeasterly directed paleocurrents and east-southeasterly trending isoclinal folds within the Eocene Brothers Peak Formation (upper Sustut Group[1]). This later structural trend was also impressed on earlier structures in the Tango Creek Formation and resulted locally in steeply plunging folds and tear faults. Such late-orogenic over-printing within a changing field of contraction also seems to be present in other outcrop areas of Sustut Group[2, 3].

Bowser Assemblage

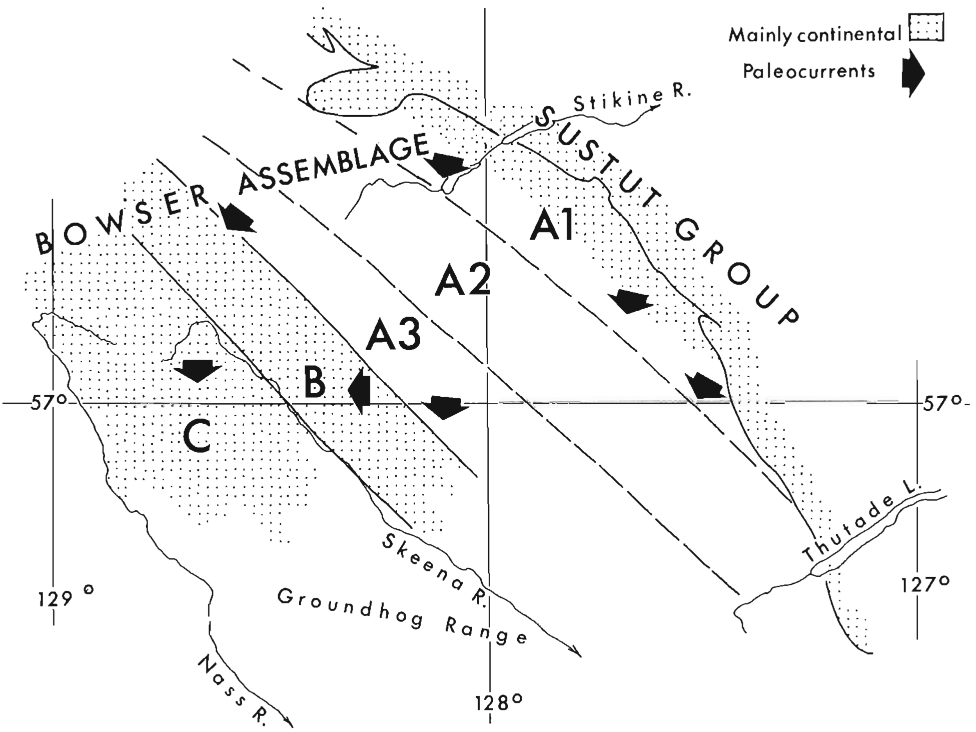
Several distinct facies belts were found within the Bowser Assemblage of the Spatsizi map-area. These belts are outlined in Figure 2. The structural relationships between the facies belts remain to be resolved because the boundaries occur mainly in major drift covered valleys where detailed stratigraphic-structural work has not been carried out.

Facies Belt A constitutes a delta (A1) – pro-delta (A2) – sub-sea fan (A3) complex of probable Late Jurassic age. A1 is made up of well sorted fluviatile conglomerate, distributary channel sandstones and interdistributary marine shales. A2 consists mainly of pro-delta shales, siltstones and local lensoid conglomerate-sandstone channels. A3 is a succession of poorly sorted conglomerate sheets, graded sandstones and siltstones.

Facies Belt B contains a continental clastic succession which was deposited on a low-gradient meandering alluvial plain and in overband areas containing distinct freshwater-lake deposits. This group of rocks is possibly of Early Cretaceous age and was derived from the east.



Facies Belt C is made up of thick alluvial fan conglomerates, intercalated with coal swamp and alluvial plain deposits. Paleocurrents flowed southerly and the facies is traceable laterally into rocks of the Groundhog Range coal area from where Upper Jurassic-Lower Cretaceous fossils have been reported[4, 5].



[1]Eisbacher, G.H.: A subdivision of the Upper Cretaceous–Lower Tertiary Sustut Group in the Toodoggone map-area, British Columbia; Geol. Surv. Can., Paper 70-68 (1971).

[2]Eisbacher, G.H.: Tectonic framework of Sustut and Sifton Basins, British Columbia; in Report of Activities, Part A: April to October 1970, Geol. Surv. Can., Paper 71-1A, p. 20-23.

[3]Eisbacher, G.H.: Tectonic overprinting near Ware, Northern Rocky Mountain Trench; Can. J. Earth Sci., v. 9, p. 903-913 (1972).

[4]Buckham, A.F. and B.A. Latour: The Groundhog Coalfield, British Columbia; Geol. Surv. Can., Bull. 16, 82 p. (1950).

[5]Frebold, H. and Tipper, H.W.: Status of the Jurassic in the Canadian Cordillera of British Columbia, and southern Yukon; Can. J. Earth Sci., v. 7, p. 1-22 (1970).

11. UPPER PALEOZOIC ROCKS OF THE WESTERN CANADIAN CORDILLERA

Project 720041

J.W.H. Monger
Regional and Economic Geology Division, Vancouver

A reconnaissance of upper Paleozoic rocks in the Omineca Mountains was undertaken preparatory to more detailed work scheduled for 1973. Areas examined are shown on the accompanying index map.

Area A, in the northern part of the Manson Creek belt, formerly though to include rocks of late Paleozoic age[1], was found to contain a section extending from latest Proterozoic to possible Mississippian. Brown, late Proterozoic carbonate is succeeded to the west by phyllite, quartzite and pods of archeocyathid-bearing lower Cambrian limestone. These rocks are overlain with slight angular discordance by approximately 1,000 feet of dolomite and dolomitic limestone, followed by slate of unknown thickness. Algalaminate textures and algal balls at some horizons in the carbonate indicate shallow water deposition, probably within the intertidal zone. In places in the upper part of the carbonate are well sorted, well rounded, etched, wind blown (?) quartz sand grains. Lower Middle or possibly late Lower Devonian fossils occur just below the slate, in a dolomite horizon that locally contains disseminated galena and sphalerite[2]. Above the slate is a thick sequence of altered basalt, locally pillowed or fragmental, with minor ribbon chert, argillite and diabase or microgabbro near the lower contact. Relationship of these rocks to the underlying slate is unknown. On the basis of lithology and geological setting they are correlated with the Sylvester Group volcanics near Cassiar and the Lower Mississippian or younger Antler Formation of the Slide Mountain Group, east of Quesnel.

Area B, in the Lay Range, was originally considered to consist of upper Paleozoic rocks[3], but appears to be composed of at least five northwest-trending fault slices of differing lithology and probably different ages. From north to south these slices are (1) volcanic sandstone and agglomerate possibly of Early Pennsylvanian age, (2) a complex zone, forming the crest of the Lay Range, with Middle Pennsylvanian carbonate pods, red radiolarian chert and argillite, overlain, apparently conformably, by conglomerate and breccia of unknown age that contains both volcanic and metamorphic clasts and which passes laterally into fine-grained, graded sandstone and argillite characterized by locally abundant worm borings, (3) hematitic conglomerate with abundant granite boulders and cobbles, correlated lithologically with the Uslika Formation of Cretaceous age[3], (4) green to maroon, locally porphyritic volcanic rocks of unknown age, and (5), southernmost, pyritiferous argillite and dark graded volcanic sandstone with local carbonate lenses, that lithologically resembles some parts of the lower Mesozoic Takla Group.

Rocks mapped as upper Paleozoic Asitka Group[4] in Area C consist of two sequences, for the most part in fault contact. The lower sequence comprises sheared greenstone, bedded chert and tuffaceous limestone of Early Permian age. Above this, and separated from it at one locality by an angular unconformity, is a sequence of little deformed green and brown volcanic flow rocks, and pink, green and maroon rhyolite flows interbedded with tuffs. The age of these rocks is not known, but they are possibly Permo-Triassic. They are overlain only by the Upper Cretaceous Sustut Group, but consistently separate Lower Permian from Upper Triassic rocks along fault contacts, and at one locality are metamorphosed together with Permian rocks.

Rocks mapped as upper Paleozoic Cache Creek Group with associated mafic and ultramafic intrusions[4], were examined in the Axelgold Range (Area D). For the most part these are highly deformed chert, argillite, greenstone and minor crystalline limestone, enclosing conformable serpentinized peridotite and metadiorite bodies. They are intruded by a spectacularly layered olivine gabbro body about three miles wide, six miles long and at least 3,000 feet thick, whose northern border is two miles south of Axelgold Peak. This body clearly crosscuts the country rocks and is much less altered than the conformable mafic magmatic rocks.

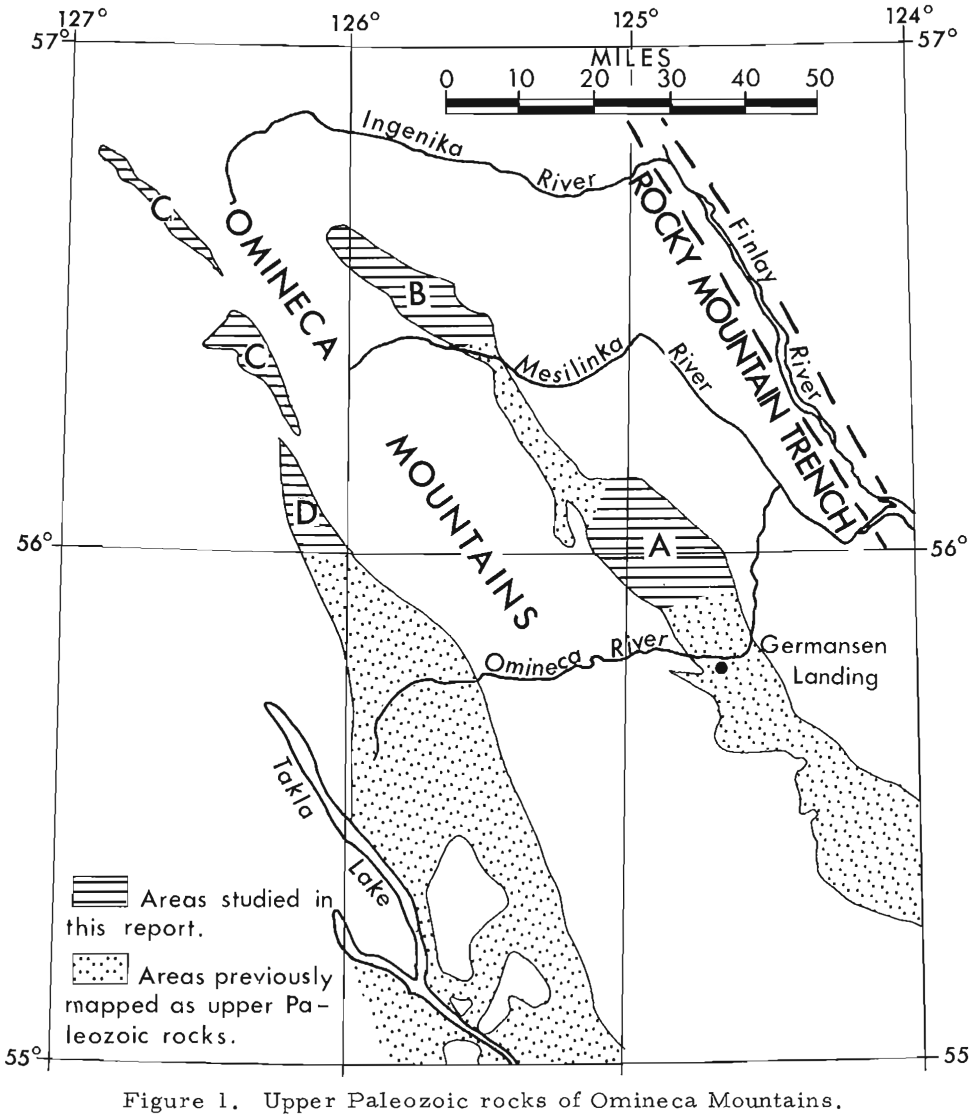


Figure 1. Upper Paleozoic rocks of Omineca Mountains.

[1]Armstrong, J.E.: Fort St. James map-area; Geol. Surv. Can., Mem. 252 (1949).

[2]Brit. Col. Minister Mines Ann. Rept. for 1952, p. A106 (1953).

[3]Roots, E.F.: Geology and mineral deposits of Aiken Lake map-area; Geol. Surv. Can., Mem. 274 (1954).

[4]Lord, C.S.: McConnell Creek map-area; Geol. Surv. Can., Mem. 251 (1948).

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12. GEOLOGY OF PACIFIC RIM NATIONAL PARK

Project 720074

J.E. Muller
Regional and Economic Geology Division, Vancouver

Introduction

On request of the National and Historic Parks Branch (Department of Indian Affairs and Northern Development) a detailed geological study of the new Pacific Rim National Park was undertaken. A total of four weeks was Spent on field work in "Phase 1" of the park. Embracing the area between Long Beach and Kennedy Lake in the Tofino Ucluelet region. Most of the area is within the previously mapped Alberni map-area[1]. Phase 2, including Effingham Islands, and Phase 3, the "Life-saving trail" area and probably also the "Nitinat triangle" will be studied in 1973 in conjunction with a new field project in the Victoria-Cape Flattery map-area.

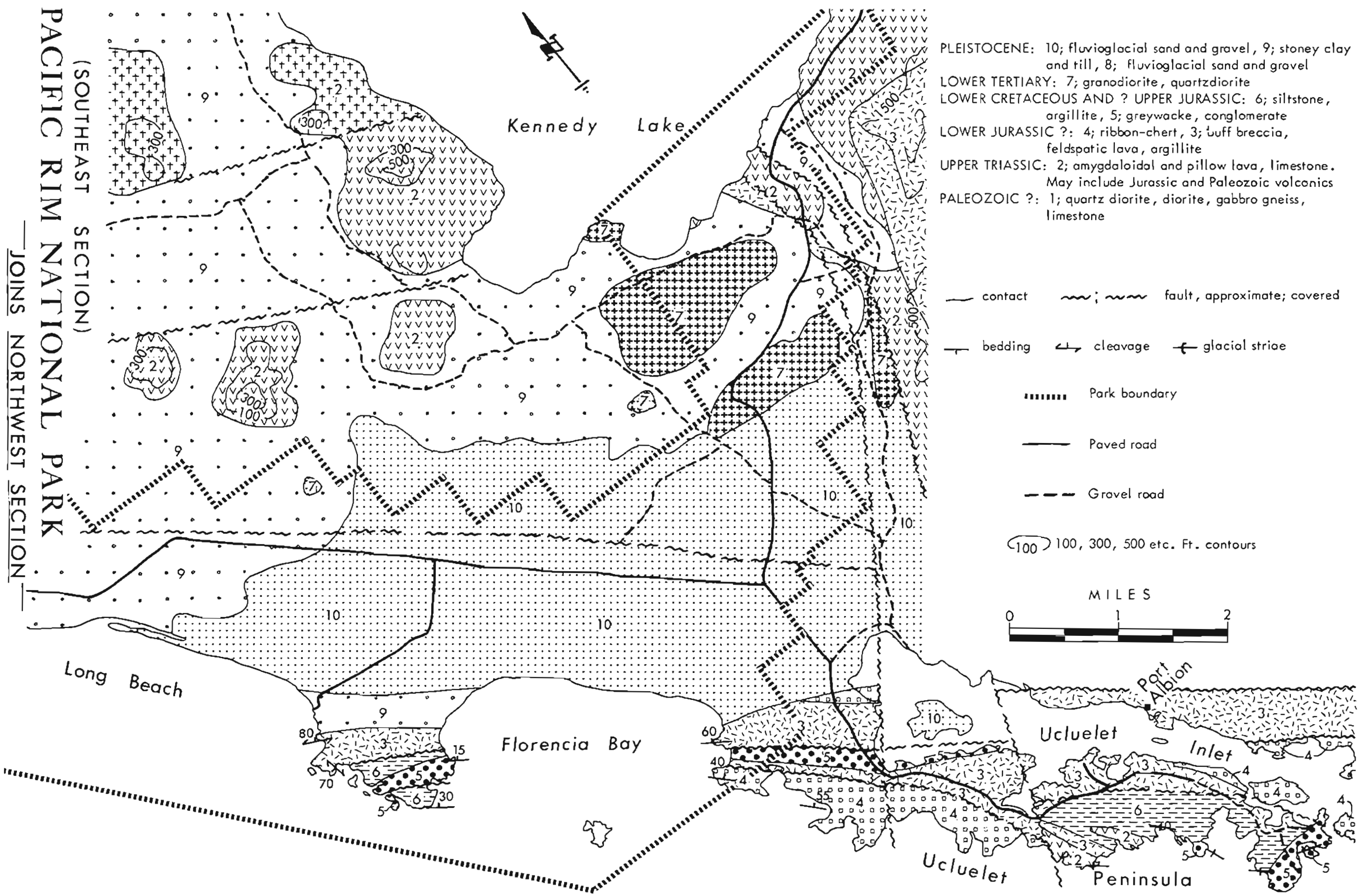
The park is an unique example of Pacific Coast semiwilderness, where sandy beaches alternate with rugged rocky shorelines, pounded by the Pacific surf and swell. Some of these rocky areas are difficult of access and park visitors are seldom encountered. The shoreline is indented by numerous surf-channels, cut out in a multitude of cross-faults. These channels must be bypassed through almost impenetrable coastal salal-growth. However, these channels afford in many instances good access and quiet water where small boats can enter. Otherwise landing from a small boat through the swell is a somewhat hazardous operation. The survey was made partly on foot and partly by rubber boat. Logging roads provide some access to the inland area.

The survey included Ucluth Peninsula, just south of the park and the previously surveyed Alberni map-area[1] because it contains formations that are not exposed elsewhere and are essential to the interpretation of the geology.

Most of the park is underlain by a belt of rocks that may be termed the "Pacific Rim Belt". The belt contains Esowista and Ucluth Peninsulas and all rocky shoreline areas between them. The unmetamorphosed but intensely deformed, sheared, brecciated and faulted rocks of this belt were earlier provisionally called "Tofino greywacke"[1]. To the northeast the Pacific Rim Belt is in fault contact with a belt of rocks, in this report called "Coastal Belt", consisting of Westcoast Gneiss Complex, Sicker (?), and Vancouver

(SOUTHEAST SECTION)

PACIFIC RIM NATIONAL PARK



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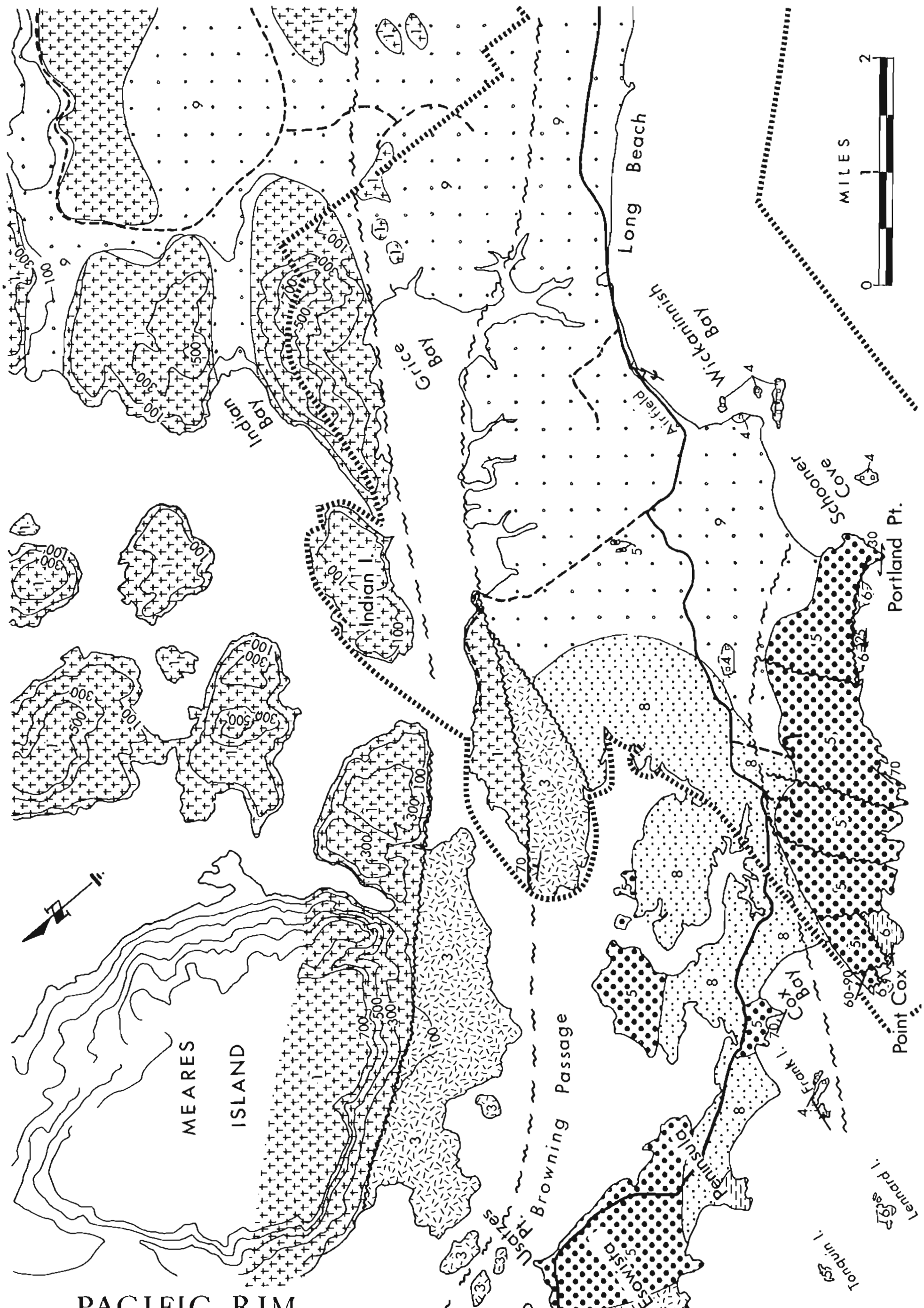

PACIFIC RIM
NATIONAL PARK
(NORTHWEST SECTION)

Group rocks that form the "basement" of Vancouver Island. To the southwest, out to sea, they are unconformably overlain by and in fault contact with Tertiary sediments. The emphasis of this report is on the Pacific Rim Belt.

Westcoast Gneiss Complex

Westcoast Gneiss Complex rocks underlie areas on the north and south sides of Grice Bay and some monadnock hills in the central park area. They have been described earlier[1] as a metamorphic-migmatitic complex of essentially basic rocks[1]. They are fine grained amphibolites, hornblende-plagioclase gneiss, hornblende-quartz diorite, diorite and gabbro and include minor-recrystallized limestone. They were probably derived from basic volcanic rocks, probably of Paleozoic age. They may well be equivalent to "Wark Diorite" of south Vancouver Island[2] and the Turtleback Complex of San Juan Islands[3] considered to be of mid-Paleozoic age.

Karmutsen and Quatsino Formations

Triassic volcanic and sedimentary rocks are combined on the accompanying map. Karmutsen Volcanics, of Late Triassic (early Karnian) age[4] underlie large tracts of Vancouver Island but are not well represented in the park area. In the Coastal Belt there are some small outcrops of typical amygdaloidal basalt-greenstone on the main highway near the turnoff to Kennedy Lake swimming-beach and in the bluff on the west side of that beach. In the Pacific Rim Belt they are the oldest rocks and are exposed as deformed basaltic, partly pillowed lavas on the outer coast of Ucluth Peninsula. They are associated with a limestone member less than 50 feet thick, similar to Late Karnian Quatsino Limestone. The limestone is also exposed in a small quarry on the highway near Ucluelet. In the Coastal Belt a greater thickness of recrystallized Quatsino Limestone is exposed on the highway along Kennedy Lake.

The main lithologies of Karmutsen Volcanics are pillow lavas and amygdaloidal flows, both represented in the area. Quatsino Limestone is generally massive and fine to coarse crystalline and contains andesitic sills.

Karmutsen Volcanics are tholeiitic basalts, probably deposited on a thin "basement" consisting of a partly metamorphosed Paleozoic volcanic-sedimentary sequence. The pillow lavas are submarine, the flows probably subaerial and the Quatsino Limestone a shallow platform deposit. Their Upper Triassic age is well established on fossils.

Bonanza Volcanics

Bonanza Volcanics of Early Jurassic age are widespread on northern Vancouver Island. They occur in Coastal and Pacific Rim Belts and as fairly good though heavily disturbed exposures just southeast of Wickaninnish Bay and Florencia (Wreck) Bay.

They are light green rhyodacite and dark green andesite, largely fine-grained but also medium-grained, feldspathic crystal tuff, lapilli-tuff, ignimbrite, and lava. Coarse breccia is also present but in many instances it is impossible to determine whether the brecciation of the rocks is volcanic, tectonic, or both. Argillite also forms an important part of the sequence and in several instances contains angular or flattened volcanic fragments. Argillite with cherty lenses is a transition stage to the ribbon-chert unit that has been mapped separately.

No fossils have been found in these rocks but lithological similarities and structural position seem to warrant their assignment to Bonanza Volcanics. The general fine-grain size and the abundance of argillaceous material suggest they were deposited at some distance seaward from a Jurassic arc.

Ribbon-chert unit

Ribbon-cherts are shown as a separate unit on the accompanying map and occur only in the Pacific Rim Belt. Their best exposures are on Frank Island, Box Island and some smaller islands between Wickaninnish Bay and Schooner Cove (most of them accessible by foot at low tide). The cherts are also fairly widespread on both sides of Ucluelet Inlet.

Chert-beds are generally one to two inches thick, more rarely four to six inches thick, taper out abruptly, and are separated by thin laminae of black argillite. The argillite-to-chert ratio varies and all gradations between chert with minor argillite to argillite with minor chert occur. The latter were mapped with Bonanza Volcanics. They are light green, grey, black and rarely reddish brown on fresh surface and weather to bright white and grey. These rocks may be essentially siliceous tuffs. Though not identified by the writer they contain, according to Danner[5], radiolarians. Like Danner the writer believes that these rocks are of Triassic or Jurassic age, and more probably Jurassic. They are considered to overlie the Bonanza Volcanics and were presumably deposited on deeper slope or ocean floor west of the Jurassic volcanic arc.

Danner[5] noted that the cherts are similar to those of the San Juan Islands, that are associated with Permian limestone. To the writer's knowledge there is no criterion to distinguish these similar formations of apparent different age. In that regard it may be mentioned that intermediate volcanic rocks of the late Paleozoic Sicker Group and those of the Bonanza Subgroup are similar in composition. Both volcanic sequences were the product of similar volcanic arcs and perhaps correlative distant, deep water sediments are also similar.

Greywacke-conglomerate unit

This rock-unit is the most wide spread formation of the Pacific Rim Belt and led earlier to the designation "Tofino Greywacke"[1]. In the park it underlies most of the hilly coastal area between Point Cox and Portland Point and outcrops in the headland between Wickaninnish and Florencia Bays.

Greywacke is generally massive and indistinctly bedded rock and except for a few siltstone interbeds attitudes are difficult to determine. They are fine to medium grained and contain poorly sorted, angular fragments of quartz, plagioclase, K-feldspar, volcanic rock, chert, minor chlorite, epidote (detrital) and biotite. Quartz and chert fragments commonly weather out conspicuously on coarse, gritty greywacke. Conglomerate is exposed on both headlands enclosing Cox Bay and best on the northerly one outside the park. It is believed to form the base of the unit and consists of greywacke with well-rounded clasts, one to six inches in diameter that are irregularly scattered throughout the greywacke matrix. Layers, lenses of tightly packed fairly well sorted clasts, and crossbedding, so common to deltaic deposits of the Upper Cretaceous Nanaimo Group, were not encountered. The cobbles are mainly chert, minor quartz-feldspar-biotite porphyry, and rare limestone. The porphyry may be derived from hypabyssal granitic rocks, associated with and intermediate between Jurassic plutons and Bonanza Volcanics[6].

The greywacke unit is composed of detritus of the Triassic-Lower Jurassic volcanic sequence. It was formed as a result of erosion following volcanism, plutonism and major uplift in Early to Middle Jurassic time. The character of the rocks seems to be indicative of mass-transport of sediment in suspension to deeper water. If the original stratigraphic position is indeed below the Valanginian siltstone unit the age is either earliest Cretaceous or Upper Jurassic.

Siltstone-argillite unit

The siltstone-argillite unit is best developed on Ucluth Peninsula south of the park, but small areas are found elsewhere with the greywacke unit.

Mostly the siltstones are black to dark grey homogeneous rocks with poorly developed slaty cleavage. They are less resistant than the greywacke unit and break readily into small chips and splinters. Only locally are graded beds of alternating fine greywacke and argillaceous siltstone present. In most instances shearing of these rocks is too intense to allow determination of "tops" from grading and bedding structures. However, such alternation of greywacke and siltstone may serve to reveal the difference at a small angle of bedding and cleavage. In places the siltstones carry lenses of limestone and ellipsoidal concretions.

The most important aspect of the siltstones is the presence of Buchia coquinas. The writer is indebted to Dr. S. Nelson of University of Calgary for supplying him with fossils discovered south of Ucluelet on a vacation-trip. Subsequently more locations were found by the writer on Ucluth Peninsula and more collections were made. J.A. Jeletzky kindly made a preliminary identification of some collections and stated that they are probably Buchia pacifica Jeletzky 1965 of mid-Valanginian age, and thus probably equivalent to those in beds of the "One Tree Formation" of Grassy Islands[7] farther north along the west coast of Vancouver Island.

The combined greywacke and siltstone units are thus established to be of Early Cretaceous and (?) Late Jurassic age and are tentatively identified as the flysch-sequence following Middle Jurassic plutonism and uplift, but preceding Late Cretaceous and Early Tertiary major tectonism.

Tertiary granitic rocks

Biotite-hornblende granodiorite forms a pluton more than five miles long in the Coastal Belt, mostly in the park southwest of Kennedy Lake and a small pluton less than one half mile wide is exposed outside the park in the Pacific Rim Belt near Tofino. The latter extends southward in a 10-foot-wide sill of aplite, well exposed along the coast. These rocks are intrusive into Triassic and Jurassic rocks, and near Tofino the contact is sharp with wedges of hornfelsic argillite protruding into the intrusive. The Tofino stock was dated radiometrically[8] as 50 ± 5 m.y. GSC 66-31 (Eocene). No dates are available for the Kennedy Lake body, but quartz monzonite from nearby Paradise Creek (GSC 66-32) is 59 ± 3 m.y. Although Jurassic dates have also been obtained from the granitic rocks at the nearby former Brynnor iron mine[1] the granitic rocks in the park are all provisionally considered to be of Tertiary age. The plutonism could be related to the intense tectonism that occurred at that time.

Late Pleistocene deposits

Little time was available for study of Pleistocene deposits of the park area but these have been studied in some detail in connection with soil and landform studies by others[9].

The entire Pacific Rim Belt as well as the area surrounding Kennedy Lake was covered by ice to a height of about 800 feet during maximum glaciation. All striae indicate that ice moved evenly southwestward and was barely diverted by the low northwestward striking ridges. Groundmoraine covers the higher ground but as the area was isostatically depressed much of the lower country was below sea level. There, marine clay with sparse shells and scattered boulders was deposited by floating ice.

After the ice receded outwash deposits were laid down on top of till and stony clay. However, some outwash deposits preceded the ice for the Tofino gravel pit, at the north end of the park, shows stony clay overlying outwash. Immediately after recession of the ice sea level was about 200 feet below the present level. Higher hills stood above the water but the low areas were filled with a level surface outwash. The former islands rise now conspicuously as monadnocks above the outwash plain.

Stony clay and overlying outwash are shown on the accompanying map as originally mapped by Valentine. An area north of the park on Esowista Peninsula is tentatively shown as pre-glacial outwash, on the basis of the observed relationships in the Tofino gravel pit.

Structure

The structure of the Coastal Belt is not clear as the rocks occur as large to small monadnock hills, separated by wide areas of Pleistocene deposits that may conceal many faults. Several faults splaying northwesterly appear to separate Coast and Pacific Rim Belts. Only in one place, east of Ucluelet Inlet and outside the park, was such a fault observed. There a zone of shattered diorite, several hundred feet wide with countless quartz and carbonate-filled cracks, weathering to orange-rusty colour, is exposed and in contact across a narrow covered interval with mylonitic tuff and breccia. Faults within the shatter-zone are north-northeast directed, almost vertical and with near-horizontal striae. These faults are apparently secondary to the main fault that should strike northwesterly, a slip-direction that is not represented in the shatter-zone. The general relationships suggest that these faults are steep faults whereby the Coastal Belt was thrust southwestward over the Pacific Rim Belt, probably also with substantial strike-slip movement.

A northeasterly-trending set of faults is inferred to cut across the general strike from Kennedy Lake to the Pacific Coast. Fault-patterns in individual outcrops commonly show northeasterly faults cutting and offsetting northwesterly faults and this relationship is inferred to hold true for the Kennedy Lake–Ucluelet fault.

Within the Pacific Rim Belt faulting and tectonic disturbance is at a maximum. Only the massive greywackes have to some extent escaped distortion and the preservation of fossils in a few places near Ucluelet is almost miraculous. No stratigraphic thicknesses could be measured for most rock-units and their mutual relationships are only inferred from a general knowledge of the areal geology.

Attitudes of "bedding planes", generally sheared and barely deserving to be classed as such, dip mostly steeply to the northeast.

Most outcrop areas show many faults and along the coast these faults are commonly eroded into surf-channels. Though no statistical study was made general observation showed a large number of strike faults trending northwesterly (300-340) and dipping 50 to 90 degrees northeast. Several of these faults showed horizontal to inclined slickensides but direction of movement was mostly indeterminable. Cross-faults striking east-northeast (70 to 90 degrees) dip 60 to 90 degrees south and are generally sinistral. Those striking north-northwesterly (0 to 30 degrees) and dipping steeply east showed in several instances dextral movement. Cross-faults generally offset strike faults.

In summary the Pacific Rim assemblage is a highly tectonized, but unmetamorphosed belt of Triassic to Lower Cretaceous volcanic and volcaniclastic rocks. Initial steep southwestward thrusting along northwest striking northeast dipping faults may later have changed into strike-slip movements. Northerly and easterly cross-faults may have been initiated together with the northwesterly faults but apparently continued longer in activity.

The time of faulting was probably at least partly post-Valanginian. Its termination is suggested by exposures just south of Tatchu Point, northwest of the area under discussion. There a shattered belt of volcanic rocks, similar to those in the park-area, is unconformably overlain by undisturbed sediments that are Upper Eocene in age (B.E.B. Cameron, pers. comm.). One may therefore tentatively conclude that in the Pacific Rim Belt fault-movement had stopped by late Eocene time.

Regional tectonics

Sutherland Brown[10] proposed earlier that the "enigmatic Leech River Group" of south Vancouver Island might be equivalent to known Jura–Cretaceous rocks of Quatsino Sound area. The Leech River schists are an assemblage of metagreywacke, slaty argillite, and their metamorphic equivalents ranging from phyllite through quartz-biotite schist to paragneiss. The metamorphic rocks were intitally of the same lithology as those of Pacific Rim and Quatsino Sound. A recent potassium-argon dating on the schist yielded 40 - 2 m.y. (R.K. Wanless, pers. comm.) indicating early Tertiary metamorphism. Thus the highly disturbed but unmetamorphosed Pacific Rim rocks may well be intermediate between unaltered, less disturbed Quatsino Sound rocks and Leech River schist. A further continuation of these rocks is apparently present in San Juan Islands.

The rim of highly disturbed Jura–Cretaceous rocks is also present at the western tip of Brooks Peninsula and thus indeed seems to border most of the west side of Vancouver Island. West of that rim an assemblage of Tertiary clastic sediments on Eocene basalts underlies southern Vancouver Island, Olympic Peninsula and the ocean floor and is generally considered to be young oceanic crust with a veneer of Tertiary sediments.

The lithology, age and intense deformation of the Pacific Rim rocks are similar to those of the Franciscan Terrane of California. However, so far no blueschist or ultramafic rocks have been found in the Pacific Rim assemblage.

Monger and others[11] have recently outlined a possible plate tectonic history of the Canadian Cordillera. They assume that in Early Jurassic time a volcanic arc occupied the Insular Belt while directly to the west an oceanic trench existed. Subduction coupled with stike-slip movement occurred below this region from Jurassic to Early Tertiary time. In several respects this model agrees well with observed conditions in the Pacific Rim Belt. This highly disturbed belt of Late Triassic to Early Cretaceous rocks may well represent the slope- and trench-deposits of the Mesozoic continental margin, compressed and crushed in the late-Mesozoic to earliest Tertiary subduction-zone.

[1]Muller, J.E. and Carson, D.J.T.: Geology and mineral deposits of Alberni map-area, British Columbia; Geol. Surv. Can., Paper 68-50 (1969).

[2]Clapp, C.H. and Cooke, H.C.: Sooke and Duncan map-areas, Vancouver Island; Geol. Surv. Can., Mem. 96 (1917).

[3]Danner, W.R.: Limestone resources of Western Washington; Wash. Div. Mines Geol., Bull. 52 (1966).

[4]Carlisle, D.: Late Paleozoic to mid-Triassic sedimentary-volcanic sequence on northeastern Vancouver Island; in Rept. of Activities, November 1971 to March 1972, Geol. Surv. Can., Paper 72-1, pt. B, p. 24-30 (1972).

[5]Danner, W.R.: Western cordilleran flysch sedimentation, southwestern British Columbia, Canada, and northwestern Washington and central Oregon, U.S.A.; Geol. Assoc. Can., Spec. Paper 7 (1970).

[6]Northcote, K.E. and Muller, J.E.: Volcanism, plutonism and mineralization; Vancouver Island; Can. Mining Met., Bull. (in press).

[7]Jeletzky, J.A.: Late Upper Jurassic and early Lower Cretaceous fossil zones of the Canadian western Cordillera, British Columbia; Geol. Surv. Can., Bull. 103 (1965).

[8]Wanless, R.K., Stevens, R.D., Lachance, G.R. and Edmonds, C.M.: Age determinations and geological studies; K-Ar Isotopic studies, Report 8; Geol. Surv. Can., Paper 67-2A (1968).

[9]Valentine, K.W.G.: Soils of the Tofino-Ucluelet lowland of British Columbia; Can. Dept. Agric., Rept. No. 11 of the Brit. Col. Soil. Surv. (1971).

[10]Sutherland Brown, A.: Tectonic history of the Insular Belt of British Columbia; Can. Inst. Mining Met., Spec. Vol. 8, p. 83-100 (1966).

[11]Monger, J.W.H., Souther, J.G. and Gabrielse, H.: Evolution of the Canadian Cordillera; a plate-tectonic model; Am. J. Sci., v. 272, p. 577-602 (1972).

13. BLANKET MOUNTAIN AREA, BRITISH COLUMBIA

Project 720053

J.E. Reesor
Regional and Economic Geology Division, Vancouver

A short period was spent in geological reconnaissance in the general vicinity of Mount Begbie during the past season, in part of an area mapped by Craig[1]. This area is situated at, and just north of the core zone of Thor-Odin-Cranberry gneiss dome[2]. Rocks consist of granitic gneisses and schists of the core zone as well as quartzite, calcium-silicate gneiss and pelitic schist of the mantling zone. Mineral assemblages in pelitic rocks include sillimanite-almandine-muscovite and indicate an upper amphibolite facies for all of the area mapped.

Structures are particularly well outlined by extensive quartzite units. The earliest recognized structural event resulted in a series of isoclinal recumbent folds with a hinge to hinge distance up to 4 miles. Axes of these folds trend generally west-southwest. A second set of folds, northward verging, with east-west axes and upright to moderately south dipping axial planes deform the isoclinal recumbent folds. These folds are best developed on a mesoscopic scale, although south of Mount Begbie they may be up to several hundred feet in amplitude. A third set of folds trend northwest, and though they are best developed on a megascopic scale along the east flank of the metamorphic complex they parallel the northwest trend of the major culmination of the Thor-Odin and Frenchman's Cap domes[2].

Strata involved in this deformation and metamorphism are lithologically similar to the latest Precambrian (Horsethief Creek Group) and the lower part of the Lower Cambrian succession (Hamill Group) of the Selkirk Mountains to the east.

[1] Craig, D.B.: Structure and petrology within the Shuswap Metamorphic Complex, Revelstoke, British Columbia; unpubl. Ph. D. thesis, Univ. Wisconsin (1966).

[2] Reesor, J.E. and Moore, J.M., Jr.: Structure and petrology of Thor-Odin Gneiss Dome; Geol. Surv. Can., Bull. 195 (1971).

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14. HAZELTON (EAST-HALF) MAP-AREA, BRITISH COLUMBIA (93 M)

Project 720038

T.A. Richards and C.J. Dodds
Regional and Economic Geology Division, Vancouver

Mapping of the Hazelton (east-half) map-area began in 1972. Figure 1 shows the distribution of lithologies as interpreted from this year's field work.

The oldest rocks in the map-area, Late Triassic age, are faulted and fractured basic volcanics and greywacke exposed only along the west shore of Babine Lake at the southern boundary of the map-area. No fossils were found in this unit, but the rocks are similar to fossiliferous Upper Triassic rocks in the Smithers map-area[1,2].

The Sinemurian, Pliensbachian and Toarcian stages of the Lower Jurassic are represented in the map-area as mappable units. The Sinemurian rocks are purple, red and maroon, well-bedded to massive tuffs and breccias correlative with Sinemurian volcanics in the Smithers map-area. Pliensbachian rocks are mainly thin-bedded (1 foot - 3 feet thick), grey, tough, shallow-water marine volcaniclastic sandstones, interbedded with 500 - 600 feet of nonmarine red and green vesicular volcanics and red volcanic sandstones. Rocks of Toarcian age occur in the eastern part of the map-area and comprise three distinct members. A lower member possibly in excess of 3,000 feet thick, consists of interbedded black shale, greywacke, volcanic breccia and few thin, pyritic limestone lenses and nodules. Sills of altered diorite 10 to 100 feet thick are common throughout the sequence. Slump structures in the greywackes suggest deposition on an easterly dipping paleoslope. Sparse ammonites indicate a Lower Toarcian age. A middle member comprises 1,000 to 2,000 feet of marine and nonmarine andesitic volcanics. The marine volcanics are green breccias, tuffs, and flows with interbeds of calcareous cemented volcanic sandstone, limestone lenses and coral reefs. Crossbedding in the sandstone indicates a westerly source. The nonmarine volcanics are reddish to purplish, vesicular flows and breccias. The upper member of the Toarcian comprises thin-bedded, shallow-water marine cherty tuff, volcanic sandstone and black shale. Excepting the black shales, this member represents a shoreline facies. The Toarcian section is overlain conformably by sediments of Early Bajocian age.

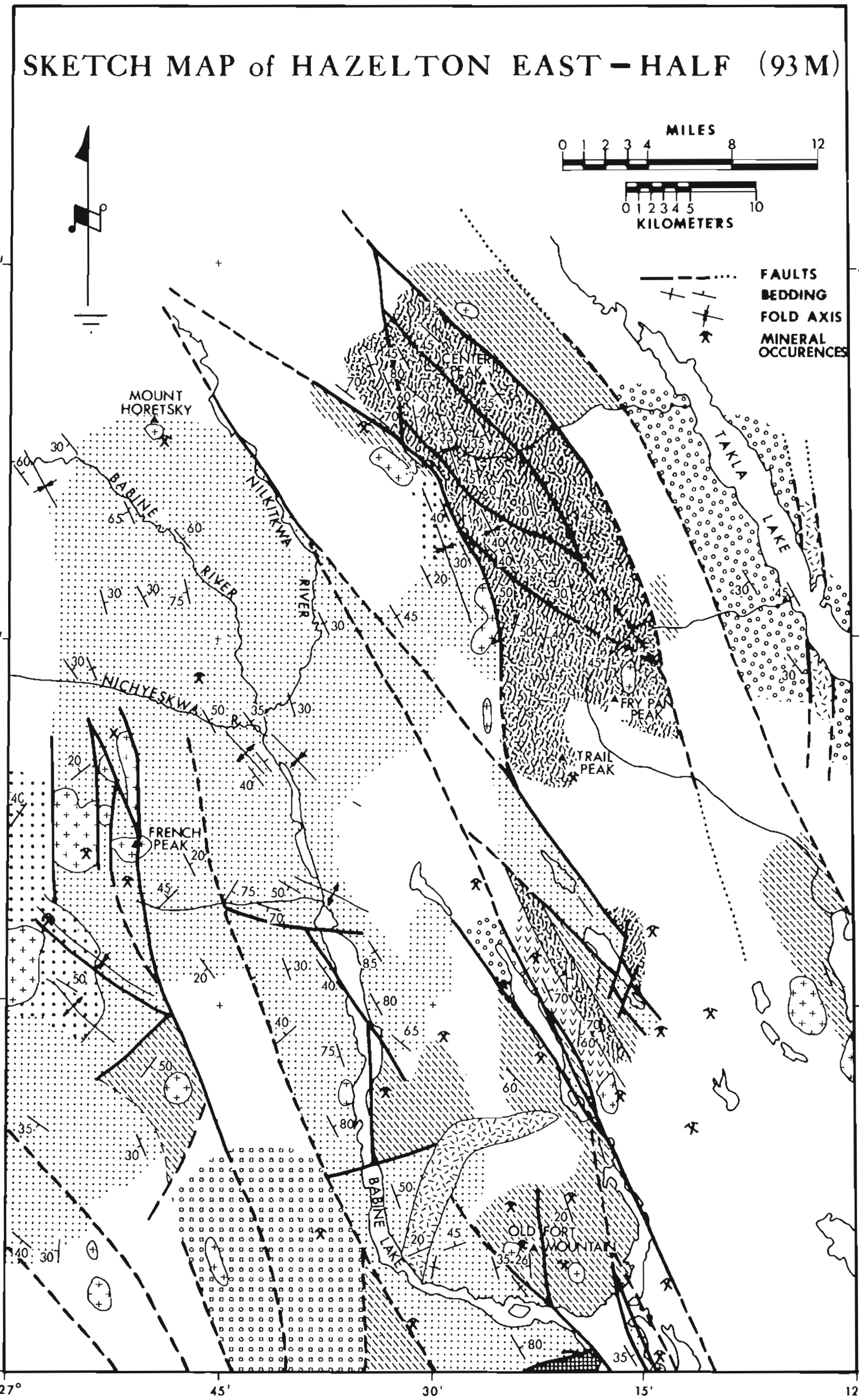
Middle Jurassic rocks are widespread. West of Nakinilerak Lake, argillite, and feldspathic greywacke are interbedded with water-lain red tuff and minor coarse breccias of Early and Middle Bajocian age. Abundant fossils indicate a nearshore marine environment. The only Callovian rocks west of Nakinilerak Lake are marine volcanic breccias. Elsewhere, they are marine black shale in the north and nearshore volcanic arenite in the south.

Upper Jurassic sedimentary rocks are best exposed southwest and west of French Peak and comprise argillite, impure sandstone and grit with a few conglomerate lenses.

Lower Cretaceous rocks can be divided into two divisions; one of pre-Albian age and the other of Albian or younger age. North of Babine Lake, the pre-Albian rocks are well-bedded, nonmarine siltstone, sandstone and chert-pebble conglomerate with some black shale and thin carbonaceous seams. Crossbedding indicates an easterly derivation. Minor intercalations of feldspar and augite porphyry breccia and agglomerate occur with the sedimentary rocks. In the southern part of the area, however, volcanic rocks dominate over clastic rocks. There, rhyolitic to basaltic agglomerate, breccia, tuffs and flows are interbedded with nonmarine clastic rocks. The Albian rocks consist mainly of nonmarine red-bed sandstone and siltstone in the north and fossiliferous marine black shale and nonmarine sandstone in the south. Some volcanics are intercalated with the Albian sediments, and west of the north end of Babine Lake, they form the dominant lithology. In part, at least the source of Albian sediments was to the west. The presence of broad leaf flora and a marked increase in the amount of clastic muscovite in Albian and younger sedimentary rocks aids in separating them from the pre-Albian clastic rocks. Some of the nonmarine clastic rocks in the northern part of the Albian subdivision may be part of the Upper Cretaceous and younger Sustut Group.

The youngest rocks in the area, of probable early Tertiary age, are acidic to intermediate ignimbrite tuffs and breccias. Some of the numerous

SKETCH MAP of HAZELTON EAST – HALF (93M)



LEGEND

LOWER JURASSIC to MID TERTIARY

intrusions - batholiths, stocks, sills and dykes of diorite to quartz monzonite composition; includes both fine grained and coarse grained types.

EARLY TERTIARY

acidic to intermediate tuffs and breccias; minor flows. includes some rhyolite and felsite intrusions.

LATE CRETACEOUS to EARLY TERTIARY

non-marine conglomerate, sandstone, siltstone and shale, some red beds.

LOWER CRETACEOUS or YOUNGER

non-marine conglomerate, sandstone, siltstone and shale; rhyolite to basaltic agglomerate, breccias, tuffs and flows; includes some augite porphyry and marine black shale.

LATE JURASSIC

argillite, impure siltstone, sandstone and conglomerate.

MIDDLE JURASSIC

feldspathic greywacke, argillite, cherty tuff, red tuff and breccia.

EARLY JURASSIC

TOARCIAN

greywacke, argillite, tuffs, marine and non-marine volcanics, limestone lenses and reefs.

PLIENSBACHIAN

marine volcaniclastic sandstone, siltstone, minor conglomerate and limestone; vesicular flows and breccia and non-marine red bed argillite, sandstone and minor pebble conglomerate.

SINEMURIAN

red, maroon and purple tuff and breccia.

LATE TRIASSIC

greywacke, argillite, water-lain tuffs and breccias.

rhyolite and felsite masses found throughout the area may be related to this unit. These rocks are probably correlative with the Ootsa Lake Group.

Numerous intrusions of differing compositions, ages and forms are present in the area. Figure 1 shows only the location of a few of these and does not differentiate as to age or composition. Relationships of the intrusive rocks to the regional geology are incompletely known. Diorite to quartz monzonite sills and stocks of Early Jurassic to Middle Jurassic age are the oldest recognized intrusions and outcrop mainly in the eastern part of the map-sheet. Large stocks and sills of tonalite, granodiorite and quartz-biotite-feldspar porphyry of probable Early Cretaceous–Late Cretaceous age appear confined to the western part of the area. Mid-Tertiary porphyries are numerous and varied in composition. They are widespread, but many occur in a broad belt in or near fault zones separating Lower Cretaceous rocks from older rocks.

Block faulting and northeast to easterly directed thrust faulting characterize the area. Folding is prominent in rocks of all ages and seems mainly to be in response to the thrust faulting. Block faulting has resulted in horst and graben-like structures.

Copper mineralization is of economic importance, with one producing mine (Bell Copper on Babine Lake) and numerous prospects. Most of the economic interest lies in the association of copper mineralization to mid-Tertiary biotite-feldspar porphyry intrusions. No new occurrences of copper were found during the summer's investigations.

[1] Tipper, H.W.: Smithers Map-area, British Columbia; in Report of Activities, Pt. A, April to October 1970, Geol. Surv. Can., Paper 71-1A, p. 35-37 (1971).

[2] Tipper, H.W.: Smithers Map-area, British Columbia; in Report of Activities, Pt. A, April to October, 1971, Geol. Surv. Can., Paper 72-1A, p. 39-41 (1972).

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15. COAST MOUNTAINS PROJECT

Project 630016

Part I: Examination of Shoreline Between Knight Inlet and Howe Sound

J.A. Roddick and W.W. Hutchison
Regional and Economic Geology Division, Vancouver

Field work during 1972 was concentrated mainly along the shore from the north end of Knight Inlet to Howe Sound, and marked the completion of the shoreline phase of the project. Some work in the interior was conducted, especially in the Tantalus Range (Vancouver, west-half), and the detailed study of the Mount Raleigh area (northeast Bute Inlet map-area) was completed by G.J. Woodsworth.

The southwest contact of the Coast Crystalline Belt is exposed on Hardwicke, West Thurlow, Vancouver and Quadra Islands. The contact is sharp on the west tip of Hardwicke Island, where quartz diorite intrudes Karmutsen Group volcanic rocks, and also near Eden Point at the west end of West Thurlow Island, but is complicated by apparent dioritization of

Karmutsen volcanics on the south shore of that island. Across the northeast shoulder of Vancouver Island, and on the north tip of Quadra Island, the Karmutsen Group is well foliated to schistose in a zone about one mile wide adjacent to the contact. Within a few feet of the contact, the volcanic rock has been altered to amphibolite. The contact crosses Quadra Island from Bodega Point to Open Bay, but is well exposed only in Open Bay. At the contact is a narrow zone of angular agmatite in which some skarn and hornfels has been produced. The Karmutsen strata are not sheared but exhibit non-cylindrical folds 200 to 500 feet across, overturned to the southwest with axial planes dipping as low as 55° to the northeast. Limestone beds in these large folds show much smaller folds having the appearance and orientation of drag-folds. West of the contact zone the Karmutsen Group exhibits only gentle open folds and low-grade metamorphism (represented by zeolite and prehnite-pumpellyite-bearing assemblages)[1].

Gneissic terrane is largely restricted to the northeast side of a line extending southeasterly from near the northwest corner of Bute Inlet map-area to the southern end of Cosmos Heights on Bute Inlet. East of Bute Inlet, this gneiss line appears to be offset northward and continues from the north end of Bute Inlet to the north end of Howe Sound.

Gabbroic bodies are restricted to the western fringe of the Coast Crystalline Belt and continue a pattern observed in map-areas to the north-west. Small gabbroic bodies outcrop on Hardwicke, West Thurlow, Read, West Redonda and Rendezvous Islands, and on the mainland at the south ends of Bute Inlet and Powell Lake.

The upper part of Toba Inlet transects about 4,000 feet of conglomerate that is of probable regional significance. The clast:matrix ratio is about 4:1, with most of the clasts being subangular, partly flattened cobbles and boulders up to 8 feet across (but most less than 1 foot), embedded in a schistose biotite-garnet-bearing, meta-arkose matrix. About 80 per cent of the clasts consist of quartz diorite and the remainder are chiefly quartzite (or rhyolite) and biotite schist. On the southeast side of Toba Inlet, the conglomerate appears to be in unconformable contact with a quartz diorite that is identical to that forming some of the clasts. The actual contact, however, was not discerned as the matrix becomes increasingly granitoid as the contact is approached, and distinguishable clasts become rare and finally disappear. The conglomerate thus seems to grade without a break into the underlying plutonic rock. Conflicting relations appear on the northwest side of Toba Inlet where the quartz diorite is separated from the conglomerate by a zone of biotite schist, quartzite and gritty arkose, which is penetrated by veins emanating from the quartz diorite. On both sides of the inlet, the conglomerate is overlain by isoclinally folded, quartz-biotite-garnet schist, quartzite, diopsidic layers and amphibolite.

The conglomerate can be correlated with that on Mount Alfred (at head of Jervis Inlet); the two occurrences are on strike, but separated by about 20 miles of plutonic rock that forms part of Big Julie Pluton. Also along strike, but about 60 miles farther southeast, is the conglomerate at the base of the Gambier Group. If this more distant correlation is valid, the Toba Inlet sequence may represent an instance of strata as young as Lower Cretaceous having undergone substantial regional metamorphism (amphibolite grade) within the Coast Crystalline Belt.

[1] Carlisle, D. and Susuki, T.: Structure, stratigraphy and paleontology of an Upper Triassic section on the west coast of British Columbia; Can. J. Earth Sciences, v. 2, p. 422-484 (1965).

Part II: Metamorphism and Plutonism in the Mount Raleigh Area, Coast Mountains, British Columbia

G. J. Woodworth

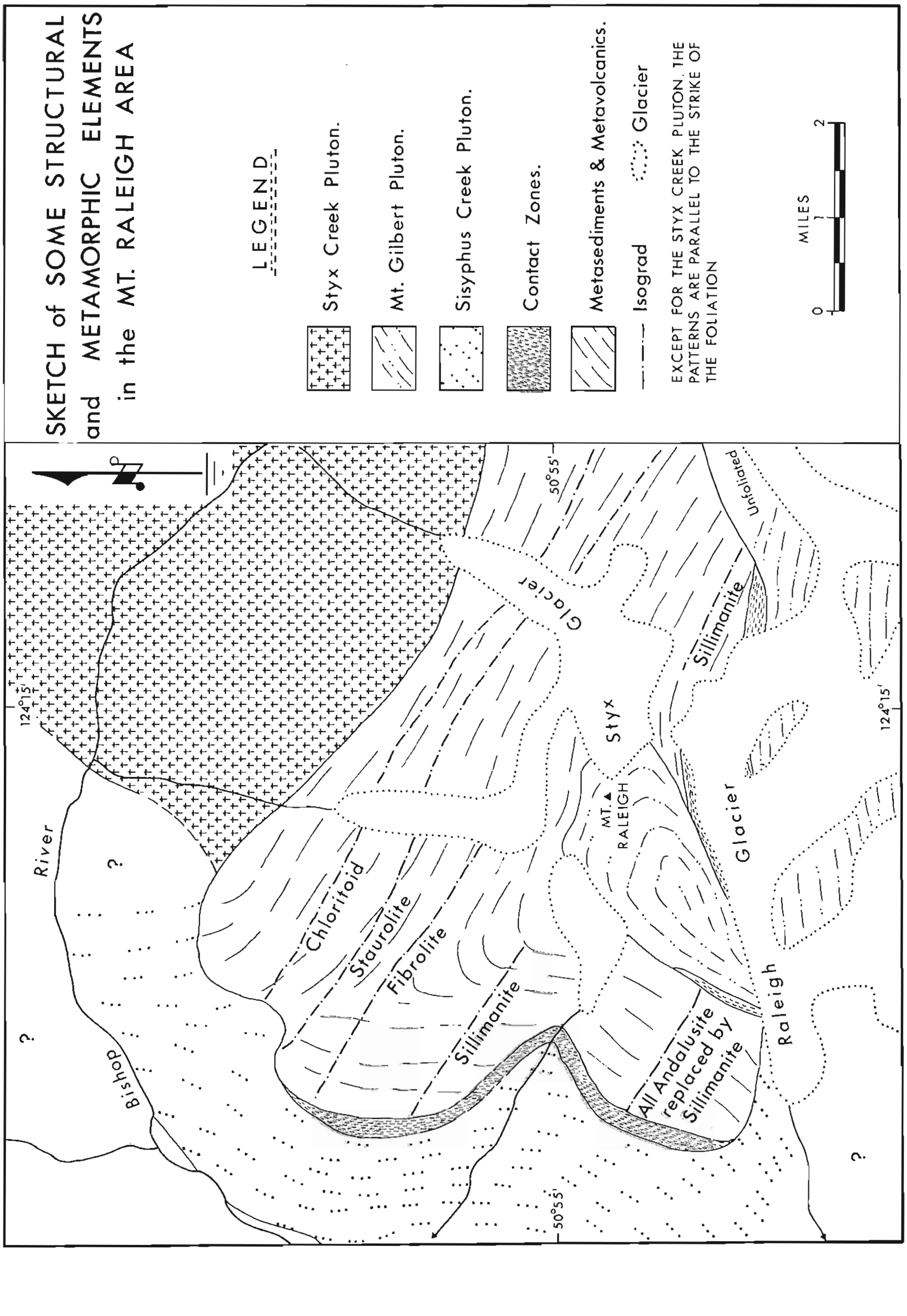
Field work in the Mount Raleigh area was completed during the summer of 1972. This report will focus on the plutonic rocks in the western part of the area and their relation to the metasedimentary and metavolcanic rocks; the stratigraphy and general structure of the stratified rocks have previously been described.[1]

At least three distinct plutons bound the metamorphic rocks in the western part of the area (Fig. 1). The Mount Gilbert pluton (including the plutonic rocks exposed on Mount Raleigh) is a poorly-foliated hornblende/biotite quartz diorite that commonly contains minor clinopyroxene. On the north side of Mount Raleigh the plutonic rock is in extremely sharp contact with the stratified rocks. Neither the plutonic rocks nor the schists are cut by quartz veins or pegmatite dykes. In the vicinity of the Raleigh Glacier, the quartz diorite is in sharp contact with a zone of fine-grained irregularly layered gneiss which is in turn in sharp contact with quartzite and biotite schist. Gently dipping undeformed pegmatite diorite is everywhere parallel to the foliation in the metasediments and metavolcanics. Contacts between the Mount Gilbert pluton and the metasedimentary and metavolcanic rocks are perhaps in part synplutonic faults.

The Styx Creek pluton is composed of homogeneous unfoliated biotite granodiorite containing abundant sphene and epidote. The contact between this pluton and the metasediments is marked by a zone up to 600 feet wide of migmatitic plutonic rock, screens and inclusions of metasediments, with aplite and pegmatite dykes intruding all rock types. On a larger scale, the contact zone of the metasediments for a distance of up to 1,000 feet from the contact are cut by gently dipping pegmatite dykes; these dykes have an average thickness of about ten feet in the contact zone, and gradually pinch out in the metasediments.

The Sisyphus Creek pluton is composed primarily of strongly foliated biotite/hornblende granodiorite. Locally, the granodiorite grades into quartz monzonite or quartz diorite. Minute pink garnets are found in trace amounts in the quartz monzonite and granodiorite, particularly in less well foliated parts of the pluton. Screens and elongate inclusions are everywhere aligned parallel to the foliation. The foliation is parallel to that in the metasedimentary and metavolcanic rocks. Contacts between the Sisyphus Creek pluton and the stratified rocks are generally marked by a lit-par-lit transition zone of gneissic quartz diorite, hornblende and biotite schists, and irregularly layered gneiss. In contrast, the contact immediately north of the snout of the Raleigh Glacier is sharp and truncates the bedding in the stratified rocks.

The pronounced southwest-plunging lineation that has been described from the stratified rocks[1] is also present in two of the plutons. In the Mount Gilbert pluton amphibolite inclusions and, to a lesser extent, hornblende crystals in the quartz diorite are aligned parallel with the lineation. The quartz diorite on Mount Raleigh contains numerous blocky mega-inclusions (up to several hundred feet wide) and screens of quartzite and marble. Within these inclusions, the southwest-plunging lineation is commonly well-developed. In the Sisyphus Creek pluton, the lineation is shown by the parallel alignment of the elongate amphibolite inclusions and hornblende crystals in the plutonic rock.


SKETCH of SOME STRUCTURAL and METAMORPHIC ELEMENTS in the MT. RALEIGH AREA
LEGEND
Styx Creek Pluton.
Mt. Gilbert Pluton.
Sisyphus Creek Pluton.
Contact Zones.
Metasediments & Metavolcanics.
Isograd
Glacier
EXCEPT FOR THE STYX CREEK PLUTON, THE PATTERNS ARE PARALLEL TO THE STRIKE OF THE FOLIATION
MILES
0
1
2
124°15'
50°55'
Bishop
River
?
Chloritoid
Staurolite
Fibrolite
Sillimanite
All Andalusite replaced by Sillimanite
Glacier
Styx
MT. RALEIGH
Unfoliated
Raleigh

Five isograds in the pelitic rocks have been mapped. The "fibrolite isograd" is defined as the first appearance of fibrolite, whereas the sillimanite isograd is the first appearance of coarse sillimanite pseudomorphous after andalusite. Muscovite plus quartz appears to be a stable assemblage even in the highest-grade rocks. The isograds strike northwest, transecting stratigraphic units and major structural trends. Limited data suggest that the isograds dip to the southwest. The isograd pattern appears to be completely unrelated to any of the plutons bordering the metamorphic rocks.

A narrow contact metamorphic aureole is superimposed upon the metamorphic pattern in the stratified rocks along the contact with the Styx Creek pluton. Within this aureole (not shown on Fig. 1), andalusite is partly replaced by fibrolite, and the metavolcanics are baked and recrystallized.

One of the major objectives of this study is to elucidate relationships between metamorphism and plutonism in this part of the Coast Plutonic Complex. The following conclusions appear to be valid:

1. The Mount Gilbert and Sisyphus Creek plutons were emplaced prior to the cessation of the main period of deformation and metamorphism of the stratified rocks. The generally strong foliation and presence of garnets in the Sisyphus Creek pluton suggest that this body was emplaced prior to or early in the period of metamorphism and deformation. The Mount Gilbert pluton may have been emplaced late in this episode of metamorphism and deformation.

2. The Styx Creek pluton was emplaced after the major metamorphism and deformation in this area, and has superimposed a narrow aureole of contact metamorphism upon the regional metamorphic pattern.

3. The regional metamorphism in the Mount Raleigh area, as revealed by the pattern of isograds, did not result from the intrusion of any of the nearby plutons. Plutonism at this level is neither a cause nor an effect of regional metamorphism in the Mount Raleigh area, but is essentially independent. The two phenomena may, however, be casually related at a deeper level than is exposed in this area.

[1] Woodsworth, G.J.: Petrology, metamorphism, and structure of the Mount Raleigh area, Coast Mountains, British Columbia; in Report of Activities, Part A, April to October, 1971, Geol. Surv. Can., Paper 72-1, pt. A, p. 41-44 (1972).

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16. CORDILLERAN VOLCANIC PROJECT, SPECTRUM RANGE

Project 700026

J.G. Souther
Regional and Economic Geology Division, Vancouver

Detailed geological mapping of the Mt. Edziza Volcanic Complex[1, 2] was extended south into the Spectrum Range (57°20'N, 130°45'W) where five distinct stages of late Tertiary and Quaternary volcanic activity are recognized.

Basalt flows that comprise the basal member of the Mt. Edziza pile extend south as a complex shield that underlies the entire Spectrum Range. These stage 1 basalts are characteristically thick, reddish-brown-weathering, crudely columnar flows associated with a high proportion of coarse, blocky scoria. They have the simple mineralogy typical of alkali basalts. Moderately zoned laths of labradorite, granules of fayalitic olivine and titaniferous magnetite are enclosed by ophitic plates of deep purple titanaugite.

The stage 1 basalt is overlain, in most parts of the Spectrum Range, by sodic rhyolite of stage 2. In the eastern part of the range, it occurs as a moderately to densely welded ashflow from 10 to 40 feet thick. Farther west, the stage 2 rhyolite is found only as boulders and cobbles in a thick layer of fluvial gravels that occupy an erosional hiatus between stage 1 and stage 3 basalts. The peralkaline nature of stage 2 rhyolite is inferred from anorthoclase rims on plagioclase and the presence of aegirine and aenigmatite as both phenocrystic and groundmass minerals.

Stage 3 basalts form a flat-lying shield that is structurally conformable with stages 1 and 2. The flows are thinner, more regular, and have better columnar jointing than those of stage 1. Also, they weather black or dark grey rather than reddish-brown. Their mineralogy is similar to stage 1 basalts, but the texture is usually intergranular rather than ophitic. Labradorite, clinopyroxene, olivine, and magnetite occur as both groundmass and phenocrystic minerals. The pyroxene is strongly zoned and has pronounced hourglass structure. Commonly the outermost zone is aegirine-augite, suggesting that the stage 3 magma was more alkaline than that of stage 1.

During stage 4 an enormous volume of trachyte and sodic rhyolite was erupted from one or more vents near the present apex of the Spectrum Range. Most of this material issued as lava, forming domes and short, stubby flows each from fifty to several hundred feet thick, and with a composite thickness of up to 2,000 feet. The base of each cooling unit is characterized by a vitreous layer of black to pale greenish-grey obsidian, locally with well-developed lithophysae. The upper part of most flows is a porous flow breccia that is commonly deeply oxidized to deep hues of red and yellow from which the Spectrum Range derives its name. The mineralogy of both the quartz deficient trachyte and the rhyolite, which contains model quartz, is typical of peralkaline rocks. The principal feldspars are sanidine and anorthoclase which are associated with aegirine, aenigmatite, arfvedsonite, and riebeckite.

A period of quiescence and deep erosion intervened between the close of stage 4 and the onset of stage 5 activity in post-glacial time. The latter activity is confined to the western margin of the Spectrum Range where olivine-rich, locally picritic, basalt issued from at least five separate vents, each associated with a small pyroclastic cone. The perfect preservation of these features, plus the presence of extensive beds of fine unconsolidated tephra, suggest that they are roughly coeval with the marginal cones of Mount Edziza (± 1,400 years B.P.).

The structure of Spectrum Range is due primarily to original differences in the mobility of the material erupted. Fluid basalt flows of stage 1 and 3 and the ash flow of stage 2, produced subhorizontal layers of great lateral extent. In contrast, the viscous trachyte and rhyolite lavas of stage 4 produced a thick local pile with steep initial dips outward from the apex of the Range. This original structure has been slightly modified by downwarping of the basaltic shield beneath the central, stage 4 dome of the Spectrum Range. The saucer-shaped structural depression is not bounded by a ring fracture, and thus is not due to cauldron subsidence. Instead, the central part of the originally flat-lying basaltic shield appears to have sagged gradually downward beneath the growing pile of stage 4 acidic lavas.

[1]Souther, J.G.: Cordilleran volcanic study; in Report of Activities, Geol. Surv. Can., Paper 66-1, p. 87-89 (1966).

[2]Souther, J.G.: Cordilleran volcanic study, 1966; in Report of Activities, Pt. A, May to October, 1966, Geol. Surv. Can., Paper 67-1A, p. 89-92 (1967).

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17. OPERATION SNAG-YUKON 115H, 115J, 115K (E 1/2), 115N (E 1/2)

Project 700025

D.J. Tempelman-Kluit
Regional and Economic Geology Division, Vancouver

Reconnaissance mapping for Operation Snag-Yukon was completed during the 1972 field season. Field work was confined to detailed investigations and helicopter spot checks of critical localities in all three map-areas. Numerous samples of metamorphic, plutonic and volcanic rocks were collected for radiometric age determination.

The distribution of major rock-units in the project area is given in sketch maps accompanying a previous report[1]. Granitic rocks of unit 3[1], considered Permian or older in that report, are now thought more probably Triassic. Unit 3[1] predates rocks of the Laberge Group (abundant boulders of unit 3 are found in the Laberge) and apparently post-dates latest regional metamorphism of units 1 and 2[1]. The regional metamorphism probably occurred in latest Paleozoic or earliest Mesozoic time.

Massive, dense, dark green basalt in northeastern Aishihik Lake (115H) map-area and mapped as unit 11? or 12? is probably Triassic and equivalent to the Lewes River Group. Boulders of this basalt are abundant in conglomerates of the Laberge Group.

The belt of rocks that extends northwestward from Tatchun Lake along Yukon River in Carmacks map-area and which was mapped as Mount Nansen Group (unit 7) by Bostock[2] was briefly examined at several localities. These rocks strongly resemble the basalts just mentioned in northeastern Aishihik Lake map-area; furthermore their stratigraphic relations differ from those of the Mount Nansen Group. This belt of basalt may also be equivalent to the Lewes River Group.

Rocks mapped as unit 12[1] (Hutshi Group) in Aishihik Lake map-area are most probably an explosive phase of the Nisling Range Alaskite (unit 13[1]) and are now tentatively correlated with the Skukum Group of Wheeler[3]. Unit 12[1] of Aishihik Lake map-area is lithologically dissimilar to rocks mapped as Hutshi Group in southwestern Laberge map-area[4].

Rocks of the Laberge Group and Tantalus Formation in eastern Aishihik Lake map-area were deposited largely in a nearshore or alluvial? environment under conditions of rapid subsidence and the conclusions of Wheeler[3] regarding equivalent rocks in Whitehorse map-area are applicable also in this region.

A brief visit was made to the recently discovered copper occurrences on Williams Creek in Carmacks map-area. Host rocks at this property are foliated medium- to coarse-grained equigranular biotite hornblende granodiorite lithologically identical to that of unit 3[1]. Disseminated chalcopyrite with some bornite is confined to steeply dipping schlieren conformable with the foliation in the granodiorite host. These schlieren, rich in biotite and hornblende, are many hundreds of feet long and 100 or 200 feet wide. They may mark zones along which movement, granulation and recrystallization took place during foliation of the granodiorite and may be related in time to movement along Teslin lineament. It seems likely that the mineralization in these schlieren was emplaced at about the time they were formed - most probably during the Triassic. Because such schlieren are common at many places in rocks of unit 3 throughout the project area and because at least one other copper occurrence like the one just described has been discovered it would seem that rocks of unit 3 offer a worthwhile target in future exploration for disseminated copper occurrences not only within the project area but in adjacent map-areas in Yukon. In Carmacks map-area rocks equivalent to unit 3[1] are included in unit 10[2] and the bodies along the southwest side of Yukon River are considered largely equivalent to those of unit 3[1] as are the large bodies south of Diamain Lake and Tatlmain Lake. These latter two bodies extend also into Glenlyon map-area.

The possibility that tungsten mineralization may be associated with the widespread skarns in central Aishihik Lake (see sketch map[1]) and northern Dezadeash map-areas is worthy of future testing. It is known that copper occurs in a number of these skarns and that tungsten is present in at least one.

Well indurated Tertiary conglomerates equivalent to unit 3 of Ogilvie map-area[5] and included in unit 15 in sketch maps accompanying a previous report[1] occurs on and near the Sixtymile River in western Stewart River map-area. This conglomerate is thought to offer good potential as a fossil gold placer and should be explored for this possibility. A small body of this conglomerate, which contains visible gold occurs on a ridge 1.7 miles south-southwest of Mount Hart.

[1] Tempelman-Kluit, D.J.: Operation Snag-Yukon; in Report of Activities, Part A, April to October, 1971; Geol. Surv. Can., Paper 72-1A, p. 36-39 (1972).

[2] Bostock, H.S.: Carmacks District, Yukon; Geol. Surv. Can., Mem. 189 (1936).

[3] Wheeler, J.O.: Whitehorse map-area, Yukon Territory; Geol. Surv. Can., Mem. 312 (1961).

[4] Bostock, H.S. and Lees, E.J.: Laberge map-area, Yukon; Geol. Surv. Can., Mem. 217 (1938).

[5] Bostock, H.S.: Ogilvie, Yukon Territory; Geol. Surv. Can., Map 711A (1942).

18. GEOCHEMISTRY

BEAR-SLAVE OPERATION

Project 720063

R.J. Allan, E.M. Cameron and C.C. Durham
Resource Geophysics and Geochemistry Division, Ottawa

The Bear-Slave Operation is a reconnaissance geochemical survey of some 40,000 square miles of the central parts of the Bear and Slave geological provinces of the Canadian Shield. Nearshore, inorganic, silty, lake sediment and surface lake water were systematically collected during the past field season at a site density of one per ten square miles. The objectives of the survey are multipurpose:

1. Mineral exploration. To delineate areas of anomalous metal content that may contain mineral deposits.
2. Geochemical mapping. To map regional geochemical variations in the composition of the upper crust.
3. Geochemistry of the environment. To show the natural abundance and amount of variation of several trace elements, some of which are potentially toxic, in a part of the country that has been little influenced by man's activities.

During the last several years work carried out by various members of the Geochemistry Section has indicated that lake sediments are an excellent medium for both reconnaissance and detailed geochemical exploration surveys within permafrost areas of the Canadian Shield. During 1971 a final orientation survey was carried out in the Bear and Slave geological provinces. This

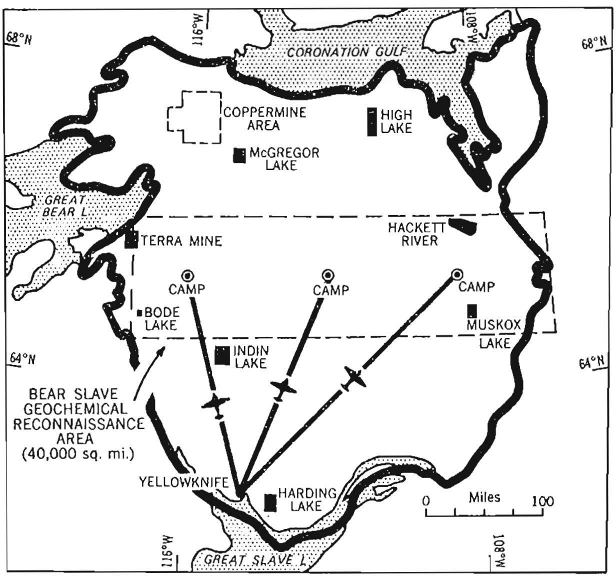

Figure 1.

Area sampled during Bear-Slave reconnaissance geochemical operation. Shows smaller areas sampled during previous orientation surveys.

Table 1
Publication map-sheets

Three map-sheets for publication	1:250,000 scale maps comprising published sheets
Wopmay River*	86-F, G (complete); 86-B, and C (north half only)
Point Lake*	86-H, 76-E (complete); 86-A, and 76-D (north half only)
Beechey Lake*	76-F, G (complete); 76B, and C (north half only)

survey involved sampling lake sediments and waters within 8 geologically different and widely separated areas. Rock samples were collected at the same time from these areas. The results [1] of this work showed that the elemental composition of inorganic lake sediments correlated well with that of the surrounding bedrock. The spatial relationship of bedrock composition to lake sediment chemistry does not appear to have been affected by the glaciations that this part of the Shield underwent. Further, the lake sediments are fine grained and are rather uniform in physical composition from lake to lake. As such they are an excellent medium for the sorption of metallic ions released from ore deposits and associated mineralization. Areas containing significant mineralization are thus readily detected by lake sediment analysis.

The Bear-Slave Operation of 1972 is a full-scale test of this type of geochemical survey. As such it was designed to test the feasibility and cost of routine surveys and to measure the benefits of the derived data across a variable geological terrane. The area surveyed extends from 64°30'N to 66°00'N and from 106°00'W to 118°00'W, covering nine 1:250,000 scale map-sheets. Its relation to the smaller areas studied in the orientation survey of the previous year is shown in Figure 1. The field operation extended from June 15th to August 5th, 1972 with sampling carried out every day from June 25th to August 2nd. Three Bell G4A helicopters were used to reach the lakes to be sampled. Water samples were collected in polyethylene bottles from just beneath the lake surface. Sediment samples were collected using extension post-hole soil augers constructed from magnesium-zirconium alloy and stainless steel. A DHC-3 Otter aircraft was used to set out gas caches for the three helicopters such that sample traverses were crudely radial in pattern and so that overflying time was kept to a minimum. All helicopters operated from the same base camp so that three base camps were successively established during the operation.

On certain days, with minimal overflying time, the sample rate per site was as low as 6.5 minutes. The average sample rate for the entire operation was 9.9 minutes per site. Approximately 150 sites (50 per helicopter), equivalent to 1,500 square miles, were sampled each day. Water samples were acidified after pH/Eh measurement at the base camp. Sediment samples were dried at the camp. In total, 4,100 sites were sampled. In the Beechey Lake map-area (see Table 1) an area of 750 square miles enclosing mainly acid volcanic rocks was sampled at a density of one site per 2.5 square miles.

In Ottawa, sediment samples were sieved to less than 250 mesh; sample preparation was completed at the end of September. Analyses by various techniques are being carried out in the laboratories of the Geological Survey,

* Unofficial name.

Geochemistry Section. The sediment samples are being analyzed for the following elements: Cu, Ni, Pb, Zn, Ag, Co, Mn, U, Hg, Mo, Ti, Ba, Cr, Be, V, Sn, Zr, Y, La, Li, Sr, As, Sb, Ca, K, Fe and Mg. Water samples are being analyzed for Cu, Zn and Hg. A measurement of organic content of the sediment samples is being made and these results will also be made available.

For publication purposes the survey area has been divided into three map-sheets, each comprising an area of three 1:250,000 scale maps. For each element the concentration at the sample site and geochemical contours drawn by computer will be superimposed on this background. A handbook, describing the logistics, field operation, analytical methods used, and relevant costs will also be published. The handbook will also indicate procedures for map interpretation, and possible exploration follow-up work.

Preliminary results for the western parts of the surveyed area indicate that the operation will achieve its objectives. The data are coherent; that is anomalous areas are defined by a number of adjacent high results rather than by just one sample point. These anomalous values then pass gradationally to background levels. The sample density chosen is based, in large part, on economic considerations. It now appears that this is sufficiently dense to define the major features of geochemical variations.

Some of the data give results which can be related to established geological concepts. Thus anomalous areas for U within the Bear Province are associated with high level granites and appear to be structurally controlled, and in the Slave Province relatively higher Zn concentrations occur at the margins of sedimentary-volcanic belts where mineralization associated with acid volcanism might be expected. Other results are completely unpredictable. Thus a large (≈3,000 square mile) and very distinct Zn anomaly extends for many miles on either side of the Wopmay fault, although the geology on either side of the fault is quite different (high level granites and volcanics to the west, highly metamorphosed eugeosynclinal sediments and migmatites to the east).

[1] Allan, R. J., Cameron, E. M. and Durham, C. C.: Lake geochemistry - a low sample density technique for reconnaissance geochemical exploration and mapping of the Canadian Shield; in Exploration Geochemistry, 1972 (Proc. 4th Internat. Geochem. Explor. Symp., London, 1972; Inst. Mining Met., London) (1972).

19. DEVELOPMENT OF GEOCHEMICAL INSTRUMENTATION

Project 700087

Q. Bristow
Resource Geophysics and Geochemistry Division, Ottawa

The field staff of the Geochemistry Section have, for some years, felt the need for a compact and very rugged pH meter for field use, including installation in float-equipped helicopters. An instrument filling all of the desired specifications has not been available in Canada.

Advantage was taken of the Special Employment Plan of the federal Winter Works Program to design such an instrument and build models for field trials. The design is available to Canadian companies interested in the manufacture of this instrument. It features rechargeable batteries giving 15 hours continuous operation on one charge, a resolution of 0.01 pH by means of a tenturn dial and null balance meter, wet storage compartment for the standard combination pH electrode built into the instrument case, small size and light weight. Military specification connectors and high insulation coating on the printed circuit board containing the integrated circuitry, ensure that readings are not affected by humidity. State of the art field effect transistors and operational amplifiers provide ultra high input impedance and excellent gain stability. The unit can be used with specific ion electrodes and for redox measurements. Six instruments were used this summer by Geological Survey field parties in locations from Newfoundland to the subarctic.

The second instrument which has been developed is a mercury vapour detector for use in the analysis of mercury in solid and liquid samples by the well-established Hatch and Ott method. It is basically an atomic absorption device incorporating the most recent advances in solid state technology, for example the conventional photomulitiplier tube is replaced by a space-age silicon photodiode coupled with an integrated circuit temperature stabilized preamplifier, the lamp emission at 2537°A (the mercury resonance line) is automatically stabilized by an optical feedback loop and a digital method of calibration is employed to obtain a direct digital readout of mercury content in nanograms. A unique logarithmic analogue to digital conversion technique, coupled with a digital peak height retrieval circuit, is used to perform the mathemetical transformation of the Beers' law absorption signal, which is required in all atomic absorption instruments.

A patent application is being made on the mercury vapour detector and both instruments are being displayed by Canadian Patents and Development Ltd., at a forthcoming manufacturers exhibition in Toronto.

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20. THE USE OF VOLATILE COMPOUNDS IN MINERAL EXPLORATION

Project 720067

W. Dyck
Resource Geophysics and Geochemistry Division, Ottawa

Procedures for taking soil gas samples and analyzing these for He, Ne, Ar, CO_2, O_2 and N_2 have been developed. The search for methods of detecting H_2S and SO_2 in soil gas is in progress.

Tests with a 300-litre ionization chamber (Fig. 1) have shown that it can be used to monitor continuously the radon content in the atmosphere. The diurnal pattern shown in Figure 2 was obtained by monitoring air from an elevation of 85 feet at the Geological Survey of Canada building in Ottawa. It is characteristic of the daily temperature inversion occurring in the atmosphere near ground level. In general the higher radon levels correspond with hazy quiet atmospheres and lower levels with clear windy or rainy days. If one can assume that the radon emanating from the ground mixes rapidly with atmospheric

Figure 1. Radon monitoring of lake waters using large ionization chamber. Core attached to the side of the boat collects radon that is released from the water. (GSC photo 202086)

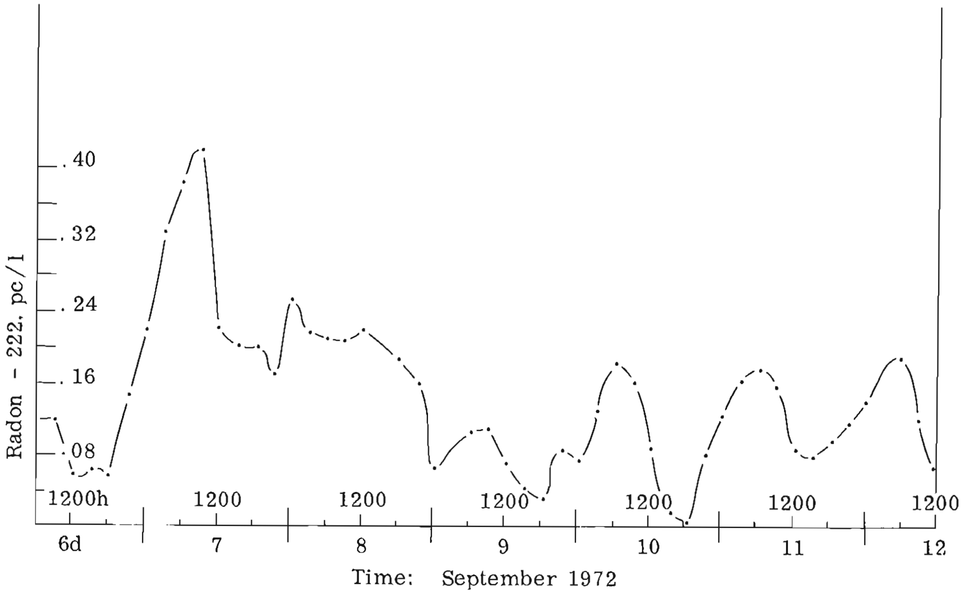

Figure 2. Variation of atmospheric radon over Ottawa.

air in a region, the ionization chamber should be useful for background corrections in high sensitivity gamma-ray spectrometer surveys.

Several tests in the Gatineau Hills showed that on windy days the air from a 30-foot height at Pinks Lake contained roughly twice as much thoron as radon and at Fortune Lake twice as much radon as thoron. These ratios are similar to those observed in soil gas and appear to reflect the relative thorium and uranium content of the soil and rock in the areas.

By placing the chamber in a boat on a lake and passing through it compressed air, which had been used to agitate the water, a reading proportional to the radon content of the water was obtained.

The tests carried out to date with the ionization chamber show that suitably modified and perfected it could become a useful tool in the search for uranium.

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21. CANADA - NEWFOUNDLAND
MINERAL DEVELOPMENT PROGRAM, PROJECT 6;
GEOCHEMICAL - GLACIAL GEOLOGICAL SURVEY (Geochemical Phase)

Project 720036

E. H. W. Hornbrook
Resource Geophysics and Geochemistry Division, Ottawa

The objective was to outline areas in Newfoundland with rich potential in metallic mineral resources, in order to facilitate discovery by exploration companies and thus contribute to the economic and social development.

This summer's pilot studies developed and tested geochemical exploration methods. The program was carried out for, and in cooperation with, the Newfoundland Department of Mines, Agriculture and Resources, Mineral Resources Division. J. M. Fleming and P. Davenport of the division were active in aspects of the survey.

Regional and detailed geochemical exploration studies were carried out in two areas of Newfoundland in the field time available. They are: A - New Bay Pond area of Notre Dame Bay, for sulphide mineralization in the volcanic and sedimentary rocks of the Wild Bight Group; and B - Daniel's Harbour area of the Northern Peninsula, for zinc mineralization associated with the St. George - Table Head disconformity. In both areas the following sample materials were collected and analyzed for Cu, Zn, Pb, Ag, Co, Ni, Mn and Hg: -80 mesh stream sediment; stream water; -80 mesh centre lake bottom sediment; lake water; -250 mesh till and -50 + 250 mesh heavy mineral separate till samples which were collected from the till-bedrock interface primarily; -80 mesh B & C horizon soils; and -80 mesh till at the peat-till interface and the occasional peat. Selected samples will be analyzed for other elements.

Conclusions at the time of writing are based on a preliminary examination of most, but not all, of the analytical data.

Conclusions are:

Area A - Lake and stream water and upper till interface sample data are, at present, inconclusive. Stream sediment data are useful providing that appropriate computer processing of the data by regression analysis is carried out to resolve the influence of manganese. Regional lake bottom sediment sampling is a successful technique when used in conjunction with geological and other applicable regional information. Overburden drilling using equipment described by Gleeson and Cormier[1] is a very useful and successful technique in suitable till conditions. In this area, till conditions were not optimum. However, till sampling data can be used to detect and indicate the probable source of till anomalies and as a discriminatory technique for evaluating conductors of geophysical anomalies.

Area B - Soil, stream sediment and lake bottom sediment sampling techniques are effective for geochemical exploration in focal and regional surveys respectively. Overburden drilling programs in shallow till provide data to detect and delineate the source of till anomalies.

[1] Gleeson, C. F. and Cormier, R.: Evaluation by geochemistry of geophysical anomalies and geological targets using overburden sampling at depth; Can. Inst. Mining Met. Special Vol. No. 11., p. 159-165. 1971.

22. DISPERSION OF FLUORINE IN THE VICINITY OF FLUORITE DEPOSITS

Project 720092

Jean-Pierre Lalonde
Resource Geophysics and Geochemistry Division, Ottawa

Three weeks of field work were carried out early in the summer of 1972 in an area containing known fluorite deposits near Madoc, Ontario. These deposits occur predominantly in Precambrian marbles and Paleozoic limestones as irregular and discontinuous veins in faults and fractures. Mineralization consists of fluorite, barite, celestite, and calcite with minor sulphides such as pyrite, sphalerite, and galena, and also bituminous material. From 1905 until 1960, one hundred and twenty thousand tons of metallurgical grade fluorspar were produced in the area.

The objectives of this study were:

1. To determine the secondary dispersion of fluorine in surface and groundwaters, stream sediments and soils.
2. To establish the feasibility of locating fluorite and barite veins with geochemical exploration methods in the Madoc area.

Regional secondary dispersions of fluorine were studied by sampling 45 soil profiles along two regional traverses, collecting approximately 60 stream sediments, 80 surface waters, and 200 ground waters. Soils were also examined along seven detailed traverses crossing known fluorite deposits or their extension. The analytical methods chosen include selective ion electrode analysis for fluoride, atomic absorption spectrophotometry for zinc, and X-ray fluorescence for barium and strontium.

The major findings after analysis are:

a. The average fluoride content of surface waters in the Madoc area is 130 ppb and values above 250 ppb may be considered as anomalous. Fluoride surface water anomalies were found in 3 lakes and 2 streams. The dispersion trains in surface waters are traceable for several miles.

b. Fluoride in groundwaters clearly delineates areas of known mineralization as well as other areas of possible interest.

c. A positive correlation exists between fluoride anomalies in groundwaters and fluoride highs in the soils of regional traverses.

d. The lateral dispersion in soils of fluoride from subcropping fluorite veins is restricted. This is probably due to a combination of three factors: the limited mobility of fluoride ion in the soils of the area, the small size of the fluorite veins, and the lack of topographical relief. Fluoride soil anomalies can be used to pinpoint subcropping fluorite veins.

e. The best soil horizon to sample in the Madoc area is the organic "A" soil horizon. It accentuates the contrast between background and anomalies.

f. Barium and zinc in soils are also useful tracers of fluorite veins in the Madoc area.

g. Geochemical exploration methods have proven useful to re-evaluate the potential of the old fluorspar mining area and may help locate new deposits.

23. SUB-AQUATIC ORGANIC GELS: A MEDIUM FOR GEOCHEMICAL PROSPECTING IN THE SOUTHERN CANADIAN SHIELD

Project 700046

M.H. Timperley, I.R. Jonasson and R.J. Allan
Resource Geophysics and Geochemistry Division, Ottawa

At present (1972) surficial geochemical methods, for use in both detailed and regional surveys, have been applied or developed with reasonable success to most areas of Canada. British Columbia, the Yukon, the Maritimes and the High Arctic can be adequately prospected by stream sediment and soil geochemistry. In the last few years large areas of the Shield in the Northwest Territories, northern Quebec and extreme north of Saskatchewan and Manitoba have been shown to be amenable to geochemical prospecting when inorganic, silty, lake sediments and frost boils are employed as the sample media. Two large units of Canada remain. These are the Interior Lowlands and the forested, non-permafrost, southern Shield. The former is primarily of economic interest in relation to oil and gas reserves, and may be better suited to various bedrock geochemistry techniques. The latter area consists of a small part of northern Manitoba and Sazkatchewan, most of Ontario and southern Quebec and the south of Labrador. It has proved to be the nemesis of geochemistry and has largely contributed to the notion that geochemistry does not work in the Shield and is thereby of dubious use elsewhere. In essence, geochemistry using surficial materials as the sample media began in what is probably the most complex of areas. However, this area of Canada is also that which contains the major part of Canada's known mineral wealth. Because of the past discovery of ore in this area, and also because of the fact that its southern location means that smaller orebodies are economical to develop, this is the area where industry wishes to apply geochemistry. However, it is also becoming increasing evident over the last few years that several geochemical projects using surficial sample media and carried out by industry in this area of the Shield, have resulted in confusing data. This problem of finding, testing and developing a viable surficial geochemical exploration technique for the southern Shield is one of the outstanding problems in geochemistry in Canada.

After studying materials found as sediments in lakes over most of the Canadian Shield, the authors believe that such media can be broadly divided into three categories:

1. Organic gels
2. Organic sediments
3. Inorganic sediments.

For a simple analogy, one can think of these three as being similar in differences and complexity to the A, B, and C horizons of soils. Within each category there are innumerable variations. However, in each category, the broad chemical, physical and as the case may be mineralogical characteristics, principles and processes are relatively uniform. The end members are 1 and 3. Category 2 is intermediate and incorporates all of the problems and complications, usually in varying degrees of both other categories. Unfortunately, most sediment samples collected from drainage systems particularly lakes, fall into category 2. Usually the samples are considered to be either from category 1 or 3 and are consequently analyzed and the results interpreted as such. This, in the authors' opinion, has been the predominant reason for some drainage system surveys producing confusing results in both the northern and southern Shield regions.

Short Definitions of Lake Bottom Materials

1. Organic gels: Materials found in organic-rich lakes, that usually occur in parts of the Shield, with a mixed deciduous-coniferous forest cover. These gels often extend for up to 30 feet or more above the inorganic sediment base of the lake. They are almost completely organic in nature, smell strongly of reducing conditions (H_2S) and are thixotropic. They dry into a hard, dark, lustreless organic cake which is difficult to break and does so conchoidally.

2. Organic sediments: Materials thought to occur in lakes in all areas of the Shield. In the north they may be incipient examples of category 1. In all areas, they represent varying mixtures of organic and inorganic sediments.

3. Inorganic sediments: Materials which occur in lakes in areas of the Shield which are sparsely forested above the treeline. The area where they predominate is above the treeline. However, they are also commonly found in areas of discontinuous permafrost in the northern zones of coniferous forest. By inorganic sediments, the authors imply various conbinations of sand, silt and clay with inorganic oxides and hydroxides and virtually no organic matter. The trace elements in this material are held on or in the silicate or sulphide lattices of the minerals comprising the sample. Usually concentrations are higher in the finer size fractions, the silt and the clay. As such, this material has been proved successful in prospecting at several scales in the northern Shield.

The two materials predominating in the southern and northern Shield are respectively organic gels and inorganic sediments.

Discussion of Organic Gels as a Sample Media

Detailed studies of organic gels in lakes in the Grenville Province of the Canadian Shield have been conducted over the last three years. More recently, sampling has been extended to two locations in the Superior Province. In order to assess the usefulness of taking organic gels as geochemical survey samples, both for detailed and regional prospecting, two main problems must be solved:

1. What is the origin of the trace elements in organic gels? i.e. the interpretation of the sometimes unusual and confusing elemental contents and relationships which are manifest in these organic gels.

2. Where in the lake should these gels be collected? i.e. the choice of material from a part of the lake that will minimize the chances of sample inhomogeneity and optimize the chances of getting a trace element concentration truly representative of the surrounding bedrock.

This latter question is the easier to solve and can largely be answered by detailed sampling of several representative lakes. The former is a problem in detailed analyses of these gels involving perhaps a considerable use of organic chemical techniques.

The first question relates to the considerable variation in the nature and structure of these gels. Observation has led the authors to believe that even these, at first appearance, homogeneous gels are in fact made up of several materials, derived from widely differing sources. These materials are thought to be:

1. Organic precipitates of colloidal origin, possibly soluble fulvates and humates.

2. Residual organic matter derived from the decay of plants, algae and plankton.

3. Pollen of predominantly local origin.

4. Inorganic minerals of very small particle size, (X-ray analysis indicates that quartz and feldspar are the dominant minerals).

Further investigation may, of course, reveal more materials or hopefully show that some of the above are insignificant in their influence on trace element variations.

Obviously item 4 will be affected by the rock type and soil types in the area, whereas, items 2 and 3 will bear a strong relationship to the local vegetation. Further, this vegetation may be related to the rock type of the area, thereby introducing further complications. Possibly, material 1 is composed of flocculated organic colloids perhaps dominated by fluvates and humates. As such, these scavengers of dissolved metals will not be significantly affected by the trace element concentrations of the original parent vegetation. Extraction and analysis of this material may remove some of the problems.

Already, it is evident that there is a large difference between the inorganic sediments from the northern Shield and the organic gels from the southern Shield. Whereas the former is largely a "lithogeochemical" sample media, the latter is largely a "biogeochemical" sample media. As mentioned, the trace element contents of the total gel may be strongly related to the preferential gathering of selected metals, to different degrees, by various source plants. We have in essence arrived at a very complex media, which may have derived a large part of its trace element content via a multistage process:

ROCK → SOIL → VEGETATION → HUMUS → STREAMS → LAKES → GELS

It may in the end prove more feasible to collect a media closer to the original bedrock. However, two main facts make the gels a good choice for the southern Shield. These are:

1. Because of its derivation and subsequent location in lakes it is obviously one of the few regionally representative sample media to be found in the area. By contrast, rock, soil or vegetation samples are very local in nature.

2. The advantages of collecting a geochemical sample medium associated with lakes in the southern Shield is apparent from a practical and economic standpoint. Sampling of these gels from small fixed wing planes is very easy and rapid. From helicopters it would be even more rapid and simple.

It is because of these facts that this medium should be assessed in considerable detail before it is rejected because of its suspected complexity.

Clyde Forks, Red Lake and Uchi Lake Sample Areas

In the light of the above discussion, samples have been collected by the authors from three localities in the southern Shield. One is in the predominantly deciduous forest area of the Grenville Province, and the other two in the predominantly coniferous forest areas of Red Lake and Uchi Lake in the Superior Province.

In the Clyde Forks area (31 F/2) approximately 150 samples of co-existing inorganic sediments and organic gels were collected from two lakes, Lavant Long Lake and Perch Lake. In the former, water is about 45 feet deep, and in the latter about 35 feet deep. Sampling was by scuba equipped divers, who also made visual observations concerning the gels. Water samples were collected in the upper 3 feet of water and near the bottom of the lake above the surface of the gels. All the inorganic sediments and gels have been analyzed for organic carbon, carbonate, S, Zn, Cu, Pb, Ni, U, Ag, Hg, As, Sb, Mn and Fe. Waters have been analyzed for Zn, Cu, Pb, Ni, U and Hg. Distribution of metals between the inorganic sediments and organic gels favoured the gels by factors from 1 to 5 depending on the element considered.

The organic gels when dried were quite variable. This variation seemed to be related to the distance from the shoreline at which the samples were collected. The deeper the water, the finer and more gel-like was the sample. In the shallow water, a mull-like chaff was prevalent. Closer to the shore the samples were, by our original definition, organic sediments. Inorganic sediments were unobtainable in the deeper parts of the lakes because of the depth of organic gels.

Preliminary carbon, Fe and Mn analyses indicated that the most homogeneous samples come from the deeper parts of the lakes. The dry samples contain between 25 and 35% by weight organic carbon and from 1 to 2% by weight sulphur.

The trace element concentrations of the gels can be related to the local geology. For example, base metals (Zn, Pb and Hg) are elevated in an arm of Lavant Long Lake which lies in Grenville marbles, whereas Cu and Ni are elevated in areas of the lake in biotite-rich gneissic rocks. This reflection is better reproduced in the gels than in the inorganic silty sediments. The water data correlate best with the organic gels. This observation is probably related to the presence of dispersed and dissolved organic materials in the waters of these organic-rich lakes. Also, this may indicate a more favourable hydrogeochemical solution to prospecting in the southern Shield than in the northern Shield, where this branch of geochemistry, with some exceptions, has been unfruitfully applied.

Sampling at Clyde Forks has been concerned with comparisons of organic gels, water and inorganic sediments to trace element concentrations in bedrock. Both lakes are in areas of known geology but, so far, unknown mineralization. The other two study areas, at Red Lake and Uchi Lake, are located in the Uchi Volcanic Belt of northwestern Ontario. As such, they are both areas of potential for the discovery of base metal mines. At Red Lake, there are several gold mines, some in operation for many years, and at Uchi Lake there are abandoned gold mines and a newly discovered and developed Cu-Zn mine. Both areas are mineralized and considered to be of high economic potential. Both are typical Archean volcanic-sedimentary belts, dominated by basic to intermediate volcanic rocks with minor amounts of acid volcanics. At both these areas, it was decided to collect only organic gels. In up to

90 per cent of the sample sites, true gels were obtained. For the remaining 10 per cent mostly organic sediments were sampled. Samples were collected using an Ekman-Birge Dredge from the floats of a DHC-2 Beaver aircraft. This procedure was extremely efficient, with samples taken in depths varying from 6 to 150 feet. There was seldom a problem in finding the correct, thixotropic sample medium and in most cases several sample bottles (1000 ml.) were filled at each site. As was mentioned above the physical nature of the gels was different from the gels from Clyde Forks. It was finer grained and less fluffy than the Clyde Forks gels. The area at Uchi Lake produced the most uniform and easily collected samples.

The Red Lake volcanic belt (52 N/4) covers some 200 square miles. In this area, three lakes were sampled in detail, one in basic volcanic, one in acid volcanic, and one in granitic rocks. Up to 30 samples of gels were collected from various parts of each of these three lakes. Several separate samples were collected at each sample site. Also, most samples were divided into sub-samples. A suite of sites was sampled in that part of Red Lake most likely to be influenced by the gold mines near Red Lake, Cochenour and McKenzie Island. Samples were also collected from widely spaced sites (2 to 3 miles apart) from most parts of the Red Lake volcanic belt. These sites were chosen to represent variations in regional geology and metallogeny. Several consecutive samples were collected at each sample site.

The Uchi Lake volcanic belt (52 N/2) covers some 300 square miles. Samples to determine dispersion from known mineralization (or recent sources of trace element pollution) were collected in three places: near South Bay Mines' Cu-Zn mine; near known minor showings on Confederation Lake (Cu-Zn) and near an abandoned gold mine on Casummit Lake (Au, Ag, As). Samples related to the regional variation in geology and mineralization were collected over the volcanic belt at intervals of some 4 to 5 miles. As at Red Lake, at all sample sites several consecutive samples were collected and samples were subdivided.

In total, at both the Red Lake and Uchi Lake areas, samples from 30 regionally scattered locations were collected. Along with the samples from the four dispersion studies and the three detail studies, approximately 200 one litre polyethylene bottles of organic gels were collected for future analysis.

Analyses of Organic Gel Samples

As mentioned previously, the success or failure of these organic gels as exploration media depends primarily on knowing both the physical site, i.e. in pollen, degraded organic matter or in inorganic materials and the chemical bonding of the trace elements in the gels. Once determined this may be related to the original source of the trace elements, i.e. surrounding bedrock, mineralization, algae or shoreline vegetation. Work currently in hand involves extraction and characterization of selected organic gel samples as well as analysis schemes to fractionate some of the samples already collected. Preliminary analyses will be made using simple extractants to help indicate the direction further studies should take. Should any of these preliminary results give trace element concentrations that can be related to known geology and mineralization, the problems of using the gels as a sample media will be greatly reduced. However, to fully understand the parameters involved in the migration and accumulation of specific elements in organic-rich drainage systems of the southern Shield, studies of the basic nature of metal binding in these subaquatic organic gels are underway.

It is expected that preliminary results at least will be available before the season of 1973, so that gels can be used in geochemical prospecting with greater confidence.

24. THE ANALYSES OF METALS IN GEOLOGICAL MATERIALS BY D. C. ARC DIRECT READING EMISSION SPECTROMETRY

Project 580175

M. H. Timperley, R. E. Horton and J. J. Lynch
Resource Geophysics and Geochemistry Division, Ottawa

An analytical method has been developed for the rapid analyses of trace metals using an A. R. L. 29000 PCQ direct reading emission spectrometer interfaced to a dedicated mini computer. The D. C. arc method is intended to produce quantitative analyses of as many metals as possible of geochemical interest in large suites (n x 1000) of samples with reasonably constant matrix composition. An example of such a suite is the 4, 100 lake sediments collected for operation Bear-Slave.

Alternative methods currently available using a direct reading emission spectrometer were considered and rejected either because their throughput was too low or because their accuracy at near-background concentrations was too poor. Studies were made of various parameters such as buffer composition, electrode dimensions, sample to buffer ratios, arcing current etc. and resulted in the decision to develop a method based on the controlled selective volatilization of metals into the D. C. arc and partial integration of the analytical lines for each metal. Following further investigations a special arc chamber incorporating a gas jet and a performed electrode to fit the chamber were designed.

The direct reader-computer system used has already been described[1]. This system is very versatile and by suitable programming, each capacitor used to store the voltage produced by light of a particular wavelength striking a phototube can be read at any time during the burning of a sample thus ensuring maximum line to background ratios. "Volatile" metals such as Cu, Zn, Pb, Ag, are measured during the initial stages of the burn while "involatile" metals such as Be and Zr, are measured near the end of the burn. This procedure eliminates one of the causes of the slow throughputs of most published methods, namely the need to use a different buffer and electrode for "volatile" metals than that used for the "involatile" metals.

Further increase in throughput is achieved by using preformed electrodes for the sample which are self-positioning with respect to the instrument optics, no electrode adjustment during the burn, automatic control of the gas flow, and computer control of spectrometer functions.

Pd and In are used as internal standards with the computer selecting the appropriate one for each metal. In the ranges of concentrations for which the method is used, the working curves are essentially linear and consequently only one standard need be used to establish working curve gradients. This standard should be a natural material of physical and chemical composition as close as possible to the samples' composition. For example, for the analysis of a suite of lake sediments the standard should be a composite lake sediment. The metal concentrations in the standards are originally determined by a combination of methods, usually atomic absorption, colorimetry, optical spectrography and X-ray fluorescence. A unique and useful characteristic of the one standard/linear working curve method is that, firstly, by including control standards during routine sample analysis, sample concentrations can be adjusted for inaccurate calibration and instrumental drift and secondly, the sample concentrations may be adjusted if more accurate analyses of the standard become available.

The instrumental details of the method used to correct for the background contribution to each analytical line are essentially the same as previously published[2,3] in which one or more phototubes are used to measure the background at various points on the spectrum. The technique described by these authors uses ratios determined from synthetic standards containing 0 ppm of the analyte metals to calculate the background contributions to the analyte lines in the natural samples. This technique was investigated and found to give inaccurate results for some metals due to the different burning characteristics of synthetic compared to natural samples. A new technique was devised based on movement of the primary entrance slit. This enables background corrections for most metals to be derived from the standard sample, and results in more accurate estimations of background contributions.

The computer program to control operation of the spectrometer and to carry out calculations was written in assembler language. The essential functions of this program are as follows:

1. The metals to be analyzed are selected.
2. The background ratios are calculated from the burning of 1-10 standard samples.
3. The gradients of the working curves are determined from the burning of 1-10 standard samples. Standard concentrations are read in prior to each burn.
4. The sample number is typed in.
5. The sample is burned.
6. The concentrations in parts per million and per cent are typed out and punched onto paper tape.
7. Operation continues from 4.

Sample throughput depends on two criteria: sample preparation time and analysis time. With the present system calibration of the instrument is required once every three or four hours. Calibration takes one hour and samples can be analyzed at the rate of 20 per hour. For a six hour day an approximate throughput of 80 samples can be expected. To achieve this throughput three persons are required for sample preparation.

The system described above has now analyzed over 2,000 sediments in routine operation and is producing satisfactory results for the following elements: Ag, Ba, Be, Ca, Co, Cr, Cu, Fe, K, La, Mg, Mn, Mo, Ni, Pb, Sr, Ti, V, Y, Zn, Zr. More comprehensive details of the method will be published at a later date.

[1] Jones, F. W. and Horton, R. E.: A data acquisition system with computer control for an optical emission spectrometer; Can. Spectroscopy, v. 16, p. 1-4 (1971).

[2] Tennant, W. C. and Sewell, J. R.: Direct reading spectrochemical determination of trace elements in silicates incorporating automatic background and matrix corrections; Geochimica Cosmochimica Acta, v. 33, p. 640-645 (1969).

[3] Thompson, G. and Bankston, D. C.: A technique for trace element analysis of powdered materials using the D. C. arc and photoelectric spectrometry; Spectrochimica Acta, v. 24B, p. 335-350 (1969).

GEOCHRONOLOGY

25. COLLECTION OF SAMPLES FROM THE KAMINAK GROUP FOR ZIRCON AGE DETERMINATION (KAMINAK LAKE AREA, DISTRICT OF KEEWATIN, N.T.S. 55K and 55L)

Project 540028

R.K. Wanless and R.D. Stevens
Regional and Economic Geology Division, Ottawa

The objective of the field activity was to obtain samples, for zircon age determination, of felsic volcanics representing the four cycles[1] identified within the Kaminak Group. The material obtained will be used to establish precisely the time of an important Archean event and, possibly, to ascertain if all cycles were deposited during one episodic event or over a measureable span of geologic time.

The authors are indebted to R.H. Ridler for accommodation and logistic support in the field and for assistance with detailed selection of sampling sites.

A technique for identifying zircons in the field was developed. This comprised a small kit used to crush, size and carry out a heavy liquid separation, followed by microscopic identification of zircon grains. The kit was small enough to be transported by helicopter and all tests were carried out on the outcrop.

Sample sites were selected on the basis of chemical analyses previously obtained, and only rocks possessing high silica were collected. It was found that rhyolitic horizons consistently yielded zircon in sufficient quantities to make concentration from a single pail (70 lb) of rock practical. Tests made on rhyodacitic and more basic rock types were not fruitful, although one sample of andesite taken from the centre of a large pillow did yield zircon.

Material was obtained from 9 sites spanning a distance of about 100 miles extending from a point west of Carr Lake, northeasterly to Kaminak and Quartzite Lakes and finally southeastward to Last Lake. The material collected is representative of felsic volcanic units in each of the four cycles found within the Kaminak Group.

In addition, four samples of a basic sill within the overlying Hurwitz Group were selected for future Rb-Sr assay and possible dating. The latter samples were selected from sites spanning a distance of 20 miles from Quartzite Lake to Kaminak Lake.

The method used to identify rocks containing zircons proved to be entirely satisfactory. When coupled with the detailed chemical data available in this region one could readily identify promising sampling localities. The method employed serves to greatly reduce the quantity of rock required to be transported to Ottawa for processing.

The application of the zircon technique to dating the volcanic succession holds much promise and should provide a precise time marker of primary importance within the Archean. In addition, as mentioned above, it may be possible to resolve the data obtained for the units of the various volcanic cycles thus establishing the length of time required to deposit the great quantities of material comprising the Kaminak Group. The data obtained will be combined with existing age data available for the plutonic complexes and diabase dykes of the region, the majority of which have been influenced by tectonic events associated with the Kenoran and/or Hudsonian orogenies.

[1] Ridler, R.H.: Volcanic stratigraphy and metallogeny of the Kaminak Group; in Report of Activities, Part A, April to October, 1971; Geol. Surv. Can., Paper 72-1, pt. A, p. 128-134 (1972).

GEOPHYSICS

26. AIRBORNE RESISTIVITY ELECTROMAGNETIC SYSTEM

Project 680089

A. Becker and A.K. Sinha
Resource Geophysics and Geochemistry Division, Ottawa

Evaluation of the proposed AEM system continued with the use of computer simulation of the system's logic.

In particular, a study of the effect of variable altitude on the system's performance indicates that this effect can be readily corrected for because the induction number for a given model (homogeneous ground) and for a given phase of secondary field varies rather slowly with altitude and its variation may be predicted from the value of altitude at each point.

The operation of the system can however pose problems in situations where a conductive horizon is overlain by a considerable thickness of relatively non-conductive drift. In these cases it will be necessary to employ the secondary field amplitude as well as its phase for guiding the system to its proper operating frequency.

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27. GROUND INVESTIGATION OF THE MONT LAURIER AIRBORNE RADIOACTIVITY SURVEY

Project 720071

B.W. Charbonneau
Resource Geophysics and Geochemistry Division, Ottawa

Introduction

A gamma-ray spectrometry survey of the Mont Laurier area was flown May 31 - June 23, 1971 by the Geological Survey of Canada. The survey is a rectangle some 33 miles long x 24 miles wide comprising a total area of about 800 square miles (Fig. 1). The airborne survey was carried out along flight lines spaced 1/4 mile apart with 400-foot flight clearance and 3,000 cu. in. of NaI (Tl) crystals 12 (9 x 4)". A sampling time of 2.5 seconds and a nominal aircraft speed of 120 mph were used. The analyser is a 128 channel model manufactured by Atomic Energy of Canada Limited. Maps were produced for potassium, uranium, thorium as well as uranium/thorium ratio, uranium/potassium ratio, thorium/potassium ratio and total count.

Groundwork was carried out during June and July 1972 within the survey area in order to verify the major radioelement changes indicated on the airborne maps and relate these changes to geology. These studies are part of ongoing ground control and interpretation work in all areas where airborne radioactivity surveys have been flown. The two ground-radiometric instruments used were developed and manufactured by AECL and are basically

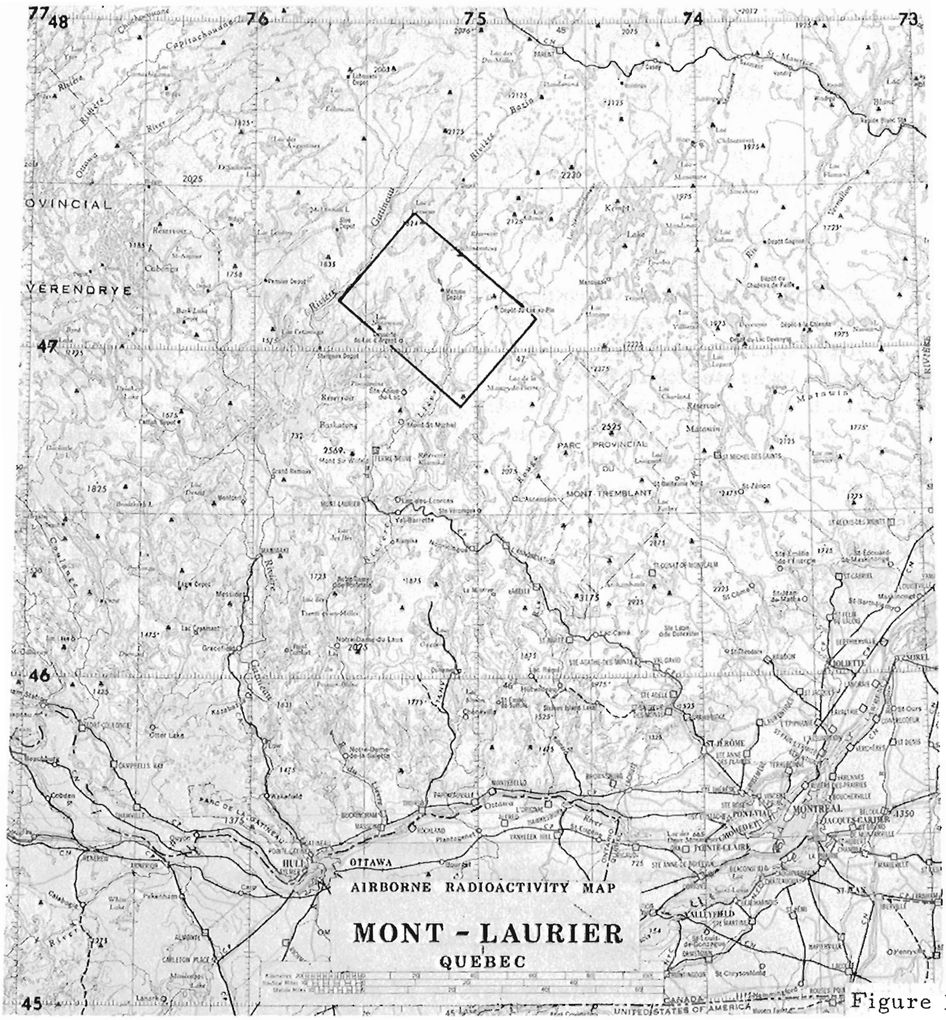


Figure 1

similar in operation to the airborne equipment. The crystal size is 22 cu. inches NaI (Tl) coupled to a 128 channel analyser set to take readings in four preset windows corresponding to potassium, uranium, thorium, total count. Calibration was effected using the 1.83 mev photo-peak of Y-88. Ratemeters manufactured by Rank Nucleonics were utilized in connection with the gamma-ray spectrometers in order to take measurements at average radioactivity locations for the outcrop overburden.

A total of 800 determinations of K, U, Th were made at 350 different localities (Fig. 2). Measurements were obtained on country rock, secondary rock types (pegmatites where available) and overburden at each locality. The ground data have been organized into ten regional profiles A-B, C-D, etc. covering some 250 miles of profile length. The profile positions are marked on the thorium map (Fig. 3). The data have verified the airborne map pattern and pointed out interesting uranium exploration targets as well. These data are summarized below and a much more complete report is in progress.

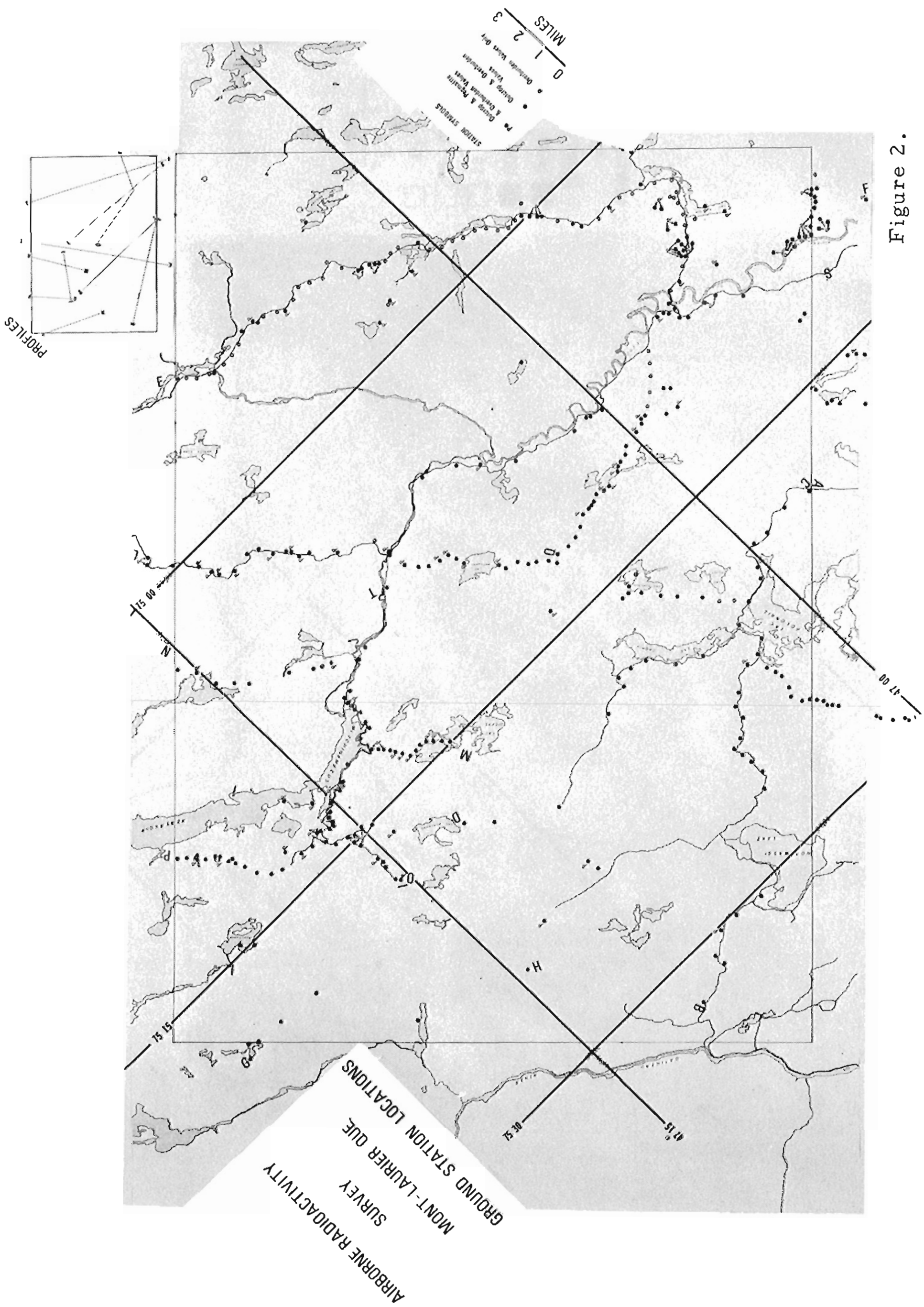

AIRBORNE RADIOACTIVITY
SURVEY
MONT-LAURIER QUE
GROUND STATION LOCATIONS
MILES
0 1 2 3
STATION SYMBOLS
PROFILES

Figure 2.

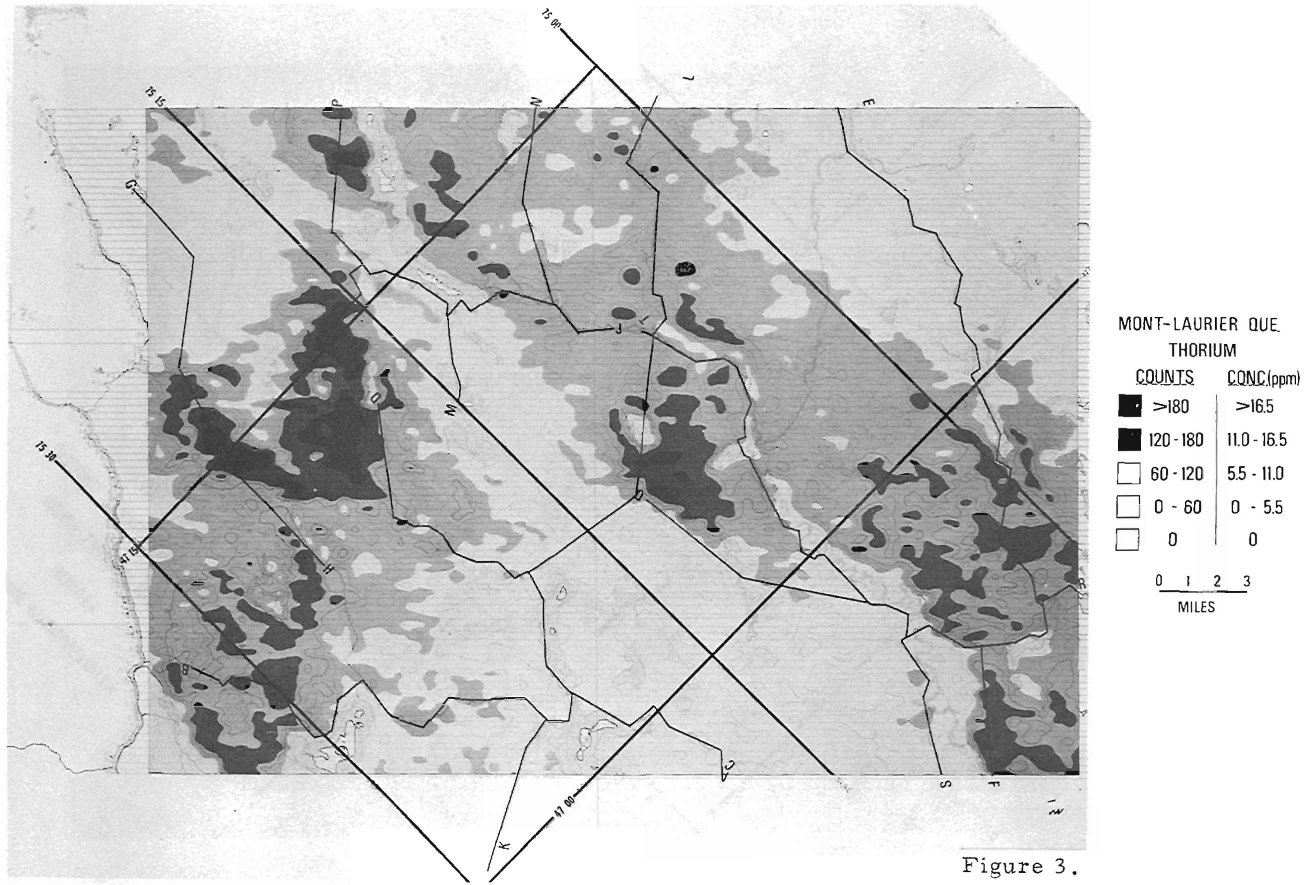

MONT-LAURIER QUE.
THORIUM
COUNTS CONC.(ppm)
>180 >16.5
120 - 180 11.0 - 16.5
60 - 120 5.5 - 11.0
0 - 60 0 - 5.5
0 0
0 1 2 3
MILES
75 00
75 15
75 30
47 15
47 00

Figure 3.

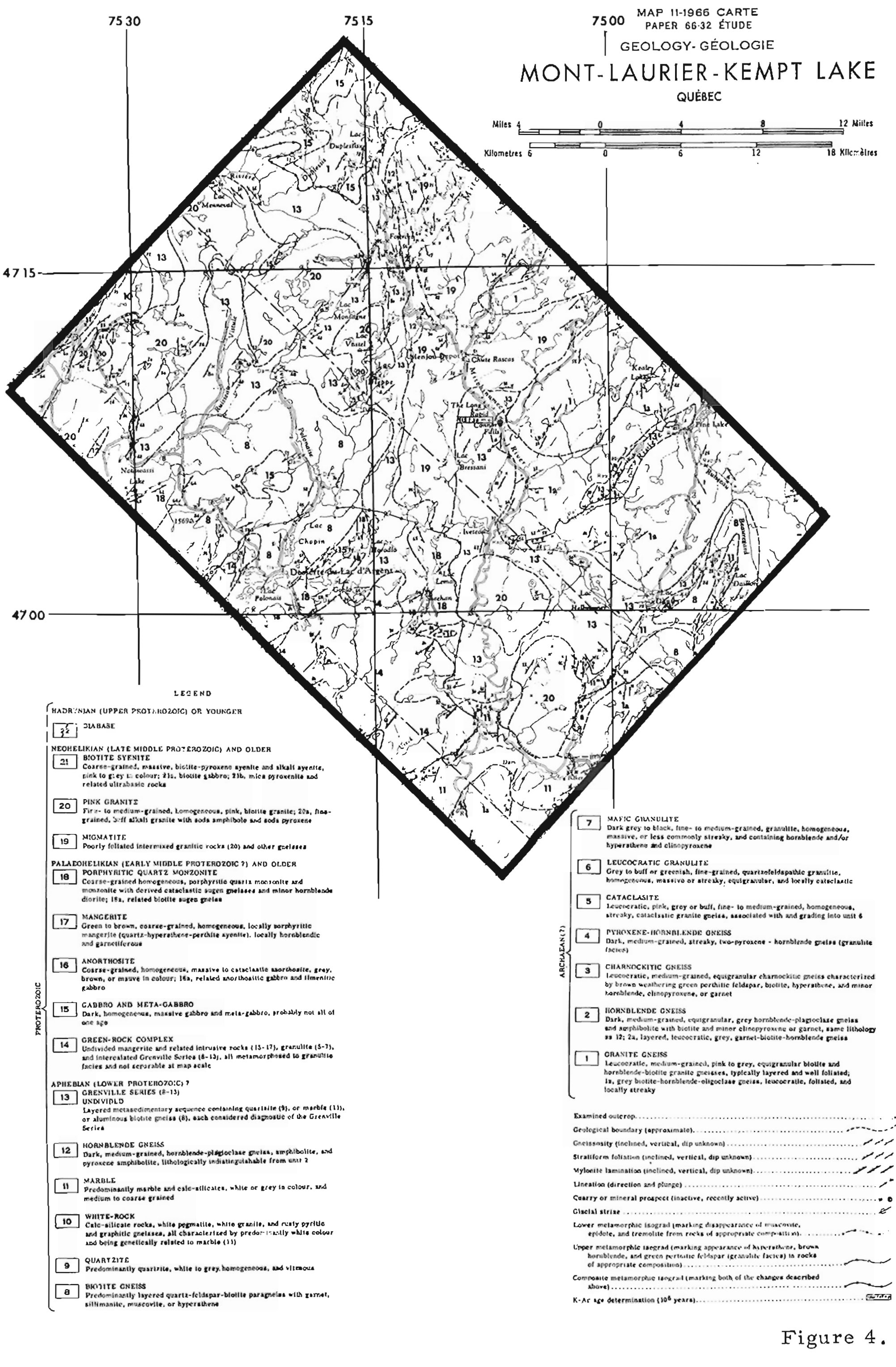

MAP 11-1966 CARTE
PAPER 66-32 ÉTUDE
GEOLOGY- GÉOLOGIE
MONT-LAURIER-KEMPT LAKE
QUÉBEC
Miles 4 0 4 8 12 Miles
Kilometres 6 0 6 12 18 Kilomètres
75 30
75 15
75 00
47 15
47 00
LEGEND
HADRYNIAN (UPPER PROTEROZOIC) OR YOUNGER
DIABASE
NEOHELIKIAN (LATE MIDDLE PROTEROZOIC) AND OLDER
21 BIOTITE SYENITE
Coarse-grained, massive, biotite-pyroxene syenite and alkali syenite, pink to grey in colour; 21a, biotite gabbro; 21b, mica pyroxenite and related ultrabasic rocks
20 PINK GRANITE
Fine- to medium-grained, homogeneous, pink, biotite granite; 20a, fine-grained, buff alkali granite with soda amphibole and soda pyroxene
19 MIGMATITE
Poorly foliated intermixed granitic rocks (20) and other gneisses
PALAEOHELIKIAN (EARLY MIDDLE PROTEROZOIC ?) AND OLDER
18 PORPHYRITIC QUARTZ MONZONITE
Coarse-grained homogeneous, porphyritic quartz monzonite and monzonite with derived cataclastic augen gneisses and minor hornblende diorite; 18a, related biotite augen gneiss
17 MANGERITE
Green to brown, coarse-grained, homogeneous, locally porphyritic mangerite (quartz-hypersthene-perthite syenite), locally hornblendic and garnetiferous
16 ANORTHOSITE
Coarse-grained, homogeneous, massive to cataclastic anorthosite, grey, brown, or mauve in colour; 16a, related anorthositic gabbro and ilmenitic gabbro
15 GABBRO AND META-GABBRO
Dark, homogeneous, massive gabbro and meta-gabbro, probably not all of one age
14 GREEN-ROCK COMPLEX
Undivided mangerite and related intrusive rocks (15-17), granulite (5-7), and intercalated Grenville Series (8-13), all metamorphosed to granulite facies and not separable at map scale
APHEBIAN (LOWER PROTEROZOIC) ?
13 GRENVILLE SERIES (8-13)
UNDIVIDED
Layered metasedimentary sequence containing quartzite (9), or marble (11), or aluminous biotite gneiss (8), each considered diagnostic of the Grenville Series
12 HORNBLENDE GNEISS
Dark, medium-grained, hornblende-plagioclase gneiss, amphibolite, and pyroxene amphibolite, lithologically indistinguishable from unit 2
11 MARBLE
Predominantly marble and calc-silicates, white or grey in colour, and medium to coarse grained
10 WHITE-ROCK
Calc-silicate rocks, white pegmatite, white granite, and rusty pyritic and graphitic gneisses, all characterized by predominantly white colour and being genetically related to marble (11)
9 QUARTZITE
Predominantly quartzite, white to grey, homogeneous, and vitreous
8 BIOTITE GNEISS
Predominantly layered quartz-feldspar-biotite paragneiss with garnet, sillimanite, muscovite, or hypersthene
PROTEROZOIC
7 MAFIC GRANULITE
Dark grey to black, fine- to medium-grained, granulite, homogeneous, massive, or less commonly streaky, and containing hornblende and/or hypersthene and clinopyroxene
6 LEUCOCRATIC GRANULITE
Grey to buff or greenish, fine-grained, quartzofeldspathic granulite, homogeneous, massive or streaky, equigranular, and locally cataclastic
5 CATACLASITE
Leucocratic, pink, grey or buff, fine- to medium-grained, homogeneous, streaky, cataclastic granite gneiss, associated with and grading into unit 6
4 PYROXENE-HORNBLENDE GNEISS
Dark, medium-grained, streaky, two-pyroxene - hornblende gneiss (granulite facies)
3 CHARNOCKITIC GNEISS
Leucocratic, medium-grained, equigranular charnockitic gneiss characterized by brown weathering green perthitic feldspar, biotite, hypersthene, and minor hornblende, clinopyroxene, or garnet
2 HORNBLENDE GNEISS
Dark, medium-grained, equigranular, grey hornblende-plagioclase gneiss and amphibolite with biotite and minor clinopyroxene or garnet, same lithology as 12; 2a, layered, leucocratic, grey, garnet-biotite-hornblende gneiss
1 GRANITE GNEISS
Leucocratic, medium-grained, pink to grey, equigranular biotite and hornblende-biotite granite gneisses, typically layered and well foliated; 1a, grey biotite-hornblende-oligoclase gneiss, leucocratic, foliated, and locally streaky
ARCHAEAN(?)
Examined outcrop
Geological boundary (approximate)
Gneissosity (inclined, vertical, dip unknown)
Straliform foliation (inclined, vertical, dip unknown)
Mylonite lamination (inclined, vertical, dip unknown)
Lineation (direction and plunge)
Quarry or mineral prospect (inactive, recently active)
Glacial striae
Lower metamorphic isograd (marking disappearance of muscovite, epidote, and tremolite from rocks of appropriate composition)
Upper metamorphic isograd (marking appearance of hypersthene, brown hornblende, and green perthitic feldspar (granulite facies) in rocks of appropriate composition)
Composite metamorphic isograd (marking both of the changes described above)
K-Ar age determination (10^6 years)

Figure 4.

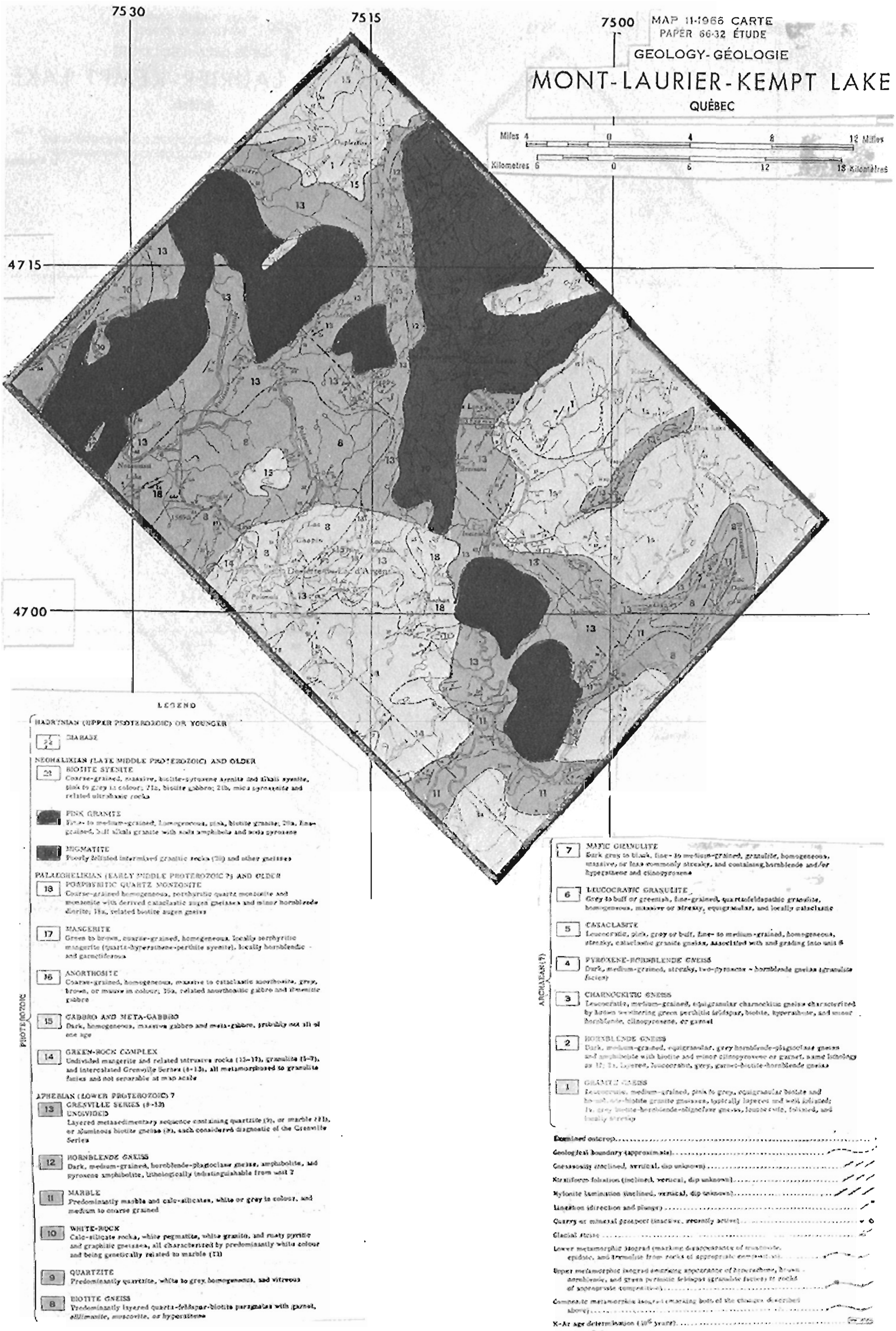

7530
7515
7500
MAP 11-1966 CARTE
PAPER 66-32 ÉTUDE
GEOLOGY-GÉOLOGIE
MONT-LAURIER-KEMPT LAKE
QUÉBEC
Miles
Kilometres
4715
4700
LEGEND
DIABASE
BIOTITE SYENITE
PINK GRANITE
MIGMATITE
PORPHYRITIC QUARTZ MONZONITE
MANGERITE
ANORTHOSITE
GABBRO AND META-GABBRO
Dark, homogeneous, massive gabbro and meta-gabbro, probably not all of one age
GREEN-ROCK COMPLEX
APHEBIAN (LOWER PROTEROZOIC) ?
GRENVILLE SERIES (8-13)
UNDIVIDED
HORNBLENDE GNEISS
MARBLE
WHITE-ROCK
QUARTZITE
Predominantly quartzite, white to grey, homogeneous, and vitreous
BIOTITE GNEISS
PROTEROZOIC
MAFIC GRANULITE
LEUCOCRATIC GRANULITE
CATACLASITE
PYROXENE-HORNBLENDE GNEISS
CHARNOCKITIC GNEISS
HORNBLENDE GNEISS
ARCHAEAN (?)

Figure 5.

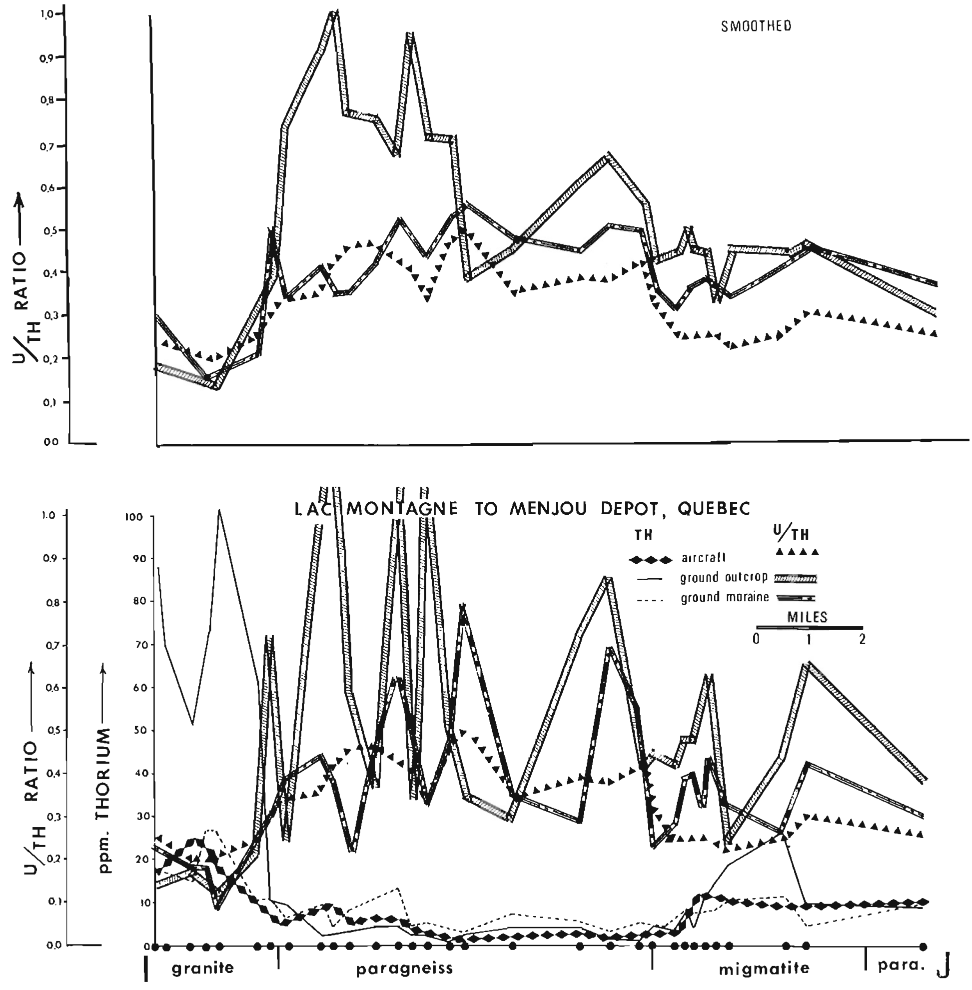


Figure 6.

Two maps were selected from the seven airborne survey maps as illustrative of the major radioactivity pattern within the survey. The thorium map shows the major radioelement variations within the bedrock. The uranium and potassium maps are quite similar in pattern to the thorium map but with less range and are not discussed here. The uranium/thorium ratio map points out two large zones of economic interest.

Thorium Variation

Considering the thorium map there are six major features, four lows, one in the northern corner, a low in the eastern corner, a low along the south-western margin of the survey. In addition a well defined low neck joins the low along the southwestern margin with the northern low. These lows are separated by two major bands of thorium high.

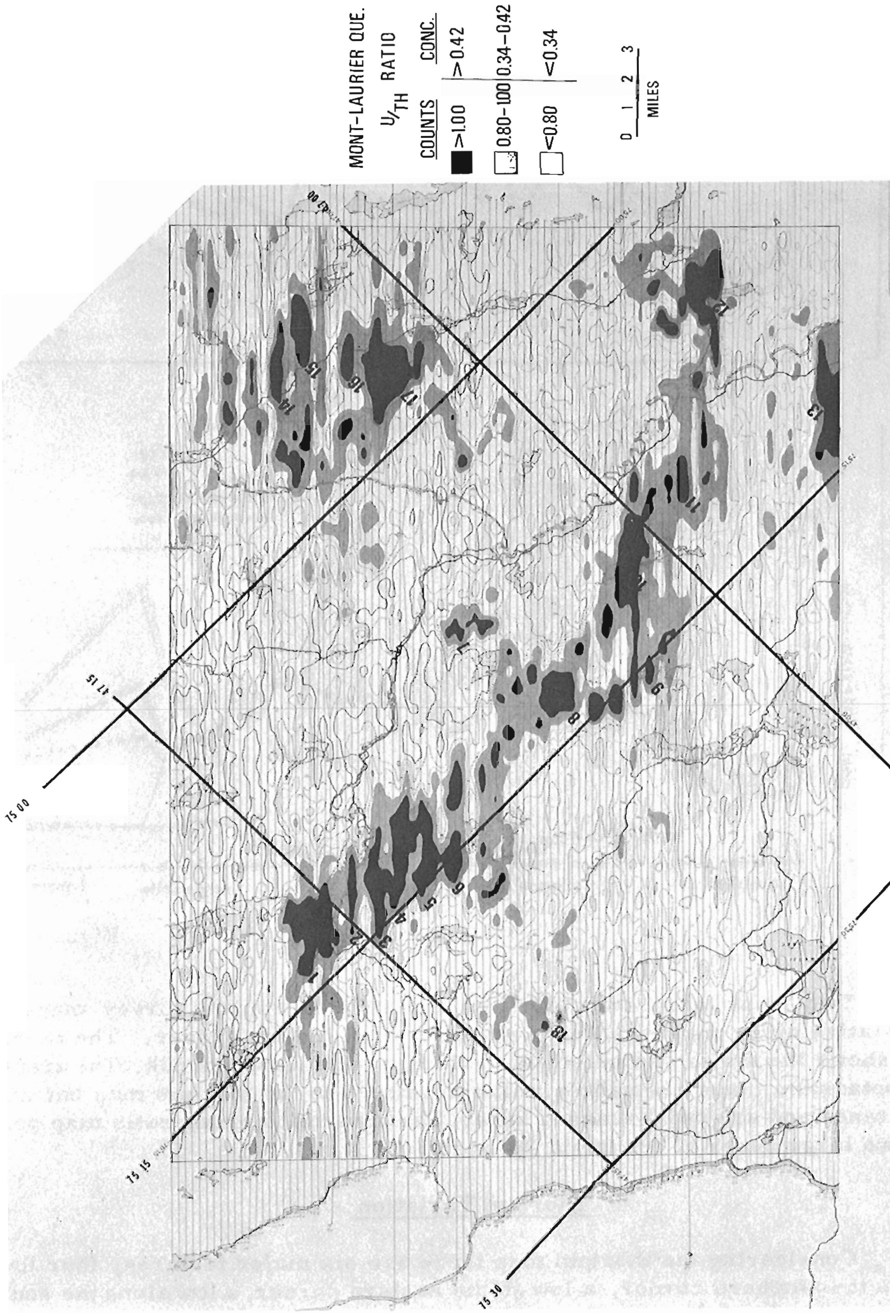

MONT-LAURIER QUE.
U/TH RATIO
COUNTS
CONC.
>1.00
>0.42
0.80-1.00
0.34-0.42
<0.80
<0.34
0 1 2 3
MILES
75 00
47 15
75 15
75 30

Figure 7

A brief summary of the thorium variation from pertinent ground profiles is placed below and serves to verify the airborne thorium pattern in terms of ground bedrock variations:

Bedrock (country rock)	Avg (ppm) thorium
Northern half of profile EF	5.5
Southern half of profile EF	31.8
Northern half of profile GH	2.5
Southern half of profile GH	34.9
Southern half of profile AB	1.9
Northern half of profile AB	17.4
Eastern high profile IJ	11.5
Central low profile IJ	5.0
Western high profile IJ	71.5

The thorium map outlines the geology[1]. For purposes of this comparison the geology is included as Figure 4 and to emphasize the comparison the geology is included in toned form as well in Figure 5. Briefly, the low along the southwestern margin correlates with an area of granulitic facies rocks designated a green rock complex. The low in the northern corner correlates with granite gneiss and younger gabbro. The low in the eastern corner correlates with granite gneiss. The neck of low joining the low along the southwestern margin with the low in the northern corner is composed of paragneiss and hornblende gneiss. The major area of high in the northern part of the survey corresponds to a large body of young pink granite, the high that extends in a southerly direction down the survey correlates dominantly with a migmatite composed of pink granite and paragneiss and with bodies of young pink granite itself.

Profile IJ, located between Lac Montagne and Menjou Depot, illustrates the detailed correlations between the ground and airborne data. The profile, presented in Figure 6, was constructed from data derived along the section line, some 15 miles in length. Radioactivity values were measured at thirty outcrops and the nearby glacial overburdens were measured as well. The values included on the profile are for country rock (not pegmatite). This profile is especially interesting in that it traverses three of the major rock types of the area: granite, paragneiss, migmatite. The ground thorium trace clearly shows the different radioelement contents associated with the three major rock types. The granite averages about 80 ppm thorium, the paragneiss averages about 5 ppm thorium and the migmatite about 15 ppm thorium. The thorium trace for overburden is sympathetic to the outcrop with the amplitude of the anomalies decreased. The overburden resembles the bedrock because of inclusions of fragments of underlying bedrock in the overlying moraine. The aircraft trace in thorium is nearly identical with the ground overburden thorium trace which is expected since along this section the surface is 90-95% overburden cover.

Uranium/Thorium Ratio Variation

The uranium/thorium ratio map is extremely interesting (Fig. 7). The map is toned in units $\frac{U}{Th}$

$< .34$
$.34 - .42$
$> .42$

Since the crustal average $\frac{U}{Th}$ is generally accepted to be .25, these units correspond to crustal average + 33%, crustal average + 66%.

Two major features emerge on this map, an elongate north-trending anomaly some thirty-five miles in length, by about three miles in width, mainly correlating with paragneiss and secondly a large circular area of anomaly some eight miles in diameter in the eastern corner of the survey, correlating with granite gneiss. These anomalous areas relate to zones of preferential enrichment of uranium relative to thorium. Within these two major anomalous areas many occurrences of pegmatite of high uranium/thorium ratio were examined. In addition, the country rock itself is enriched in uranium relative to thorium even though the absolute radioactivity levels in the country rock may be quite low. In fact the uranium/thorium ratio anomaly corresponds to a great extent with a radioelement low in thorium as well as in uranium (uranium map not shown). In addition to the two major zones a minor uranium/thorium high occurs just within the southwestern margin of the survey area and an isolated high occurs to the west of the long anomalous zone. The ratio anomaly map has been subdivided into 18 separate anomalies (Fig. 7) and the radioelement values in uranium, thorium, uranium/thorium ratio of the pegmatite and of the country rock containing the pegmatite have been summarized below in the chart. In addition, the type of pegmatite pink or white has been marked in the chart. In this paper only the major pegmatite occurrence within each isolated anomaly is included in the chart along with the associated country rock.

Lesser amounts of pegmatites occur in the map-area away from the anomalous zones but these pegmatites are much less extensive and generally of normal or only slightly higher than normal U/Th ratio although some small bodies with above normal U/Th ratio levels were noted. To the north of U/Th ratio anomaly No. 1 and to the south of U/Th ratio anomaly No. 12 numerous pegmatites occur but their ratios are low. The U/Th ratios return to normal levels in country rocks about five miles from the axes of the major anomalies.

The glacial moraine composition in U/Th is normal to the north and east of the major elongate U/Th anomaly but higher over it and higher to the south and west implying some glacial smearing of material down ice. U/Th ratio of glacial overburden stations north and east of the elongate anomaly is .30. For stations along profile A-B, south and west of the high, U/Th ratio in overburden averages .43.

Two major types of pegmatites occur in the area designated in the chart as "pink" and "white". The major difference between the two types is that the pink has potash feldspar, quartz, biotite and muscovite, the white has oligoclase, feldspar and white microcline as well as quartz, phlogopite and minor amounts of graphite, diopside and apatite. The white pegmatites occur near marbles and might bear genetic relationship to them. The pink pegmatites probably relate to the young pink granite. Both types of pegmatites are to be found within the major uranium/thorium anomalous zones described. Whether the pegmatites are pink or white, they are of high ratio within the

ANOMALY NO.	URANIUM PPM	THORIUM PPM	URANIUM/THORIUM RATIO	TYPE OF PEGMATITE OR COUNTRY ROCK
1	107.12	96.05	1.11	pink pegmatite
	0.98	1.60	0.61	paragneiss
2	264.60	311.48	0.85	pink pegmatite
	1.30	1.60	0.81	paragneiss
3	130.03	63.05	2.03	pink pegmatite
	2.43	2.22	1.09	paragneiss
4	107.12	96.04	3.52	pink pegmatite
	0.50	0.98	0.51	paragneiss
5	47.72	33.09	1.44	pink pegmatite
	2.11	2.22	0.94	paragneiss
6	20.29	12.71	1.60	pink pegmatite
	0.67	0.37	1.82	paragneiss
7	72.77	27.33	2.66	pink pegmatite
	2.77	6.66	0.42	paragneiss
8	41.44	21.33	1.94	pink pegmatite
	3.80	5.33	0.71	paragneiss
9	31.90	22.60	1.41	pink pegmatite
	1.50	2.00	0.75	quartz monzonite
10	22.30	13.30	1.67	white pegmatite
	2.20	4.70	0.47	paragneiss
11	25.00	4.10	6.12	pink granite
	2.20	3.50	0.63	green rock
12	388.59	78.67	4.94	white pegmatite
	3.99	6.67	0.60	paragneiss
13	26.77	62.00	0.43	fine grained granite
	1.38	3.33	0.42	fine grained granite
14	5.84	4.67	1.25	pink pegmatite
	2.16	6.67	0.32	granite gneiss
15	33.66	7.33	4.59	pink pegmatite
	3.07	6.67	0.46	granite gneiss
16	28.13	11.33	2.48	pink pegmatite
	2.50	2.67	0.94	granite gneiss
17	32.74	7.33	4.46	pink pegmatite
	2.77	6.67	0.42	granite gneiss
18	4.52	14.67	0.31	pink pegmatite
	2.12	10.67	0.20	paragneiss
AVG	77.25	49.89	2.38	pegmatite
AVG	2.14	4.14	0.67	country rock

Note: The U/Th ratio average is the average ratio not the ratio of the averages.

airborne U/Th ratio high zones on the map and of lower ratio away from these regional anomalies implying coherent overall control of the U/Th ratio.

The results of this work are especially interesting because of the fact that terrain at the northern end of the elongate U/Th ratio anomaly zone is under claim to Lac Forestier Uranium Mines and two adjacent blocks at the extreme south end of the long anomalous zone are under claim by Canadian Johns Manville and Mount Laurier Uranium Mines respectively. This work these three claim blocks are all in reality on a continuous feature and the intervening 35 miles of country takes on added exploration-interest.

The U/Th ratio profile (Fig. 6) cuts across the axis of the major elongate U/Th anomaly on the survey maps. This profile serves to illustrate the detailed correlations between airborne and ground radioactivity obtained in the study. The U/Th profile from the aircraft trace is very close in level to the U/Th profile derived from overburden and shows that the anomaly increases to about U/Th = 0.50 both from the air and ground overburden average. The U/Th profile derived from the country rock outcrops is jagged but clearly shows the normal U/Th ratio over the granite, the sharp increase in U/Th ratio over the central zone and the return to lower values to the east over the migmatite. The U/Th ratio smoothed diagram in the upper part of the illustration is derived from the lower diagram by running average over three points plotted at the centre of each set of three. The smooth profile makes the correlation of the airborne U/Th map with the ground U/Th profiles more clear. The U/Th ratio variation in the outcrop is sharper than the values shown by moraine or aircraft profile and increase to about 0.80 which compares favourably with the average U/Th ratio in country rocks within the U/Th anomalies recorded in the preceding chart U/Th = 0.72.

SUMMARY

1. The airborne thorium map is an accurate reflection of the total surface composition in thorium.
2. The radioactivity maps (especially thorium) illustrate the regional geology as well as does an aeromagnetic map with the advantage that the two different maps best define different rock types making their joint use doubly effective.
3. The glacial moraine composition in the area bears a distinct radiometric resemblance to the underlying bedrock.
4. The values of uranium/thorium ratio in the airborne survey maps relate quantitatively to the total surface uranium/thorium composition.
5. The uranium/thorium ratio defines principally two major zones of economic interest that would have been missed in a less sensitive survey incapable of measuring uranium/thorium ratio anomalies.
6. These uranium/thorium ratio anomalies define zones of injection of considerable amounts of high ratio pegmatite and as well increase in uranium/thorium ratio of the country rocks.

[1] Wynn-Edwards, H.R., Gregory, A.F., Hay, P.W., Giovanella, C.A., and Reinhardt, E.W.: Mont Laurier and Kempt Lake map-areas, Quebec; Geol. Surv. Can., Paper 66-32 (1966).

28. THE USE OF TOTAL RADIOACTIVITY MEASUREMENTS FOR RECONNAISSANCE AIRBORNE SURVEYS

Project 720071

A. G. Darnley
Resource Geophysics and Geochemistry Division, Ottawa

Earlier work carried out with the Geological Survey high-sensitivity airborne gamma spectrometer equipment has shown that there are regional variations in mean ground surface radioelement content between different areas of the Canadian Shield[1]. It has also been shown that there are zones within the Shield with widths ranging from a few miles to tens of miles, and in excess of 100 miles in length, containing rocks with several times the radioactivity of the surrounding region. Within and marginal to these zones it has been shown that there can be localized and differential concentrations of the radioactive elements which may be of economic interest. The physical dimensions and the relative radioactivity of these zones is such that it is not necessary to employ high-sensitivity gamma spectrometer equipment in order to locate them. For preliminary reconnaissance purposes, simpler and much less expensive total radioactivity measuring equipment should suffice to identify these zones. High-sensitivity equipment remains essential in order to map the distribution of the individual radioelements within these zones.

In order to demonstrate the suitability of total radioactivity measuring equipment for reconnaissance purposes, and at the same time increase knowledge about regional variations within the Canadian Shield, a scintillation counter with a single 5 x 5 inches NaI (Tl) detector crystal (volume approximately 100 cubic inches) was installed in a Beech Queenair aircraft. Count rate was recorded on a strip-chart in parallel with radar altitude, and with manual fiducials to correlate with visual position fixes at 5 - to 10-mile intervals. The prime requirement for the data was to detect small changes in radiation level with as much certainty as possible, and to accept poor spatial resolution. For this reason, the rate meter time constant was set at 8 seconds. The aircraft was flown at 180 mph, 500 feet above ground. With this combination of airspeed and time constant it is impossible to determine a true mean count rate for any surface less than about 1.2 miles in length. Indicated count rates were in the range of 100 to 150 cpm (over water) and 200 to 1,000 cpm over land, which, due to a technical defect, were considerably less than the count rates theoretically achievable with the detector volume available. However, this deficiency does not detract from the general conclusions.

During the last week of July 1972, results were obtained with this equipment on a route flown from Ottawa to Val d'Or, Chibougamau, Great Whale and Fort Chimo; along the north and south sides of Frobisher Bay, Baffin Island, and as far west as the Koukdjuak Plain; Hall Beach to Pelly Bay via the Rae Isthmus; and from Baker Lake to Yellowknife. The compatibility of the results with those obtained from the high-sensitivity gamma spectrometer equipment was demonstrated in the vicinity of Yellowknife. A prominent radioactive feature found in 1971 about 70 miles east-northeast of Yellowknife between 111° and 112°W was clearly recognizable on the profile from Baker Lake. It was marked by an approximately twofold increase in count rate (to between 800 and 1000 cpm) over a distance of about 25 miles.

The reconnaissance flight showed that similar large features of anomalous radioactivity exist in south Baffin Island and in the Melville Peninsula. The largest of these extends over about 45 miles along the north side of Frobisher Bay, Baffin Island, between the head of Anna Maria Port and the head of Waddell Bay (68°W, 63°47'N to 67°W, 63°20'N). Both east and west of this belt and on the south side of Frobisher Bay along the axis of Metaincognita Peninsula the average level of radioactivity is high (c. 600 cpm). Across the width of the Melville Peninsula between 87°W, 67°10'N and 83°W, 68°15'N there is a generally high level of radioactivity with peaks at approximately 86°20'W, 67°17'N, 84°25'W, 67°54'N, 83°15'W, 68°12'N. The average levels of radioactivity, both in southern Baffin Island and in the Melville Peninsula around the south end of Committee Bay appear comparable with average levels found across the northwestern side of the Canadian Shield between Lake Athabasca and Great Bear Lake.

The traverse across New Quebec between Fort Chimo, Great Whale and Chibougamau shows average levels of radioactivity of the order of 50 per cent of those observed over Shield rocks in south Baffin and Melville Peninsula. The highest count rates in the New Quebec profile were observed in the area to the west of Koksoak Island in the Koksoak River (about 69°10'W, 57°55'N) which is within the Proterozoic fold belt, and about 75°58'W, 52°28'N between the Eastmain and Opinaca Rivers east of James Bay. The relatively low average count rates found across the Superior Province in New Quebec (300 to 400 cpm) are compatible with earlier findings that the Superior Province contains rocks of lower average radioactivity than the Churchill, Bear and parts of the Slave Provinces[1,2].

One conclusion which may be drawn from this reconnaissance flight is that sufficient radiometric "relief" exists along the cross-section flown to infer that the gross distribution of radioactivity over much of the Shield could be mapped with relatively widely spaced flight lines using simple total radiation measuring equipment in fast flying light aircraft. It would however be important to ensure that equipment used for such surveys, and the measurements obtained, were carefully and frequently standardized in order to ensure compatibility of all data, and provide numerical values bearing a known relationship to values provided by other radioactivity measuring equipment. It must be re-emphasized that total radiation surveys could not substitute for high-sensitivity gamma spectrometer surveys, which would be necessary to map the distribution of individual radioactive elements in any areas of special interest.

[1] Darnley, A.G., Grasty, R.L., and Charbonneau, B.W.: A radiometric profile across part of the Canadian Shield; Geol. Surv. Can., Paper 70-46 (1971).

[2] Eade, K.E., and Fahrig, W.F.: Geochemical evolutionary trends of continental plates - a preliminary study of the Canadian Shield; Geol. Surv. Can., Bull. 179 (1971).

29. AIRBORNE INPUT SURVEYS

Project 660043

A.V. Dyck
Resource Geophysics and Geochemistry Division, Ottawa

Work is nearing completion on the preparation and publication of results from the airborne INPUT surveys flown in the Hawkesbury, Ottawa, Winkler, Manitoba and Drumheller, Alberta areas[1]. It has been recognized that a generalized scheme for the interpretation of INPUT data is not possible. Instead a unique method must be developed for each area using some prior knowledge of the geology.

Theoretical decay curves for 2- and 3-layer models were computed using the digital simulation method[2,3] to aid in the interpretation. In addition a scale model experiment was devised[4,5] to verify the results of the mathematical model and extrapolate them to more complex situations.

In the Hawkesbury area it was found that the amplitude and decay time of the INPUT decay curve are sensitive to the thickness and conductivity of the Champlain Sea clay which is the second and most conductive of three electrically distinct layers. A conducting wedge model is required to explain the features of the Hawkesbury data. Furthermore, if this model is assumed the data can be corrected for altitude variations of the survey aircraft. Application of the interpretation technique over a test profile has shown that quantitative estimates of thickness and conductivity of the marine clays can be made which agree with those obtained from a ground DC resistivity survey.

[1] Collett, L.S.: Airborne INPUT Surveys, Winkler, Manitoba, Drumheller, Alberta, Ottawa, Ontario, in Report of Activities, Part A, April to October, 1968; Geol. Surv. Can., Paper 69-1, pt. A, p. 78 (1969).

[2] Becker, A.: Simulation of time-domain, airborne, electromagnetic system response; Geophysics, v. 34, no. 5, p. 739-752 (1969).

[3] Sinha, A.K., and Collett, L.S.: Electromagnetic fields of oscillating magnetic dipoles placed over a multilayer conducting earth; Geol. Surv. Can., Paper (in prep.).

[4] Becker, A., and Dyck, A.V.: Time domain EM theory, in Report of Activities, pt. B, November 1969 to March 1970; Geol. Surv. Can., Paper 70-1B, p. 25 (1970).

[5] Becker, A., Gauvreau, C., and Collett, L.S.: Scale model study of time domain electromagnetic response of tabular conductors; Can. Mining Met. Bull., v. 65, no. 725, p. 90-96 (1972).

30. GAMMA-RAY SCATTERING CORRECTIONS FOR THE AIRBORNE MEASUREMENT OF URANIUM

Project 720084

R. L. Grasty
Resource Geophysics and Geochemistry Division, Ottawa

In gamma-ray spectrometry, high energy photons which are incompletely absorbed in a detector appear as counts in a lower energy window. Counts appearing in the potassium window may be due to potassium photons, scattered high energy photons, or lower energy photons of the uranium and thorium decay scheme. Provided the gamma-ray spectrum reaching the detector remains the same, a constant fraction of the counts in the higher energy window will appear in the lower energy windows. These factors are known as the Compton scattering coefficients.

It has generally been assumed that these Compton scattering coefficients remain constant and that the spectrum is unchanged with increasing elevation. However, due to scattering which occurs in the air, there tends to be a build-up in the lower energy part of the spectrum with increasing elevation. This build-up will result in an increase in the scattering corrections which have to be applied. The importance of these height dependant corrections is not fully appreciated and can cause significant differences in the apparent uranium, particularly in situations of high thorium.

For the Geological Survey Skyvan system, the scattering corrections have been determined using the calibration slabs at Uplands airport, Ottawa. The technique has been described in detail[1]. In order to investigate the variation of corrections with height, these slabs were flooded with successive depths of water, up to a depth of 6 inches. This is equivalent to approximately 400 feet of air. The gamma-ray spectrum received by a 5 x 5 inch NaI (Tl) detector, mounted on a tripod, 9 inches above the centre of each pad, was recorded on magnetic tape. These results are presently under investigation.

As a follow-up to the ground measurements, two test strips in the Yellowknife and Fort Smith area of the Northwest Territories were flown at 12 different altitudes between 100 and 600 feet. The Yellowknife strip had a high uranium content with very little thorium; the Fort Smith area having high thorium and low uranium. Preliminary results showed the apparent uranium count-rate variation with height was totally different for the two areas and indicated a significant fraction of air-scattered high energy gamma-rays from the thorium decay series were appearing in the uranium window.

This demonstrates that over ground with abnormal U/Th ratios the present airborne method of estimating mean ground uranium concentration is inaccurate especially if a height correction has to be applied. However, it should be noted that in general the range of variation of U/Th ratio is small[2]. This work forms part of a continuing program to develop quantitative methods of measuring K, U and Th from the air.

[1] Grasty, R. L., and Darnley, A. G.: The calibration of gamma-ray spectrometer for ground and airborne use; Geol. Surv. Can., Paper 71-17, (1971)

[2] Darnley, A. G., Grasty, R. L., and Charbonneau, B. W.: A radiometric profile across part of the Canadian Shield; Geol. Surv. Can., Paper 70-46, (1971).

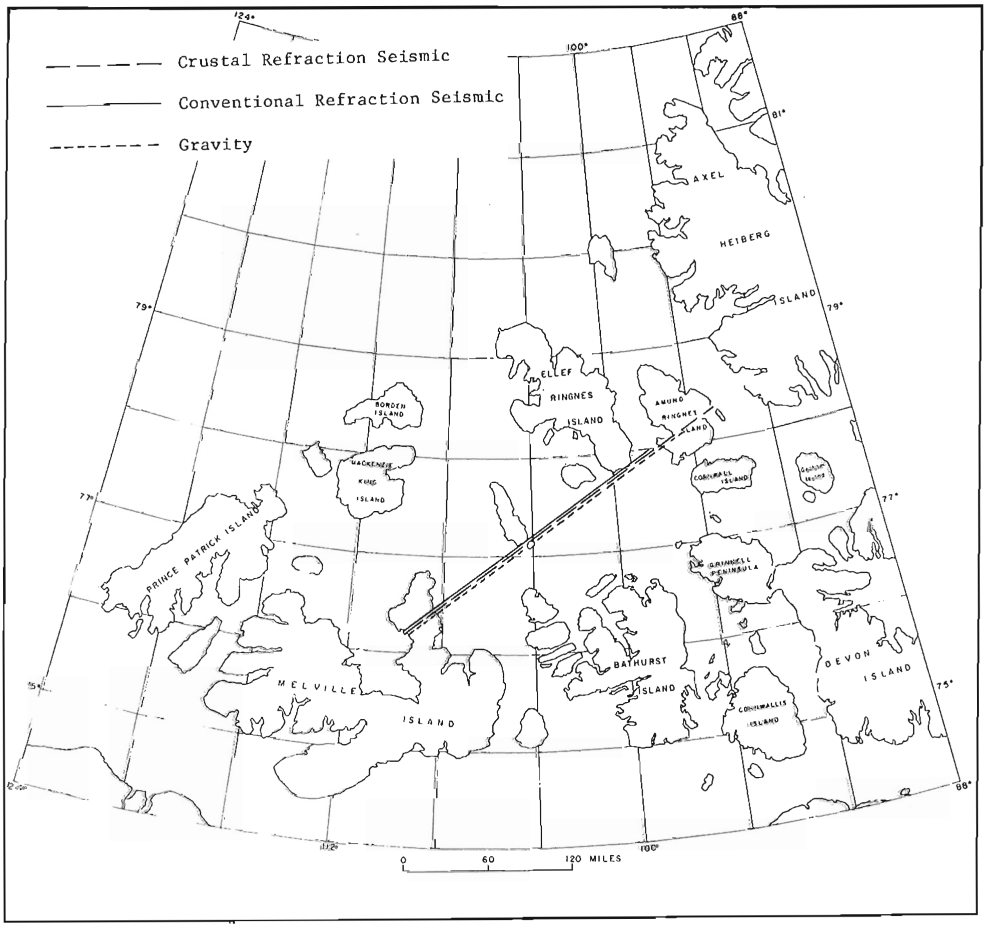
31. SEISMIC REFRACTION - SVERDRUP BASIN

Project 720005

G. D. Hobson
Resource Geophysics and Geochemistry Division, Ottawa

A unique co-operative project involving industry and government was carried out in the Canadian Arctic Islands in April-May, 1972. Seismic refraction data pertaining to the sedimentary section were obtained over approximately 230 miles, gravity over 250 miles with 4,800-foot-spacing and crustal seismic data at Drake Point, King Christian Island and Eureka (see Figure 1). A preliminary report has been submitted to the 6 oil company initial subscribers with a final report to be submitted by November 30, 1972.

Analysis is proceeding to incorporate correct water depths, refinements in timing precision, and definition of seismic velocities and positions of structures by means of reversed profile delay time studies. These data and interpretations may be purchased at any time during the four-year period of confidentiality.



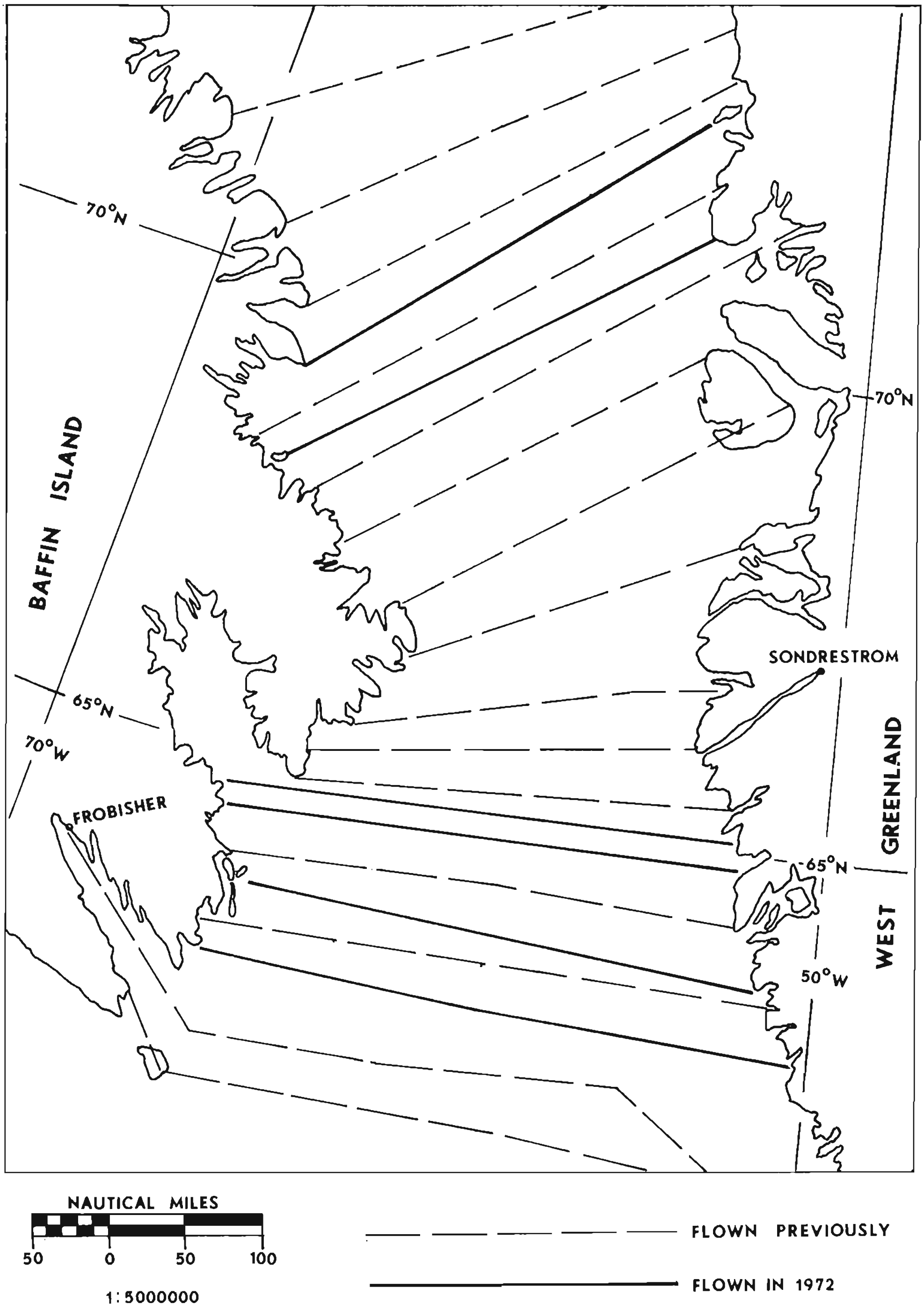


Figure 1.

Hood and Bower

32. DAVIS STRAIT: LOW-LEVEL AEROMAGNETIC PROFILES OBTAINED IN 1972

Project 650007

Peter J. Hood and Margaret E. Bower
Resource Geophysics and Geochemistry Division, Ottawa

The co-operative aeromagnetic project with the National Aeronautical Establishment was continued during 1972 and a low-level aeromagnetic survey operation was carried out in Davis Strait. The North Star aircraft of the National Aeronautical Establishment which is equipped with a cesium magnetometer was used. The objective of the field operation was twofold, the first objective was to obtain low-level aeromagnetic profiles across the Davis Strait in order to throw light on the underlying geology, particularly the extent of the basalt flows which are known to extend over a much greater area offshore than those observed at the known onshore exposures at Cape Dyer on Baffin Island and in the vicinity of Disco Island on West Greenland. The second objective was an evaluation of a computerized electronic navigation system which uses Omega fixes and Doppler drift to compute the most probable position at any given instant. Concurrently the Model 4 Interdata computer installed in the aircraft also calculated the total field values from the output of the cesium magnetometer. The latitude and longitude of the survey aircraft was determined every 10 seconds and recorded on digital magnetic tape together with the total field readings, and was also displayed in real time to the aircraft navigator on a cathode-ray storage scope. Throughout the exercise Omega ground monitors were operated at Frobisher and Sondrestrom (see Fig. 1) which were the bases of operation to ascertain the skywave corrections. The operation lasted from June 12 to 26th and was terminated by persistent fog in the Davis Strait area especially on the Canadian side which reduced visibility at times to less than one mile. Six lines were flown in the Davis Strait area (see Fig. 1) which were positioned to obtain information between the lines flown in earlier surveys. Total productive line mileage was approximately 2,300 line miles.

33. SHALLOW SEISMIC SURVEYS, YUKON COAST

Project 680037

J.A. Hunter and L. Rosnuk*
Resource Geophysics and Geochemistry Division, Ottawa

A shallow seismic refraction program was carried out on the Yukon coast in conjunction with mapping of the surficial geology of the area by members of the Terrain Sciences Division (Project 690047). Seismic sections were produced in the Blow River delta and at selected points along Babbage River to detect the presence of and map the top of permafrost. Seismic profiles were shot near Komakuk, Herschel Island, Fish River, Okpioyuak Creek, Rapid Creek and Sabine Point. Velocity structure of permafrost in the overburden was correlated with drillhole information. Permafrost velocities were observed in various types of surficial materials from clays to gravels. As well, some velocity observations were made on bedrock outcrops. Eighteen locations were visited and 85 profiles were obtained using the FS-3 hammer seismograph.

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34. SHALLOW SEISMIC REFRACTION SURVEYS, NEW BRUNSWICK AND NOVA SCOTIA

Project 680037

J.A. Hunter, L. Rosnuk* and K. Keeler*
Resource Geophysics and Geochemistry Division, Ottawa

A hammer seismic program was initiated in the Caledonia Mountain area of New Brunswick (NTS 21 H/15) and the Cobequid Mountain area of Nova Scotia (NTS 11 E/5, 11 E/12) in co-operation with W.J. Scott of the Electrical Methods Section (Project 670041, VLF Mapping). The object of the survey was to provide details of drift thickness and material type by the refraction method as fundamental data to be used in the assessment of new electrical prospecting techniques. Approximately 550 profiles were obtained in the two survey areas.

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35. SHALLOW SEISMIC REFRACTION SURVEY MACKENZIE RIVER VALLEY

Project 680037

J.A. Hunter, R.A. Burns, R. Good* and P. Bazeley*
Resource Geophysics and Geochemistry Division, Ottawa

Shallow seismic refraction profiles were shot at various locations along the Mackenzie River Valley in the vicinity of Fort Simpson, Norman Wells and San Sault Rapids to investigate structure and velocity in surficial materials in permafrost. Profiles were recorded with a 12-channel seismograph over drillholes in co-operation with projects 720068 and 710020.

*Student assistants.

Several profiles were shot in the delta region to investigate the occurrence of ground ice and near-surface structure in permafrost. Approximately 50 sites were occupied where anomalous structures were known.

A marine shallow refraction technique was tested in the Mackenzie Bay and Kugmallit Bay areas. The instrumentation was designed to probe up to 200 feet under the sea bottom in shallow water and to provide both velocity and structural information. Several sites were occupied in the vicinity of Garry Island, Pullen Island, Kittigazuit, Tuktoyaktuk and Toker Point. The lateral and vertical distribution of permafrost was mapped successfully with the apparatus. Work on the improvement of this technique is continuing.

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36. ELECTRICAL ROCK PROPERTIES

Project 630049

T.J. Katsube
Resource Geophysics and Geochemistry Division, Ottawa

1. Electrical Non-Linear Phenomena in Rocks

Electrical currents that flow through rocks generally increase linearly with applied voltage. However, there are cases where, above a certain voltage or a certain current density, the rate of current increase rises above the normal rate. This is referred to as the electrical non-linear phenomenon. This phenomenon can also be presented in terms of conductivity increase with applied voltage. Usually this phenomenon is seen below 10^3 Hz.

The concept of "non-linearity" is similar to that of "decomposition voltage" of electrodes immersed in an electrolyte. The decomposition voltage is a characteristic of conductors immersed in liquids, and it varies according to the type of conductor. This electrochemical phenomena occurs above a certain charge density. The critical charge density for a serpentenite sample is 10^{-8} coulombs/cm^2. In terms of critical current density, it is 3.1×10^{-10} amperes/cm^2 at 10^{-2} Hz, or 3.1×10^{-7} amperes/cm^2 at 10 Hz. A galena sample shows two critical charge densities, one at 6.0×10^{-7} coulombs/cm^2 and the other at 8.0×10^{-5} coulombs/cm^2.

This study appears to be of much interest and of great importance to the mining and geophysical industry in Canada. For this reason, measuring systems are being set up in the laboratory in order to measure and characterize various types of minerals and rocks.

This measurement consists of two different frequencies of electrical current, applied to the sample at the same time. The frequency of the lower frequency current is fixed to 0.1 or 0.01 Hz, and the voltage is varied from about 0.3 to 300 volts. The higher frequency current is varied from 1.0 to 10^4 Hz, while the voltage is fixed at approximately 0.3 volts. The impedance and phase of the higher frequency modulation voltage acts as an indicating device for the lower frequency carrier signal and hence, changes according to the electrical parameters of the sample. This entails a very complex measurement and ways of automating and speeding up the measuring technique are presently being devised.

The application of this new idea may be useful in borehole geophysics for the detection of not only the existence of sulphide mineralization, but also the type of minerals in the host rock.

2. Electrical and EM Propagation Characteristics of Igneous Rocks

Electrical measurements on a set of igneous rocks consisting of selected samples of acidic and basic types has been completed. This data will be used to study the electrical conduction and EM wave propagation through the rocks.

Chemical analysis and thin section studies of these rocks are also being carried out. From the investigations so far there is a clear distinction between the characteristics of acidic and basic rocks. There may also be a difference between plutonic and volcanic rocks. This suggests that something of interest to the detection of different rock formations by airborne EM methods may appear as a result of these studies.

Another aspect of this study which is of importance is on the precise measurement systems and techniques that are being developed. The level of these systems and techniques are approaching those of the ASTM (American Standards of Testing Materials) and N. B. S. (U. S. A.) in order to cope with the complex earth materials. It is felt at this point that there is a requirement to raise the standards on accuracy and precision between measuring systems and techniques used by all investigators on electrical rock properties in order to establish credibility of the data reported by each laboratory.

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37. EGMA SEISMIC SURVEY

Projects 710096, 710097

P. G. Killeen and G. D. Hobson
Resource Geophysics and Geochemistry Division, Ottawa

A portable refraction seismic survey was carried out in the following areas of Ontario and Quebec during the winter of 1970-71:

1. Timmins-Kirkland Lake area, Ontario
2. Rouyn-Noranda area, Quebec
3. Val d'Or area, Quebec

The purpose of the seismic project was to use seismic instrumentation to examine overburden, and to define bedrock topography in the Timmins-Val d'Or areas. It was also intended to test and apply instruments under winter conditions in conjunction with an overburden drilling program in the same area.

The Huntec model FS-3 portable seismograph was used with a 16-lb. sledge hammer for an energy source. The refraction seismic method was employed, with about half the refraction profiles being reversed[1,2,3]. Seismic stations were generally at quarter mile intervals, along existing east-west roads and trails. Due to the additional difficulties of winter operation, each seismic crew consisted of three men rather than the usual two.

Four crews worked out of a field office set up in Timmins, Ontario, and four crews worked out of La Sarre, Quebec. Each office was staffed with one man for computation and plotting of field results. The geophysics project supervisor planned and co-ordinated the work being carried out by the seismic crews from the two field offices.

The entire project was carried out in areas normally subjected to below-zero temperatures for most of the winter. This led to several problems of winter operation, which are discussed below.

(a) Cold temperature: Cable breaks became such a common occurrence that operations were severely affected. This was solved by changing to a rubber type cable which was guaranteed by the manufacturer (Beldon) to remain flexible to -22°F. Even with this cable, the most often-flexed parts of the cable, namely at the connectors, still broke. The normal Cannon- or Bendix-type plugs were replaced with twin-lead trailer light system connectors. These were easily replaced in the field when they broke using only a mechanical connection, twisting the bared wires together and taping. No solder was needed. The cost of the connecting plug was also less by at least a factor of 10.

The wooden sledge hammer handles broke more often than they would have during the summer operation, but this was not considered too serious. A spare hammer was carried by each group of two crews working together in a given area.

(b) The snow: When working on unplowed trails, each hammer location had to be prepared by digging a hole to the ground surface. A special steel "impact plate" consisting of a three-foot pipe with both ends welded shut was used. A handle was welded on the side for carrying and for holding the plate-post in upright position while hammering on it. The saving in snow shovelling time was considerable. The delay time introduced by the 3-foot pipe was less than 1/4 millisecond - a negligible amount.

(c) Frozen ground: Flat geophone bases were used on the frozen ground, rather than the spike bases normally used in soft terrain. The seismic velocity of the frozen surface showed in many of the records as first arrivals, but were usually lost quite quickly, and the true arrival times through unfrozen overburden were obtained.

(d) Transportation: On roads, the normal procedure of operation from the rear of a truck was used, but for deep snow, the instruments were placed on toboggans and towed behind snowmobiles. This caused an increase in the rough handling of the instruments, but the only problem that occurred was the loosening of the heavy NICAD batteries from their clips, which was prevented by inserting foam pads to maintain pressure on the batteries to keep them in place. The inertia switches on the hammers were protected with a metal shield cut from stovepipe and taped to the handle. In this project area the snow was dry and only very wide track of twin-track snowmobiles were able to travel through the deep snows by February. On the other hand, some parts of the area could only have been covered when the ground was frozen, as they are too swampy for summer operation. It might be mentioned that record snowfall accumulations were present in the area in the winter of the survey.

(e) Other problems: Along roads, an exceptionally large amount of 60 cycle noise was encountered. All efforts to properly ground the instruments and equipment failed in some areas and the station locations were moved away from the road at a later date using the snowmobiles. No solution to this problem was found.

In the Timmins area (NTS 42A), approximately 800 seismic refraction profiles were completed for depth determinations along east-west trending lines. Since locations were mainly at quarter mile intervals, a distance of about 200 line miles was covered. Some areas of special interest were detailed at closer intervals.

Approximately 450 seismic refraction profiles were completed in the La Sarre, Quebec area (NTS 32D). Depth determinations were made at quarter mile intervals along east-west trending lines for a total of 110 line-mile coverage.

The shallow seismic coverage in the Val d'Or area (NTS 32C) consisted of 130 profiles over 30 line miles.

Survey results indicate fairly high relief in the bedrock topography. This is not surprising when one observes the relief in the bedrock to the south of the clay belt. It is probably valid to assume the same relief continues northward in the project area. Steep dips of the overburden-bedrock interface in some parts of the areas are beyond the limitations of the seismic method, which assumes relatively flat or gently dipping interfaces.

A total of 1375 seismic refraction profiles were completed for all areas covering an approximate distance of 340 line miles. The work was accomplished utilizing eight FS-3 portable refraction seismic instruments in a working time of 82 crew weeks (3 man crews). Difficulties of winter operation were successfully overcome, and it was possible to meet the objectives of the survey.

[1] Hobson, G.D., and Grant, A.C.: Tracing buried river valleys in the Kirkland Lake area of Ontario with a hammer seismograph; Can. Mining J., v. 84, no. 4, p. 79-83 (1964).

[2] Hobson, G.D., and Carr, P.A.: Hammer seismic survey, Moncton map-area, New Brunswick; Geol. Surv. Can., Paper 65-43 (1967).

[3] Hobson, G.D., Scott, J.S., and Van Everingden, R.O.: Geotechnical investigations, Red River Floodway, Winnipeg, Manitoba; Geol. Surv. Can., Paper 64-18 (1964).

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38. MAGNETIC TEST RANGE NEAR TIMMINS, ONTARIO

Project 720080

L.J. Kornik and P.H. McGrath
Resource Geophysics and Geochemistry Division, Ottawa

This project was initiated to evaluate the usefulness of high resolution ·eromagnetic survey data as an aid to detailed geological mapping programs. ·ring the summer of 1972, a geophysical test range was established about

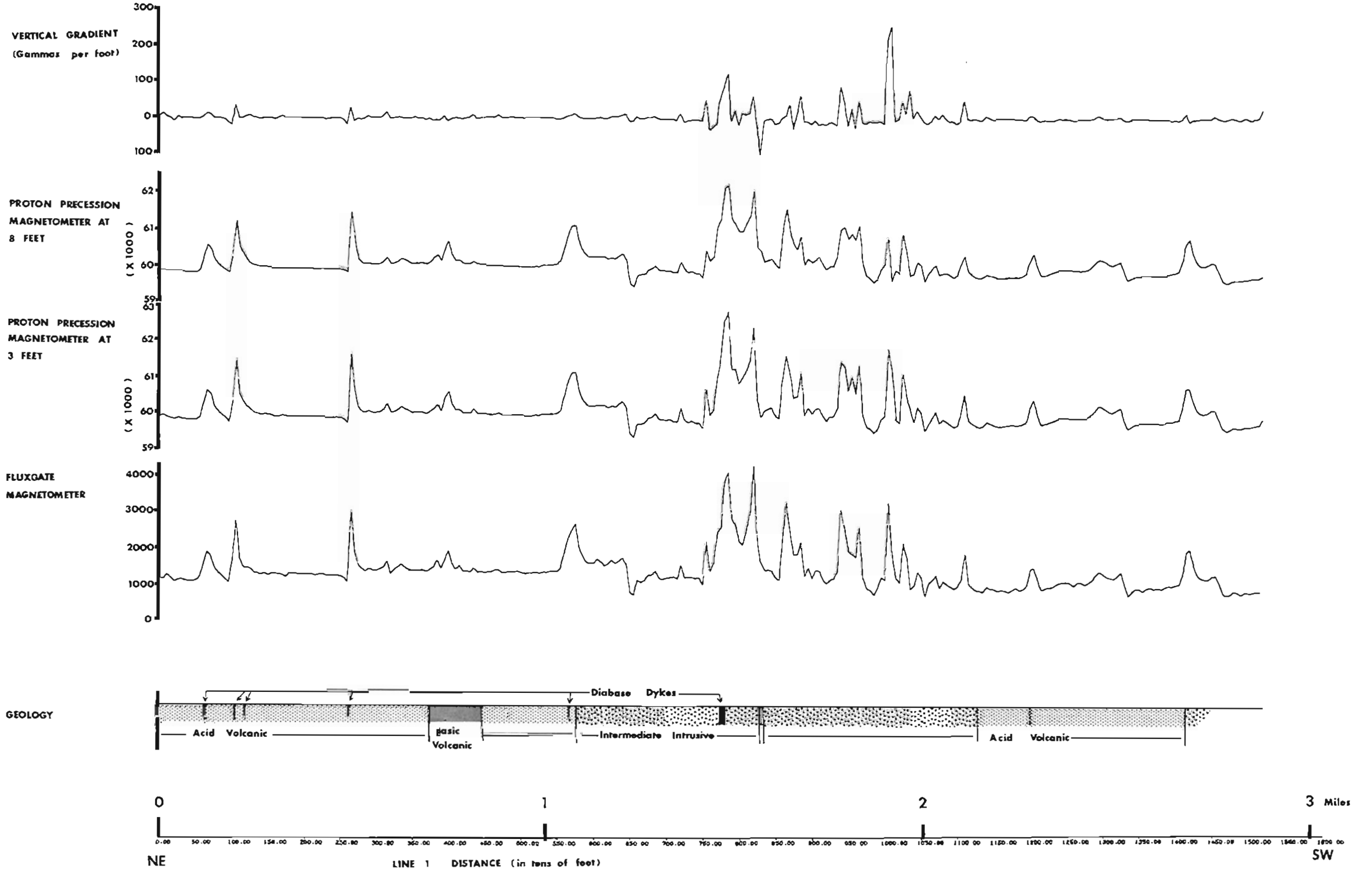

Figure 1. Geological cross-section and ground magnetometer profiles along Line 1.

15 miles northwest of Timmins in Godfrey Township extending in a southwesterly direction from Highway 576. Seven survey lines approximately 3 miles in length spaced 500 feet apart were cut through the bush. The lines were chained and stations flagged every 50 feet. Magnetic field readings were taken at each survey station with a Scintrex MF-1 fluxgate magnetometer and with a Sander NPM-3 proton precession magnetometer. At each survey station readings were obtained with the sensing head of the proton precession magnetometer held at two different heights in a vertical line in order to measure the local vertical gradient close to the ground surface. Also where outcrops permitted, in-situ magnetic susceptibility readings were taken using a Scintrex SM-4 susceptibility meter; and from outcrops with a detectable magnetic susceptibility, oriented drill-core samples were obtained using a portable 1 1/4 inch diamond drill for subsequent remanent magnetism determinations. The geology of the test range was also mapped, the test range has approximately half outcrop exposures with the remaining areas covered by swamps or drift deposits.

All ground measurements were completed on the test grid during the past field season. The survey data have been transferred onto punched cards and the computer is being utilized to correct, display and manipulate the data. The data will be compared to aeromagnetic survey data recorded by the Geological Survey Queenair aircraft which is equipped with a high-resolution optical absorption magnetometer. The aeromagnetic data have been obtained at several survey altitudes along the grid lines. The aeromagnetic data and various filtered versions of these data will then be compared with the ground magnetic measurements and observed geology. The purpose of this comparison is to demonstrate the usefulness of high-resolution airborne data to detailed geological mapping programs.

Figure 1 illustrates the type of ground information gathered on the test grid. This figure consists of ground magnetometer profiles and the geological cross-section along Line 1 of the Timmins test range. Immediately above the geological cross-section is the vertical magnetic field profile obtained with the fluxgate magnetometer. Above the fluxgate profile are two total field magnetic profiles obtained with the proton precession magnetometer. The lower of these profiles represents the magnetic field at 3 feet elevation and the upper profile is the magnetic field at 8 feet elevation. The difference between the 3-foot and 8-foot readings at the same station divided by their separation distance is considered to represent the vertical magnetic gradient at that station. The resultant vertical magnetic gradient values are given in the uppermost profile in Figure 1.

A comparison of the geology and the ground magnetometer profiles reveals the essentially non-magnetic character of the acid volcanic rocks compared to the more magnetically-active areas underlain by intermediate intrusive rocks and diabase dykes. The dykes in particular are readily recognizable from their sharp, relatively large amplitude magnetic anomalies. The areas of basic volcanic rocks while being only slightly more magnetic than their acid counterparts do have sufficient magnetic character to be readily recognizable on all the profiles in Figure 1. Moreover there is considerable magnetic relief within a given formation, especially the intermediate intrusive rock, which is correlatable across many of the survey lines. This relief gives rise to the so-called "fine structure" observable on high-resolution aeromagnetic profiles and may be displayed using appropriate filtering techniques to enhance the higher frequency components of the airborne data.

39. FEDERAL-PROVINCIAL AEROMAGNETIC SURVEYS

A. Larochelle
Resource Geophysics and Geochemistry Division, Ottawa

British Columbia (Geoterrex)
Project 690066

Up to the end of September 1972, 66,500 line miles out of a total of 73,000 line miles included in this project had been flown. This year's production amounts to 24,000 line miles. Compilation of this work is in progress although to September 30, 1972, only 22 out of the 90 1-mile map-sheets included in this project have been printed. Field operations are expected to be completed before the end of the present calendar year.

Keewatin and Mackenzie
Project 690068

Progress in the flying of this aeromagnetic survey amounts to 71,000 line miles for the present calendar year. Field operations were concentrated east of meridian 96°E, to assist geological mapping activities of other divisions of the Branch. Eighty one-mile maps were published during the year in the area of this project.

Labrador-Melville-Coppermine
Project 690072

Approximately 2,400 line miles of aeromagnetic survey were flown in the Melville Peninsula component of this project, and 9,400 line miles in the Labrador component, east of meridian 64°W and south of 55°N latitude. The South Baffin Island area forming part of the original contract has been deleted in favour of two areas of equivalent size in Melville Peninsula and Coppermine districts. It is not anticipated that flying in the Coppermine area will be initiated before 1975. This modification of the original contract was done to facilitate projected field activities of other divisions of the Branch.

Quebec
Project 690073

This year's production in the flying of this aeromagnetic survey amounts to 55,523 line miles, leaving 13,100 line miles to be flown for completion of a total of 258,000 line miles. Forty-eight one-mile aeromagnetic maps included in this project were released jointly by the Department of Natural Resources of Quebec and this department during the year. It is anticipated that the remainder of the flying will be completed before the end of this calendar year (1972).

British Columbia (Lockwood)
Project 700023

With the flying of 4, 096 line miles of aeromagnetic survey in map-sheet 94D (east half), field work related with this contract is now complete. Compilation of the resulting data is also complete and the last aeromagnetic maps are scheduled to be issued in November 1972, jointly by the Department of Mines and Petroleum Resources of British Columbia and this department.

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40. AIRBORNE RADIOACTIVITY MEASUREMENTS OVER THE CANADIAN SHIELD

Project 720071

K.A. Richardson
Resource Geophysics and Geochemistry Division, Ottawa

Cross-country Reconnaissance

Previous work[1] has shown a considerably higher level of radioactivity in the northwestern part of the Canadian Shield than in the central Superior Province and the area to the east along the Grenville Front. In addition, superimposed on this general base level are belts of high radioactivity a few tens of miles in width and several tens of miles in length (Fort Smith, N.W.T., Wollaston Fold belt, Saskatchewan, Manitoba; and Favourable Lake - Setting Lake, northwestern Ontario). The 1972 cross-country flight path took a more southerly route between Sudbury and Armstrong than previous years to verify the generally low count rate over the central Superior Province, and intersected the belt of high activity trending east-west through the Favourable Lake - Setting Lake area of northwestern Ontario, indicating the continuity of this belt over a length of at least 120 miles. The northeast-southwest trending radioactive high through the Wollaston Lake area was intersected in the southwest near 57°N, 105°W, and in the northeast near 60°15'N, 100°W. The radioactivity level is subdued to the southwest, but high to the northeast, giving this radioactive belt an extent of over 250 miles. A flight line north from Stoney Rapids showed that the high radioactivity of the Fort Smith belt does not continue to the northeast, paralleling the MacDonald Fault, beyond 110°W longitude.

Carswell Structure, Saskatchewan

A survey over this area was flown to determine pattern of radioactivity distribution prior to extensive disturbance of the surface by exploration and development work on uranium occurrences in the Carswell Dome. Eight hundred line miles were flown at line spacing of one mile. The average count rate over the dome is quite low, with uranium concentrations averaging a few tenths of a part per million, and thorium on the order of 2 ppm. The most prominent uranium concentration is located east of Cluff Lake, where the level reaches approximately 4 ppm, with thorium concentration increasing to approximately 4 or 5 ppm. The values given are preliminary, and intended only to give an order of magnitude to the levels observed.

Bear-Slave Provinces, N.W.T.

9,200 line miles of gamma-ray spectrometry data were collected in the Bear-Slave Provinces, covering map-sheets 86 A, B, C, F, G, and H, at 5 kilometre line spacing. This area overlaps the western half of the regional geochemical survey of lake waters and sediments (Project 720063).

Highest thorium and uranium concentrations occur in the area of massive granite, granodiorite and allied rocks in the Bear Province, west of the Wopmay Fault, and particularly in the northern half of map-sheet 86 C. Some lesser concentrations occur in the Slave Province in areas of granitic gneiss on map-sheet 86 A.

In the area between the Wopmay Fault and the Bear-Slave boundary, one particularly strong thorium anomaly, with only a small increase in uranium, accompanied by a magnetic anomaly of about 2000 gammas, occurs. Located near 65°10'N, 115°50'W, this anomaly extends 2 miles along the flight line, and is not apparent on adjacent flight lines 3 miles to the north or south. The coincidence of radioactivity and magnetic anomalies over this relatively small area are suggestive of a carbonatite occurrence and indicate an area that warrants some ground investigation.

[1] Darnley, A.G., Grasty, R.L., and Charbonneau, B.W.: A radiometric profile across part of the Canadian Shield; Geol. Surv. Can., Paper 70-46 (1971).

41. EXPERIMENTAL HIGH-RESOLUTION AEROMAGNETIC SURVEYS: 1972

Project 680081

P. Sawatzky, D.W. Olson, and Peter J. Hood
Resource Geophysics and Geochemistry Division, Ottawa

During the past summer the Geological Survey Queenair B80 aircraft, which is equipped with a digital-recording rubidium-vapour magnetometer system, was used to carry out high-resolution experimental aeromagnetic surveys of two areas in co-operation with provincial mines departments.

The first experimental aeromagnetic survey was carried out in the Kirkland Lake area of northern Ontario (see Fig. 1) during the period June 24 to July 7, 1972. P. Sawatzky was party chief for this operation. Approximately 8,000 line miles were flown using a line spacing of one-quarter nautical mile (1,520 feet) at a flight elevation of 1,000 feet. The main survey lines were oriented in a north-south direction, and double control lines spaced 5 nautical miles apart which are indicated on Figure 1, were flown in an east-west direction. The aircraft operated from the airport at Earlton.

The second experimental aeromagnetic survey (see Fig. 2) was carried out in the Bathurst mining camp in northern New Brunswick with the aircraft operating from the airport at Charlo on Chaleur Bay. D.W. Olson was

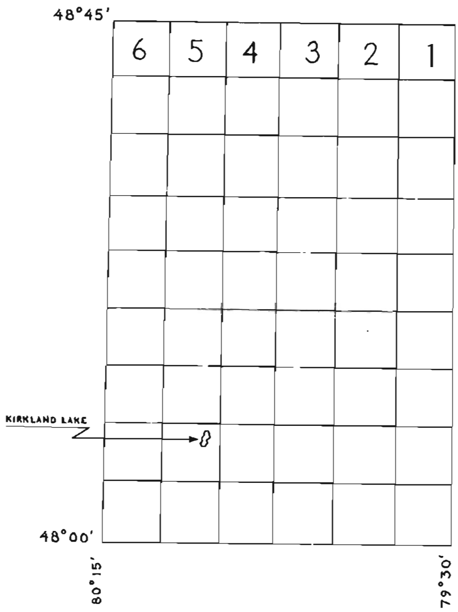
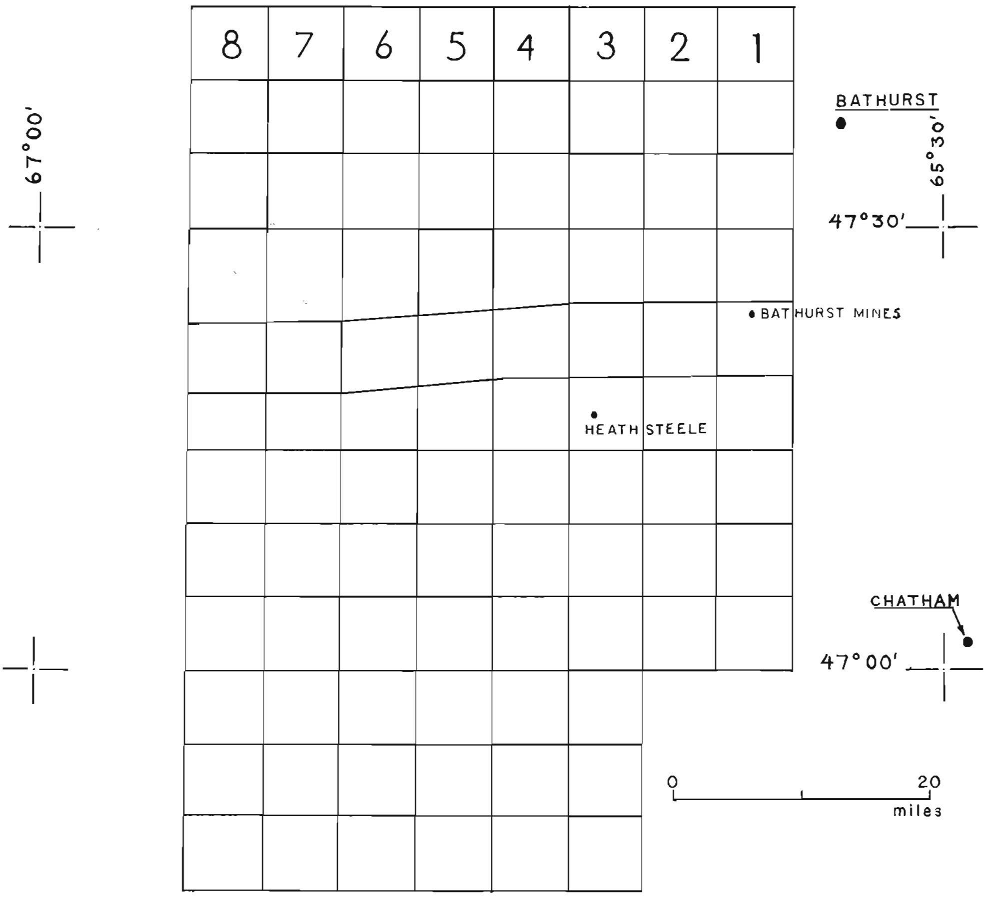


Figure 1.

Survey area flown with the Geological Survey high-resolution magnetometer survey system in Ontario during 1972.

Figure 2 (below).

Survey area flown with the Geological Survey high-resolution magnetometer survey system in New Brunswick during 1972.



party chief for the operation and approximately 13, 100 line miles of aeromagnetic survey data were obtained at one-quarter nautical mile-line spacing during the period August 25 to October 5. Because of the topographic relief of the area, it was necessary to fly the north-south survey lines at three different barometric altitudes. Sub-areas 1 and 2 (see Fig. 2) were flown at 1, 500 feet, areas 3, 4 and 5 were flown at 2, 500 feet and areas 6, 7 and 8 were flown at 3, 000 feet above sea level. As indicated on Figure 2, double control lines were flown in an east-west direction 5 nautical miles apart at the three elevations.

For both surveys, the flight track film was developed and fixed as soon as possible after each survey flight. The track film was then used in the field to recover the flight path of the survey aircraft. Any gaps in excess of 1.5 times the flight-line spacing (2, 280 feet) for 5 miles were filled in by reflying extra lines. The digital data recorded on the magnetic tapes were also checked for registration using a Cipher Model 850H magnetic tape reader coupled to an Interdata Model 70 computer whose output was fed to a Versatek Model 200A line printer.

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42. VLF MAPPING

Project 670041

W. J. Scott
Resource Geophysics and Geochemistry Division, Ottawa

Detailed ground geophysical surveys were carried out in a small area in New Brunswick and another in Nova Scotia to look for correlation with geology. Methods employed were VLF-EM, magnetics, shallow seismic, D.C. resistivity and radiohm.

The area in New Brunswick was approximately 10 miles south of Elgin, in the Caledonian Mountain belt. This area had been included in a multi-sensor geophysical survey flown for the provincial government in the summer of 1971. The test area in Nova Scotia was in the Cobequid Mountains, approximately 8 miles south of Collingwood Corner.

In both areas contacts and conductive faults were identified from the ground data. In the Cobequid area, tentative determinations of rock types made on the basis of the radiohm data, agreed with geological control supplied by the Nova Scotia Department of Mines.

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43. COLOUR AERIAL PHOTOGRAPHY EAST OF GREAT BEAR LAKE, DISTRICT OF MACKENZIE (86 F)

Project 630031

V.R. Slaney
Resource Geophysics and Geochemistry Division, Ottawa

Some 3,000 line miles of experimental aerial colour photography has been flown within the area of sheet 86F, Calder River. The project was flown at 7,500 feet above average ground level using a Wild RC10 camera and Kodak 2445 (colour negative) film. Stereo-coverage has been obtained over a total area of approximately 4,500 square miles.

The film has been annotated and indexed and appears to be of reasonable to very good quality.

The photography will be used to provide photogeological interpretations of select areas:

1. To aid the interpretation of airborne gamma-spectrometer and magnetometer data (Project 720071).
2. To assist in the analysis of data obtained from a regional geochemical survey of lake sediments (Project 720063).
3. To provide information for a regional field mapping program planned for the summer of 1973.

Flight indices and log sheets for this imagery will be placed on Open File at the Geological Survey later in the year, and the negatives made available to the National Air Photo Library.

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44. WEATHER SATELLITE PICTURES

Project 700089

S. Washkurak
Resource Geophysics and Geochemistry Division, Ottawa

The Geological Survey has established a capability for receiving weather satellite pictures at the Blackburn Geomagnetic Observatory site near Ottawa. Each picture covers an area measuring approximately 1,700 miles square. Daily coverage of the entire North American continent including the Arctic Islands is obtained showing the cloud, snow and ice conditions. This is suitable for planning and controlling survey activities from Ottawa, or if used as a portable system it can provide weather information to an isolated base in the north. This would be advantageous for air survey operations from the point of view of operational efficiency and safety.

An example of ESSA VIII imagery May 24 and August 15 is in the accompanying figures. Note the ice fissure in Hudson Bay on Figure 1; Great Bear Lake and Lake Athabasca are still ice covered. Figure 2 shows how little the ice broke up during the 1972 shipping season. Lancaster Sound is

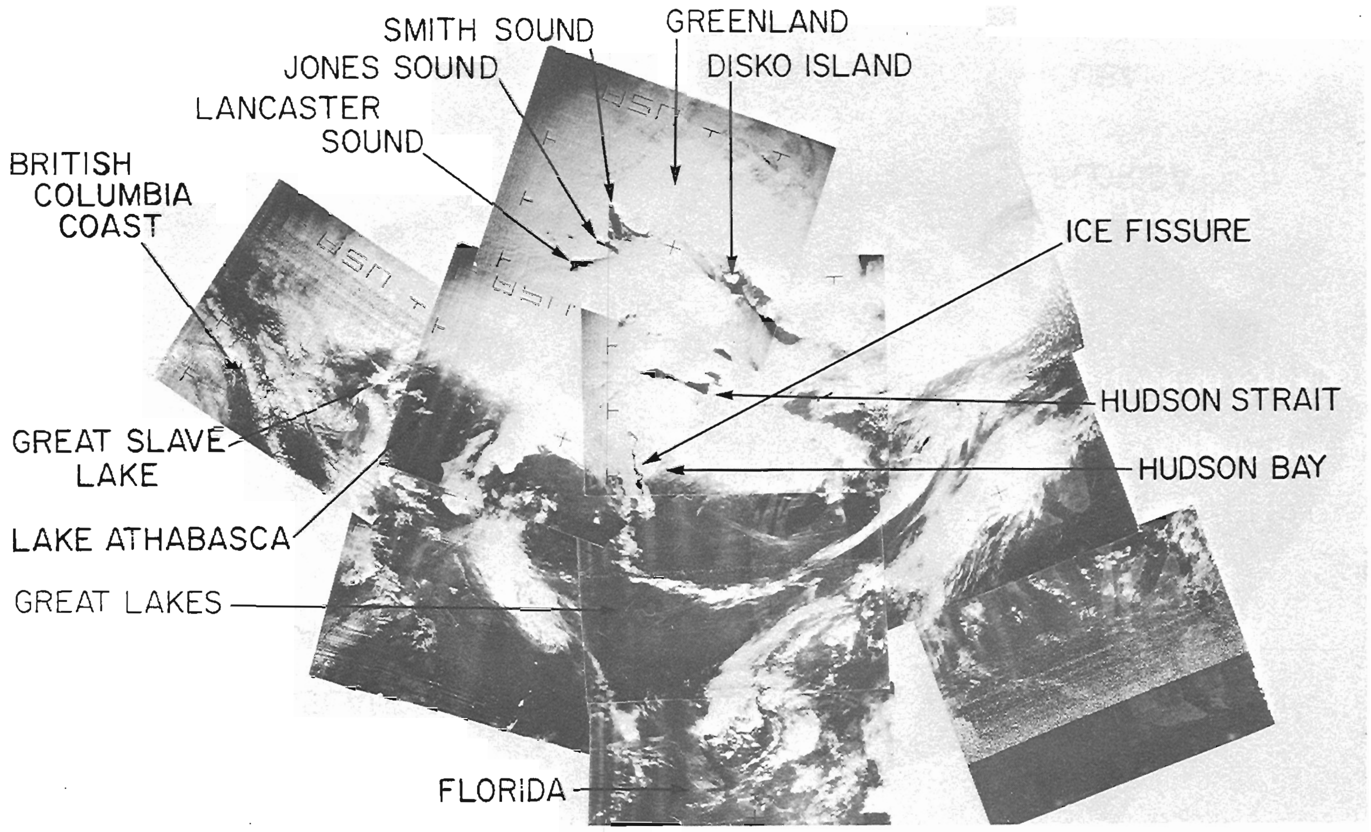

Figure 1. Photo mosaic of North America obtained by the ESSA VIII satellite on May 24, 1972.

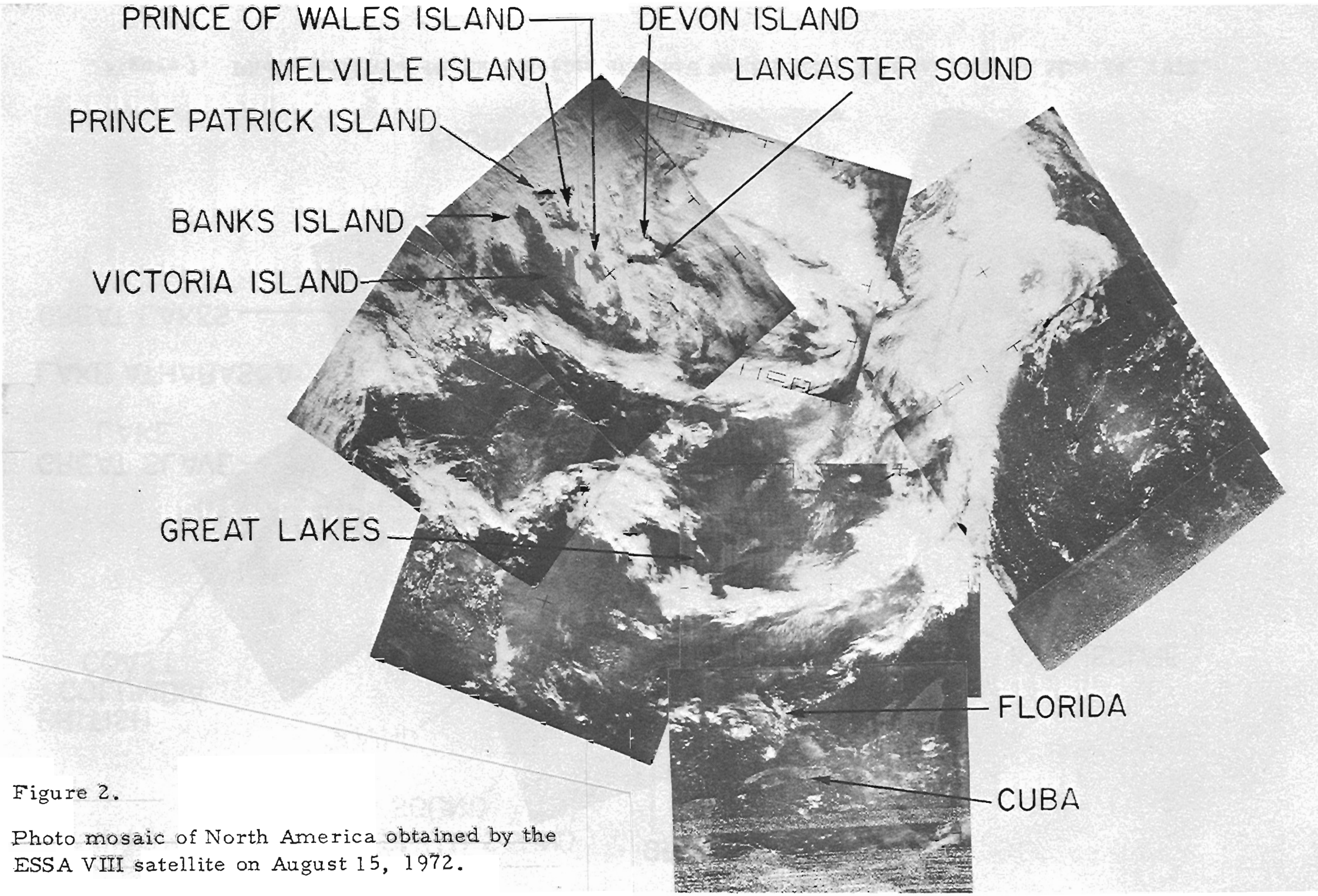

Figure 2.

Photo mosaic of North America obtained by the ESSA VIII satellite on August 15, 1972.

only open to Resolute, Cornwallis Island. Future satellites (October 1972) will have improved (one-half mile) resolution which will show better ground detail.

Two improved meteorological satellites are scheduled for launch in the first quarter of 1973. The GOES system is a new synchronous satellite operating at 1960 MHZ. ITOS "D" is a modified version of the polar-orbiting TIROS operational satellite system. Both will operate in the S-band portion of the frequency spectrum to handle the increased data rate required for high-resolution imagery instead of the present 137 MHZ for the ESSA series. GOES will provide visual and infrared observations of the entire earth disc from synchronous orbit with a ground resolution of one-half and 5 nautical miles. Measurements will also be made of the magnetic field to 0.1 gamma portion, electron and X-ray flux at various energy levels by means of the space environment system. This information may be useful to correct or plan airborne magnetic or gamma-ray surveys. The ITOS-D"D imagery with one-half mile ground resolution and 800 mile field of view should compliment the high resolution ERTS imagery.

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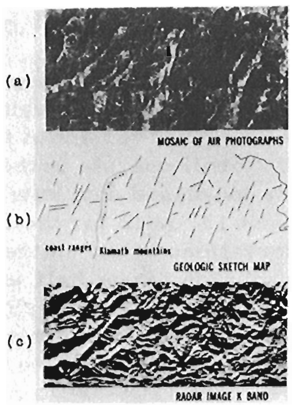
45. OPTICAL DATA PROCESSING

Project 700090

S. Washkurak
Resource Geophysics and Geochemistry Division, Ottawa

Signal processing of information with coherent light has been understood in principle for nearly a century. Abbe showed that the Fraunhoffer (far field) diffraction pattern of a picture negative is the two-dimensional Fourier transform of the light distribution in the picture. The transform presents the input information in a form that is exceptionally convenient for frequency analysis. If the density distribution on the original picture is looked upon as a two-dimensional function F(x, y) the transform is a corresponding two-dimensional function $U(W_x W_y)$ of the spatial frequencies in the x and y directions. Due to the square-law detection of film the transform becomes the two-dimensional power spectrum of the input information at the output. Fourier transformation is a method of analyzing non-periodic signals into their component frequencies. The light distribution is, in fact, a frequency analysis of the input function. The radial co-ordinate represents the frequency and the amplitude (brightness) at any point represents the amplitude of the corresponding frequency.

The apparatus for producing a Fourier transform is sometimes called a diffractometer. Light travelling through the system starts off as the input function; the apparatus generates the Fourier transform and reconstructs the input function. Optical processing is carried out by inserting optical filters in the spatial frequency plane to analyze and modify the reconstructed function. These optical filters consist of opaque discs (high-pass filter), annual rings (low-pass filter) and wedges or knife edges for selective directional filtering which are maintained in their proper position in the filter plane by appropriate mechanical positioning devices.



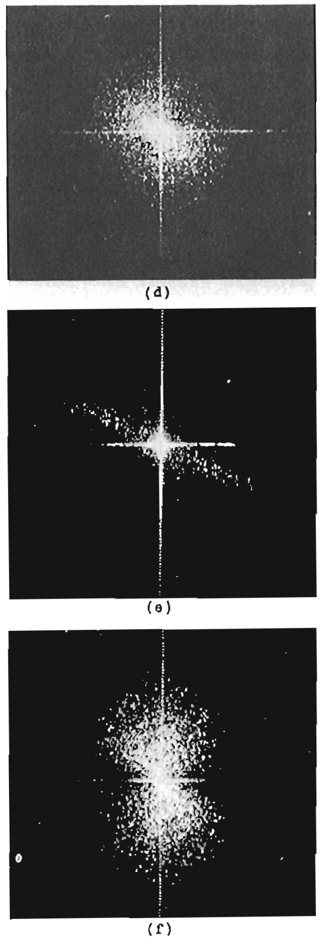


Figure 1.

GRANTS PASS AREA, OREGON.
NASA HQ SA67-16501 (portions of Westinghouse, 1967, p. 17).

(a) Air photo mosaic
(d) Transform of (a)
(b) Geologic sketch map
(e) Transform of (b)
(c) Radar image K band
(f) Transform of (c)

Similarly, exponential bandpass and second derivative filters can be used to process digitized magnetic data. With the aid of correctly controlled filtering the accuracy of interpretation of computed maps can actually be taken as the basis for quantitative interpretation. Second-derivative filters enhance the lateral separation of adjacent anomalies and attenuate the regional effects. A problem frequently encountered in geological studies is the statistical analysis of two-dimensional lineations. Preferred orientations are generally obvious to the eye on the transform patterns even when they are not obvious on the original picture. Through their diffraction patterns, features can be described quantitatively in terms of directions, spacings and symmetries. Features can be compared at different scales, contour maps of different variables (geophysical, topographic, structural) in the same area can be compared through their diffraction patterns and by filtering.

Published photographs, drawings and maps constitute a vast resource of information, much of which can be processed optically.

This past summer an optical bench (diffractometer) has been set up to evaluate some of the problems associated with optical data processing. In an ideal diffractometer a perfectly parallel beam of light of constant amplitude and phase must illuminate the whole aperture of the system. The lower lens between the mask and the focal plane must be identical for all beams parallel to a given direction. These conditions are very difficult to achieve in practice due to four main reasons. The quality of the lens, including dust, bubbles, grease; incorrect adjustment; irregular amplitude and phase coherence; and incorrect focussing. The requirements for a diffractometer are in many ways more stringent than those for other optical systems such as projectors and telescopes.

Figure 1 shows three Fourier transforms of imagery of the same area[1]. The geological sketch map is in a sense the result of extreme filtering by the geologist who prepared the map.

[1] Westinghouse Electric Corporation 1967. Side Look Radar AN/APQ-7 for NASA, 46 pp.

46. MARINE GEOSCIENCE

GEOCHEMICAL INTERACTIONS BETWEEN WATER AND PARTICULATE SOLIDS AND MODELS FOR THE MECHANISMS OF METAL DISPERSION AND ACCUMULATION IN MARINE ENVIRONMENTS

D. E. Buckley
Atlantic Geoscience Centre, Dartmouth

Little more than 100 years ago the German geologist J. G. Forchammer discovered, after 20 years of analyses, that sea water and river water contained markedly different proportions of major cations. His conclusions that "the quantity of elements in sea water are inversely proportional to the facility with which the elements are made insoluble by general chemical or organo-chemical actions" is still basically valid, but still presents perplexing problems to geochemists attempting to construct theoretical models of marine systems. The essence of the problem of geochemical equilibrium is to identify and define the mechanisms of injection and removal of chemical elements from solution.

The marine inorganic geochemistry cruise for 1972 was planned to collect data pertaining to both aspects of elemental injection and removal. Phase I of the cruise was carried out to complete previous sampling in the La Have River and Estuary, Nova Scotia[1,2]. Phase II of the cruise was designed to gather new information on the possible occurrence of nepheloid

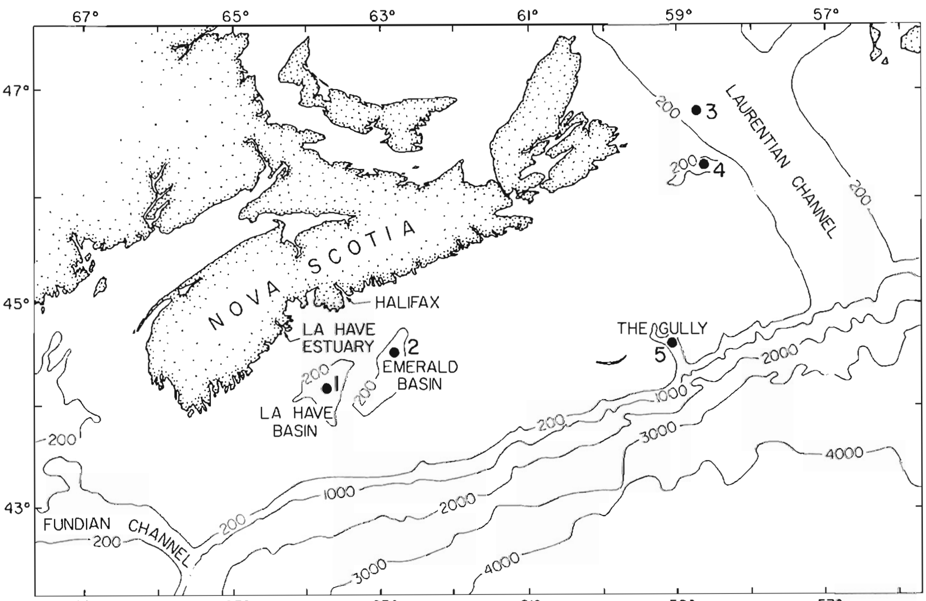


Figure 1. Major sampling stations on Scotian shelf, Cruise 72-019, CSS DAWSON.

layers in bathymetric basins and troughs of the continental shelf off Nova Scotia (Fig. 1), and to determine the significance of these layers with respect to processes of mineral and metal deposition.

Phase I – La Have Estuary, June 20-21:

A 13-hour monitoring station was carried out at one location in the geographic centre of the La Have Estuary. Shipboard operations included hourly sampling of the water column at three depths with simultaneous measurements of current velocities, water temperature and salinity. Tidal levels were measured from shore installations. Turbidity of the bottom water was continuously monitored by a prototype nephelometer recently developed at the Bedford Institute of Oceanography.

Analyses were carried out in the ship's laboratories for dissolved mercury, chloride ion, and sewage bacteria, while dissolved and particulate organic carbon and total suspended particulate matter were collected for later analyses at the Bedford Institute. Water samples were also collected for later analyses of trace elements and major cations. These data and observations will be combined with earlier data for other stations in the La Have River and Estuary[3,4] for the purpose of constructing a model of geochemical flux between a river-estuarine system and the coastal marine environment. Preliminary data indicate that the river-generated flux (advective mode) predominates in the upper half of the water column, while the tidal-generated flux (diffusive mode) accounts for exchanges below 5 metres depth. Bacterial concentrations are extremely high (1500 to 5900 colonies/100 ml) in surface fresh water as a result of direct sewer discharges in the estuary. Dissolved mercury was also highest in surface waters (0.161 μg/ℓ), probably as a result of urban injections previously found near Bridgewater[5].

Laboratory work is continuing to determine the net flux of 9 trace elements including Mn, Fe, Co, Ni, Cu, Zn, Cd, Pb and Al as well as the major cations. In addition, organic carbon (dissolved and particulate) and total particulate matter are being analyzed to determine their significance with respect to geochemical partition and interaction.

Phase II – Nova Scotia Continental Shelf, June 22-28:

Among other authors, Ewing[6,7] and Thorndike[6,8] have published most on the occurrence and significance of nepheloid layers in the ocean. These authors have reported nepheloid layers mainly in areas of the deep ocean or on the continental rise and slope. These layers of fine suspended minerals have most commonly been associated with strong horizontal currents and assumed vertical turbulence, thus supporting the hypothesis of a steady state phenomenon. This phenomenon is thought to effect significantly sediment transport and deposition in the ocean basins, but little attention has been paid to the possible occurrence of these layers in shallow basins on the continental shelf nor to the geochemical significance of the layers as they may effect metal adsorption and deposition.

On this phase of the cruise a nephelometer was used to locate and measure the optical cattering properties of the nepheloid layers in four bathymetric depressions on the Scotian Shelf. In the La Have Basin (43°42'N, 63°52'W) a layer more than 50 metres thick was found above the bottom (basin depth 260 metres). In Emerald Basin (43°57'N, 62°55'W) the layer was thinner, extending upward from the bottom interface about 20 metres. In the St. Lawrence Channel (Cabot Strait, depth 413 metres) and in a shallow depression off Cape Breton Island (45° 38'N, 59° 33'W, depth 200 metres) a layer 40 metres thick over the bottom was measured. All layers contained 1.3 to 1.7 mg/ℓ of suspended clay-sized particulate matter. The optical scattering data indicate that the concentration of suspended particulate matter in the layers is about 5 to 10 times the quantity found in the water above the nepheloid layer.

These layers and associated waters were sampled to obtain detailed chemical and mineralogical information on the nature of the suspended matter and to determine the trace element composition of both water and particulate matter. Water analyses were carried out on board the ship using atomic absorption spectroscopy. Suspended particulate matter was concentrated by the use of onboard constant flow centrifuges which removed particles larger than 0.2 μm from large volumes (300 to 400 litres) of water.

[1] Buckley, D.E.: Cruise Report No. 70-016, CSS DAWSON; Atlantic Oceanographic Laboratory, Bedford Institute (1970).

[2] Buckley, D.E.: Cruise Report No. 71-034, CSS DAWSON; Dept. Energy, Mines and Resources, Science and Technology, Marine Geology, Bedford Institute (1971).

[3] Cranston, R.E. and Buckley, D.E.: Geochemical data for the La Have River and Estuary, Project 70-23 Inorganic Geochemistry; Data Series/ BI-D-72-1/January 1972, Atlantic Geoscience Centre, Dept. Energy, Mines and Resources, Bedford Institute of Oceanography (1972).

[4] Cranston, R.E. and Buckley, D.E.: Geochemical Data from a 25-Hour Station, La Have River, Nova Scoita; Project 71-23A Inorganic Chemistry; Data Series/BI-D-72-12/ July 1972; Atlantic Geoscience Centre, Dept. Energy, Mines and Resources Bedford Institute of Oceanography (1972)

[5] Cranston, R.E. and Buckley, D.E.: Mercury pathways in a river and estuary; Envir. Sci. Technol., v. 6, no. 3, p. 274-278 (1972).

[6] Eittreim, S., Ewing, M., and Thorndike, E.M.: Suspended matter along the Continental Margin of the North American Basin; Deep-Sea Res. v. 16, p. 613-624 (1969).

[7] Ewing, M. and Connary, S.D.: Nepheloid layer in the North Pacific; Geol. Soc. Amer., Mem. 126, p. 41-81 (1970).

[8] Hunkins, K., Thorndike, E.M. and Mathieu, G.: Nepheloid layers and bottom currents in the Arctic Ocean; J. Geophys. Res., v. 74, no. 28, p. 6995-7008 (1969).

47. DEVELOPMENT OF SHIPBOARD METHODS FOR MARINE GEOCHEMICAL ANALYSES

R. E. Cranston
Atlantic Geoscience Centre, Dartmouth

Introduction

Techniques for the collection and analyses of geochemical samples have been developed or altered to meet the requirements of a shipboard laboratory. These methods include the following: trace element analyses of sea water by chelation-solvent extraction and atomic absorption spectroscopy, total mercury analyses of sea water, collection of suspended particulate matter, and determination of in situ suspended particulate matter. Three general aspects were studied during the 1972 field season (June 22-28, July 4-10, and September 25-October 6) on the CSS DAWSON.

Storage of Trace Element Samples

Many problems can result from storing water samples prior to trace element analyses. Three approaches to minimize storage effects are as follows: (1) using a biological inhibitor (poisons such as sodium azide) to prevent biological alteration of trace constituents, (2) lowering the pH to reduce adsorption of trace metals on the container walls during storage, and (3) conducting analyses immediately after collection of the sample. Poisons may be ineffective in inhibiting some biological activity, while storing the samples at natural pH allows trace metals to adsorb on the container surfaces. If the pH storage system is used, trace element species that are not ionic metals in the natural system (e.g. hydroxides, organo-metallic complexes) can be broken down by the acid to produce greater ionic concentrations than were originally present. This distinction is important if accumulation of trace metals in sediment by ionic adsorption and exchange is to be evaluated.

Following are other advantages for doing geochemical analyses on board ship. Results are immediately available which enable changes in the sampling pattern to be made, an important factor since ship time is at a premium and it is essentially impossible to return to an area for additional samples in one field season. Other advantages are more efficient use of ship time, ship space and technical personnel; and a significant reduction in sample storage requirements.

The June cruise involved detailed geochemical sampling in five locations (see D. E. Buckley this publication). Chelation-solvent extraction and atomic absorption analyses for Al, Cd, Co, Cu, Fe, Mn, Ni, Pb and Zn were carried out in duplicate on board ship for 24 sea water samples[1]. The precision obtained at sea was equivalent to that obtained at the Institute laboratory. Improved accuracy was obtained at sea because a majority of the storage problems were eliminated.

Dissolved mercury analyses were carried out in duplicate for 65 water samples using a flameless atomic absorption technique[2]. The precision was equivalent to that obtained at the Institute laboratory. The mean mercury concentrations were significantly higher than those obtained prior to 1972 for land-based analyses of similar waters. This result coincided with the reported loss of mercury during storage that has been found by Coyne and Collins[3].

Baseline Study

The field trip in July was part of an interdisciplinary study aimed at establishishing an environmental oceanographic baseline for the Halifax to Bermuda transect. Duplicate mercury analyses were obtained for 90 water samples to establish a precise and accurate baseline for dissolved mercury in the ocean section.

Methods for Studying Suspended Particulate Matter

Gravimetric studies of suspended particulate matter in sea water were carried out to evaluate the performance of various types of membrane filters[4]. In addition, a prototype model of a nephelometer developed at the Bedford Institute of Oceanography was evaluated. Results from the filter studies indicate that Nuclepore filters are the best gravimetric filters with respect to weighing characteristics and retentive efficiency. Solvinert filters are not as retentive as the Nuclepore, however they have a larger load capacity. In previous field programs, Millipore MF membrane filters were used to collect particulate matter. As a result of the filter evaluation study, they were rejected because of their high weighing variability and their tendency to retain a large amount of sea salt after they were dried.

The prototype nephelometer accurately defined anomalous amounts of suspended matter prior to sampling and demonstrated tidal effects on the suspended load at the water-sediment interface. The evaluation study was continued during the September-October field activities to calibrate the instrument quantitatively by obtaining light-scattering profiles for various wavelengths of light and to compare these results with data on suspended loads obtained from Nuclepore and Solvinert membrane filters. The results are useful in evaluating geochemical partitioning between solid and liquid phases as well as introducing the outstanding features of the new nephelometer to other disciplines where particulate studies are important (e.g. fishery, environmental, and hydro-engineering studies).

[1] Buckley, D. E., Winters, G. V. and Cranston, R. E.: Chelation-solvent extraction and atomic absorption spectroscopy as a method for evaluating trace metal hydrolysis in natural waters; Mar. Chem. (in prep.) (1972).

[2] Cranston, R. E. and Buckley, D. E.: Mercury pathways in a river and estuary; Envir. Sci. Technol., v. 6, no. 3, p. 274-278 (1972).

[3] Coyne, R. V. and Collins, J. A.: Loss of mercury from water during storage; Anal. Chem., v. 44, p. 1093-1096 (1972).

[4] Cranston, R. E. and Buckley, D. E.: The application and performance of microfilters in analyses of suspended particulate matter; (in prep.) (1972).

48. UNDER-WATER, DIAMOND DRILL TRIAL AND SUPPORT SURVEY NORTHEAST OF BELLE ISLE, NEWFOUNDLAND

I.M. Harris
Atlantic Geoscience Centre, Dartmouth

A two-day program (Oct. 1-2, 1972, on board CSS DAWSON) of diamond-drilling, seismic reflection profiling and sonar side-scanning was carried out northeast of Belle Isle, Newfoundland (Fig. 1). The study area was selected on the basis of previous seismic reflection records obtained by the Bedford Institute [1]. The purpose of the program was (1) to test a newly designed electric rock-core drill, and (2) to investigate the bedrock and surficial geology of the area.

Seismic profiling and sonar side-scanning were conducted simultaneously on the survey lines shown in Figure 1. A BOLT air-gun fitted with a one-cubic-inch firing chamber was employed as the seismic energy source. A DREA-design Moby fish containing a side-scan transducer was the acoustic source employed in side-scanning. An Alphine-Gifft depth recorder was operated continuously.

The seismic profiling was used to distinguish the structure and seismic characteristics of the bedrock and the approximate depth of overburden along the survey lines. The seismics and sonar side-scanning together allowed inferences regarding the general nature of the substrate and provide a basis

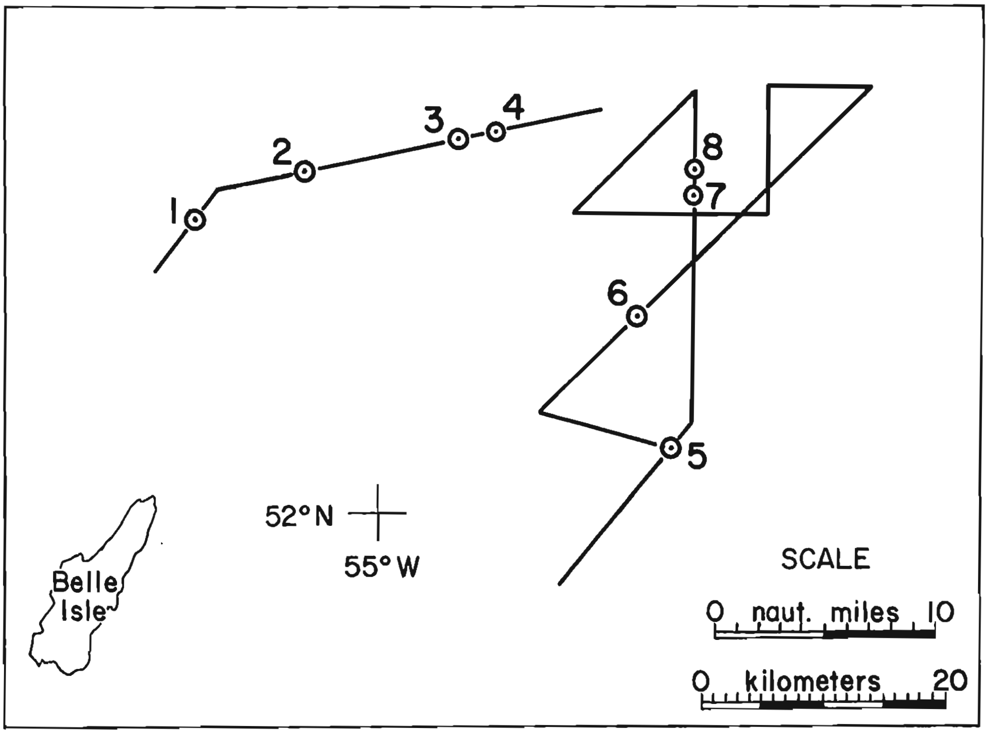


Figure 1. Survey area. Lines indicate seismic reflection and side-scan sonar tracks. Circled dots indicate drill sites.

for selecting drill sites. The side-scan sonar records revealed numerous linear features on the sea floor, commonly several miles in length and apparently caused by the grounding of icebergs.

The electric rock-core drill, designed and constructed by the Metrology Section of the Atlantic Oceanographic Laboratory, Bedford Institute, is a surface controlled bottom coring unit capable of taking 2.54 cm x 5.8 m cores. The unit is geared for drill-barrel penetration rates of either 15.25 cm/min. or 30.5 cm/min. The drill-barrel extraction rate is 3 m/min. and the drill-barrel rotation rate is 1,200 rpm. The unit has a dry weight of approximately 1,000 kg. The present electrical cable and load line allow operation in water to depths of 330 metres. During operation an instrument panel on board continuously records total drill barrel extension and rate of extension, tilt of drill frame, motor current, drill barrel rpm and flushing pressure.

A total of 25.4 m was drilled at eight drill sites, and a total 5.2 m of core was recovered. The core recovery is not representative of drill performance in bedrock, as much of the drilling was in unconsolidated overburden. The drill recovered probable bedrock at Drill Site 1 (44 cm of dark grey dolostone). Drill Site 2 (219 cm of quartzite) and Drill Site 4 (44 cm of quartzose sandstone). These rocks are similar to lower Paleozoic rocks on Belle Isle and nearby Newfoundland and Labrador [2]. The side-scan and seismic records indicate extensive subcrops of seismically "hard" rocks at these sites. At the remaining sites, the drill bottomed in boulder till and recovered mixed suites of plutonic rocks, quartzite, sandstone, chert and volcanic rocks representing the larger till fragments. Piston-core samples indicate that the till matrix consists of intermixed sand, silt and clay.

The seismic records indicate gently folded rocks with good seismic penetration beneath the till mantle in the vicinity of Drill Sites 5, 6, 7 and 8. Previous seismic records [1] indicate that rocks of this general type underlie an area of roughly 370 square miles and pass beneath relatively undeformed Mesozoic and Cenozoic rocks to the northeast.

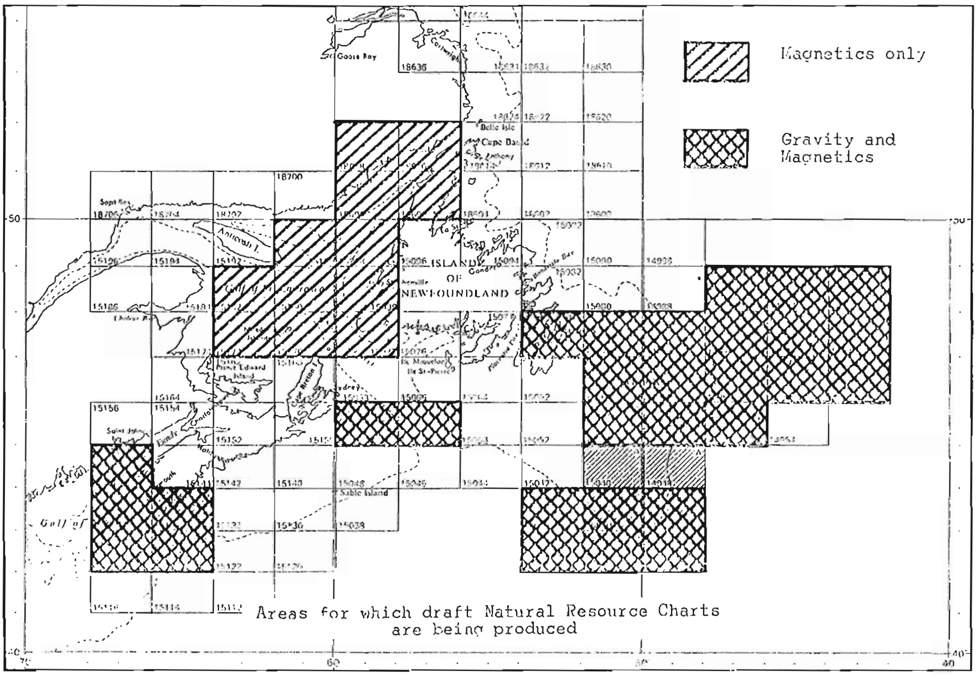
[1] Grant, A.C.: The continental margin off Labrador and eastern Newfoundland - morphology and geology, Can. J. Earth Sci. (in press).

[2] Williams, Harold and Stevens, R.K.: Geology of Belle Isle - northern extremity of the deformed Appalachian miogeosynclinal belt, Can. J. Earth Sci., v. 6, p. 1145-57.(1969).

49. NATURAL RESOURCE CHARTS

R.T. Haworth
Atlantic Geoscience Centre, Dartmouth

The data collected on all Bedford Institute cruises prior to 1972 in which there has been geophysical participation have been reduced and digital magnetic tapes containing the data in a standard format have been produced. To allow for the expeditious release of this data an industrial contract has been issued to produce draft Natural Resource Charts at a scale of 1:250,000 in the areas shown in Figure 1 from the 128000 gravity and 181000 magnetic



field data points available. Since such a contract is unique both with this type of data and to operations of the Atlantic Geoscience Centre, considerable effort was expended in identifying the criteria necessary to define the contractual requirements. All companies considered competent to bid were invited to a bidders conference at which time the tender specifications were discussed. All bidders were required to furnish proof of their competence by completing two trial charts. On the basis of the quality of these and the tender price, a contract has been issued to Computer Data Processors of Calgary as a result of which 72 draft Natural Resource Charts will be completed by January 1973. It is anticipated that these charts will be published by the Canadian Hydrographic Service within a further six months. By the end of September 1972, 26 charts had been submitted to AGC for consideration as final products, and an additional 30 charts had been produced in some preliminary form.

Note: The gravity editions of the area indicating "Magnetics only" in the Gulf of St. Lawrence have already been prepared at AGC and are either published or in press.

50. GEOPHYSICAL INVESTIGATION OF THE LAURENTIAN CHANNEL AND SOUTHERN GRAND BANKS OF NEWFOUNDLAND

R. T. Haworth
Atlantic Geoscience Centre, Dartmouth

During cruise BI 72-009 DAWSON, 8141 km of gravity and magnetic field data were collected (in addition to the shallow seismic reflection data collected by Dr. L.H. King and associates) on a series of lines extending from the western edge of the Laurentian Channel to the Avalon Peninsula between the Newfoundland coast and the continental slope. A track chart may be found in King's submission to this publication. The data have been published as a data report containing data listings and anomaly profiles [1].

The most prominent feature of the entire survey was a 1500γ positive magnetic anomaly coincident with a 70 mgal positive free air gravity anomaly in the centre of Whale Bank. There is an indication that the anomaly is elongated in a west-northwest to east-southeast direction, although if this is the case, there is a very abrupt termination in the vicinity of Whale Deep to the east. All lines to the east of this termination showed little magnetic activity although gravity anomalies remained conspicuous.

At the western edge of the survey area, the tracks were planned to trace the eastern extension of the Orpheus gravity anomaly. It appears that the two "claw"-like limbs of the anomaly in the Laurentian Channel extend over to St. Pierre Bank where the "claws" clasp each other and the anomaly reduces in magnitude. The anomaly does not seem to die out as it reaches the eastern wall of the Laurentian Channel as was earlier thought. Coincident with the northern limb of the gravity anomaly in the Channel is a positive magnetic anomaly whose high frequency characteristics die out while crossing the Channel, and whose extension across the Channel is less pronounced.

The 1972 data have been compiled with all other data previously collected in this region preparatory to detailed model studies to be carried out in 1973. In trial runs with the gravity modelling program it is clear that very low density rocks at shallow depth are responsible for the isolated gravity lows which fall within the eastern portion of the Orpheus anomaly.

[1] Haworth, R. T., L. F. Barrett and J. B. MacIntyre: Bathymetry, gravity and magnetic data. Crusie BI 72-009 DAWSON. Data Series BI-D-72-14, September 1972.

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51. CONTINENTAL MARGIN OF EASTERN CANADA

C. E. Keen
Atlantic Geoscience Centre, Dartmouth

Several experiments were carried out from CSS HUDSON during a four-week cruise in July 1972 to the continental slope and rise areas of the Scotian Margin and the southern margin of the Grand Banks. The data collected includes seismic reflection, seismic refraction, gravity, magnetic and bathymetry measurements. Five successful coring stations were also completed.

The first experiment was designed to survey an area within the quiet magnetic zone of dimensions 70 km by 150 km. A Loran-C navigation system was used to obtain precise positioning to within 200 m. The track spacing was 7 km. A buoy magnetometer was moored in the survey area to enable corrections to be made for temporal variations of the magnetic field. Preliminary results show that the topography of layer 2, over which lies about 3 km of sediment is lineated in the direction of the Quiet Magnetic Zone boundary. Also the magnetic anomaly field is lineated in the same direction. A more detailed analysis is now in progress.

Several lines of a reconnaissance nature were completed over the Scotian slope and rise and the southern margin of the Grand Banks. The seismic reflection results suggest that the Scotian margin and the Grand Banks margin exhibit different characteristics. The Scotian margin is marked by a prominent reef complex on the continental slope. Farther seaward, the oceanic basement exhibits topographic relief sometimes exceeding 1 km. This basement is overlain by about 3 km of sediment. The southern Grand Banks margin, near the tail of the Banks is characterized by significantly less sediment than the former area and the oceanic basement is flat except for numerous buried seamounts. No obvious magnetic slope anomaly is associated with this margin. The latter is a prominent feature of the Scotian margin.

Four crustal seismic refraction lines were completed on the slope and rise off the Scotian shelf. A complete interpretation of these is not available. However, preliminary results suggest that the oceanic crustal layers exhibit anomalously high velocities of about 7.3 km/sec.

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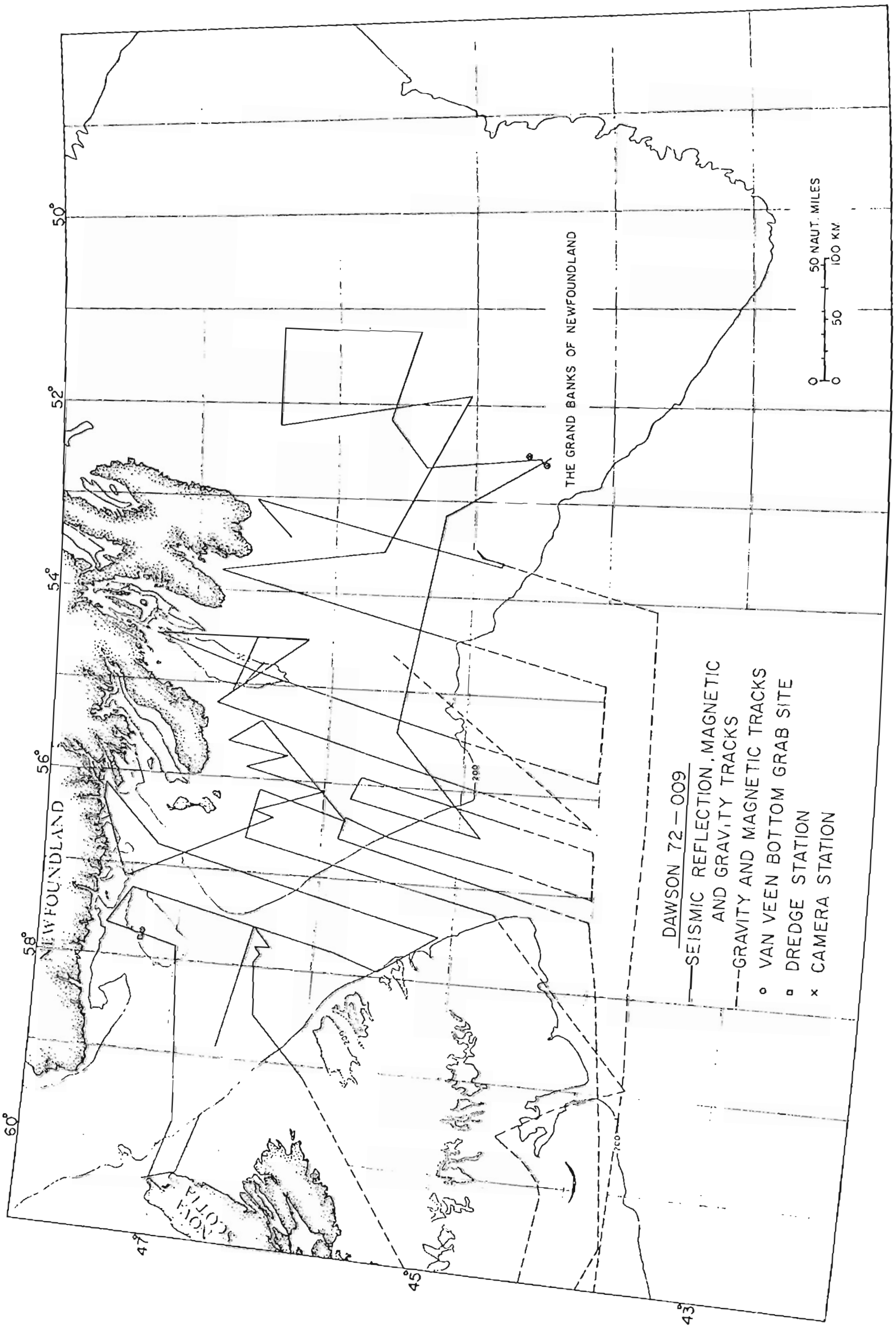
52. MARINE ACTIVITIES ON THE GRAND BANKS

Lewis H. King, Brian MacLean and Gordon B. Fader
Atlantic Geoscience Centre, Dartmouth

Atlantic Geoscience Centre investigations on the Grand Banks during the 1972 field season consisted of one 5-week cruise on the CSS DAWSON. Attention mainly was directed to the western part of the Grand Banks across the Laurentian Channel, St. Pierre, Green and Whale Banks (Fig. 1). The cruise primarily was designed to obtain seismic, gravity, and magnetic coverage of the area and will be followed in 1973 by a bedrock and bottom sampling cruise. The following was completed: 1,150 miles of seismic reflection profiling, 3,300 miles of gravity and magnetic profiling, 1 dredge haul, 3 grab sample stations, and 3 camera stations.

The main scientific objectives of the Grand Banks program are: (1) to obtain a better understanding of Appalachian geology between Nova Scotia and Newfoundland, (2) to extend our knowledge of Appalachian geology seaward beneath the submerged Atlantic Coastal Plain Province in the Grand Banks area, (3) to obtain information on the broad structural framework of the area, (4) to map the surficial geology of the area, and (5) to map the sub-Pleistocene bedrock geology of the area.

Preliminary results suggest that Carboniferous strata is continuous from Cape Breton to within a few miles of the south coast of Newfoundland. The Mesozoic and Cenozoic coastal plain units onlap the Carboniferous and older basement rocks flanking the Avalon and Burin Peninsulas.


NEWFOUNDLAND
NOVA SCOTIA
THE GRAND BANKS OF NEWFOUNDLAND
50°
52°
54°
56°
58°
60°
47°
45°
43°
200
0 50 100 KM
50 NAUT. MILES
DAWSON 72–009
—SEISMIC REFLECTION, MAGNETIC AND GRAVITY TRACKS
---GRAVITY AND MAGNETIC TRACKS
o VAN VEEN BOTTOM GRAB SITE
▫ DREDGE STATION
× CAMERA STATION

53. BOTTOM STUDIES OF THE BEAUFORT SEA

B.R. Pelletier
Atlantic Geoscience Centre, Dartmouth

Sediment sampling of the continental shelf underlying the Beaufort Sea (Fig. 1) continued in two phases during the field season of 1972. In the first phase, a helicopter was required for the operations over the ice and this was supported by the Polar Continental Shelf Project during the months of April and May. The western portion of the area was completed on a 5-km sampling grid. In the second phase, sampling was undertaken from the CSS PARIZEAU with the support of the Canadian Hydrographic Service, Marine Sciences Directorate, Victoria, British Columbia. This work was carried out in the eastern portion of the Beaufort Sea, and brought to completion approximately 85 per cent of the contemplated sampling program for the area. Only the northeastern portion remains and this is expected to be completed during the spring of 1973 with the use of a helicopter.

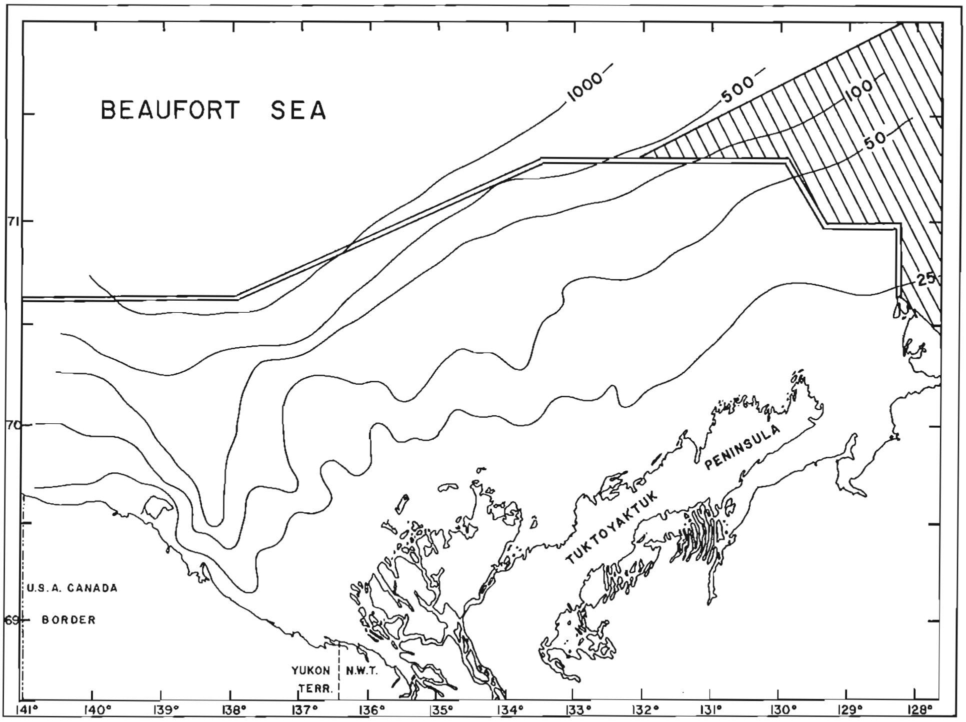


Figure 1. Bottom sampling area in Beaufort Sea. Sampling completed on 5-km grid in area south of double line. Diagonally ruled area in northeastern portion to be completed in 1973.

Side-scan sonar records of the sea floor were further studied and a compilation is being made of the ice-scour features shown on the records. The general east-southeast trend of the scours persists throughout the area, as already reported [1]. Echo-sounding records obtained by the Canadian

Hydrographic Service are also being examined in order to determine the depth and frequency of scouring, and to examine the frequency of ancient scours some of which are partially or completely infilled by subsequent sedimentation.

[1] Pelletier, B.R. and Shearer, J.M.: Sea bottom scouring in the Beaufort Sea of the Arctic Ocean; 24th Internat. Geol. Cong., Sec. 8, Marine Geology and Geophysics, p. 251-261, 1972.

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54. GEOPHYSICAL STUDIES OF BAFFIN BAY AND ADJACENT CONTINENTAL MARGINS

D.I. Ross
Atlantic Geoscience Centre, Dartmouth

Analysis of geophysical data obtained from CSS HUDSON in the Baffin Bay area in 1971 [1] has continued. No additional field work was carried out during the 1972 field season.

Analysis of the seismic refraction data[2] has provided good crustal structural control across the Bay from Baffin Island to Greenland. The central oceanic basin consists of 4 km of sediment with seismic velocities varying from 2.1 km/s to 4.2 km/s underlain by 4 km of oceanic basement giving a total depth of 10 km to the Mohorovicic discontinuity. Mantle velocities of 7.7 to 8.5 km/s were observed. The sediment thickness across the basin is suprisingly uniform although it increases to 6 km towards the northern continental margin. It is presumed that both layer 2 and layer 3 exist within the oceanic basement although two distinct velocities were not observed on all oceanic lines. The thickness of these layers increases somewhat towards Greenland. This is consistent with the interpretation of gravity data obtained. Bouguer and free air gravity maps of the area have been prepared which enable the continental-oceanic boundary to be mapped with considerable precision over the majority of the area.

Seismic reflection and refraction data have provided information on a number of basinal features on the adjacent continental shelves. The largest of these are the Melville Bay graben off northwest Greenland and the Lancaster Sound graben between Baffin and Devon Islands. Other troughs of significance have been delineated trending northwest to southeast in southern Nares Strait region. The extent of these have not yet been accurately defined but it seems likely they are tensional features developed as Greenland and Arctic Canada separated during the formation of the oceanic basin.

Co-operative work with the Greenland Geological Survey [3] has enabled the known onshore geology of central West Greenland to be extended offshore in an attempt to explain the major features of the central and northern West Greenland shelf. In particular the Melville Bay graben appears to be a true marginal graben developed during the initial rifting of Canada and Greenland and therefore predates the period of active sea floor spreading in the Bay. Gravity data indicates that the maximum thickness of sediment (10 km) occurs at the southern end of the graben. A maximum sedimentary velocity of 4.6 km/s was observed in the central region of the graben. Although the tertiary basalt province of Disko Island-Nugssuaq Peninsula has been extended out into the offshore region it is still not clear how it is connected with the basalt province of Cape Dyer and the thick pile of oceanic basalt forming the Davis Strait sill.

Additional seismic data in the southern Bay-Davis Strait area is required before the significance of the occurrence of tertiary basalts can be related to the history of the formation of the Bay.

[1] Ross, D. I.: A. O. L. Cruise Report No. 71-032 CSS HUDSON (19 August - 22 October 1971).

[2] Keen, C. E. and D. L. Barrett: Seismic Refraction Studies in Baffin Bay: An example of a developing ocean basin; Geophys. J. Roy. astr. Soc. (in press) (1972).

[3] Ross, D. I. and G. Henderson: New geophysical data on the continental shelf of central and northern West Greenland; Submitted to Can. J. Earth Sci. (1972).

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55. STUDIES OF BENTHONIC FORAMINIFERA IN THE RESTIGOUCHE ESTUARY, QUEBEC

C. T. Schafer
Atlantic Geoscience Centre, Dartmouth

The aim of this study is to describe the nature of the sublittoral environment and the Holocene history of typical coastal areas by surveying the temporal and geographic distribution of living and fossil foraminifera in several representative bays and estuaries in the Atlantic Provinces. Two important applications of this study include: (1) the establishment of standard (or baseline) geographical zonations for dominant species inhabiting coastal estuarine environments and (2) the identification of possible indicator species that can be used to define and (or) map the geographic extent of polluted coastal environments.

During August and September of 1972 foraminifera were collected in grab samples at 72 stations in central Chaleur Bay between Black Cape and Paspebiac, Quebec (Fig. 1). This area has yielded the most interesting foraminiferal distributions to date because the boundary between the typical Chaleur Bay fauna and the more marine Gulf of St. Lawrence fauna is located in this area.

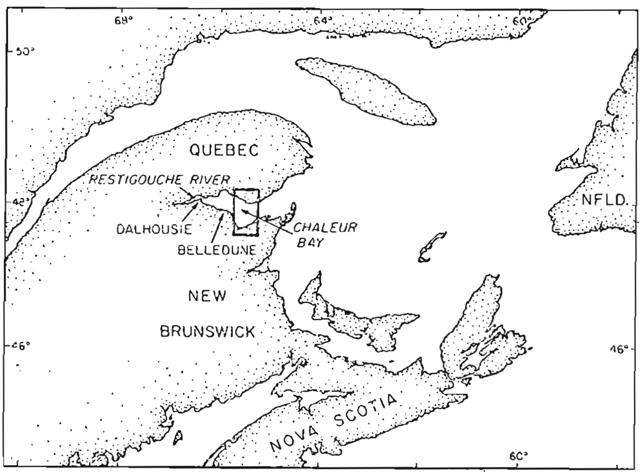

Figure 1. Location of study area.

In the latter part of September a gravity coring program was initiated in the western part of Chaleur Bay using CSS DAWSON. Ten cores ranging up to two metres in length were collected. Pronounced shell and wood chip horizons, indicative of past environmental variations, were observed in several of the core samples.

A recently developed instrument designed to measure minute differences in turbidity (nephelometer) in nearshore waters was tested in Chaleur Bay during the CSS DAWSON cruise. Initial observations indicate marked differences in turbidity between the eastern and western portions of the Bay. These differences reflect generally high and homogeneous turbidity in areas near Dalhousie, New Brunswick. Areas east of Heron Island have less turbid water in the upper 20 metres, but a pronounced "nepheloid" layer of varying thickness over the sediment-water interface. The effect of these layers on the distribution of species is not clear at this time.

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56. MAGNETIC VARIATIONS

S. P. Srivastava
Atlantic Geoscience Centre, Dartmouth

An assessment of the methods used in applying diurnal correction to marine magnetic data.

Magnetic data from simultaneous recordings at several places along the Gulf of St. Lawrence[1] were used in estimating the errors involved when using magnetic variation data from the Institute to apply diurnal correction to the Gulf of St. Lawrence data. The errors were not found to be significant. Thus a system was set up to apply diurnal correction to the Gulf of St. Lawrence data. The system has been used on a routine basis to apply diurnal correction to the marine magnetic data using the recordings from a nearby shore based station. The development of such a system has resulted in more reliable magnetic Natural Resource Charts of the Gulf of St. Lawrence.

Field trial of the equipment to monitor the magnetic variations at sea was carried out during a cruise of the continental margin off Nova Scotia. A magnetometer housed in a surface buoy was moored in 4,000 metres depth of water at about 41.5° and 60° W. Due to malfunctioning of the magnetometer only one and a half days long recording was obtained. The recording is being used in estimating the error involved when using the recording from the Institute to apply diurnal correction to the magnetic data collected beyond the Nova Scotia shelf.

[1] Srivastava, S.P.: Diurnal variation of the total magnetic field along the east coast of Canada; Earth Planet. Sci. Letters, v. 10, no. 4, p. 423-429 (1971).

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57. GEOPHYSICAL STUDIES OF THE CONTINENTAL MARGIN AND OF THE DEEP SEA OFF THE WEST COAST OF CANADA

S.P. Srivastava
Atlantic Geoscience Centre, Dartmouth

Detailed interpretation of the data collected off the west coast of Canada during HUDSON-70 expedition[1] show that the continental margin off Vancouver Island is severely faulted. Compilation and interpretation of gravity data across the margin show that the area west of the margin is in isostatic equilibrium. The thickness of the sediments lying at the foot of the slope off Vancouver Island decreases to the north as obtained from Bouguer gravity anomaly map of the region. This variation in the thickness of the sediment at the base of the slope has resulted from a change in the direction of motion of various plates in this region as revealed by the change in the tectonic pattern[2,3] along the margin from south to north and by the characteristics of the magnetic anomalies across the margin.

The magnetic data collected by the National Ocean Survey group of National Oceanic and Atmospheric Administration, Department of Commerce, Rockville, Maryland, U.S.A., in the northeast Pacific has been interpreted jointly[4]. The compilation of magnetic data in the form of profiles show that a high order of correlation exists among the magnetic anomalies in the northeast Pacific. The decrease in the offset of the anomalies to the east along Surveyor fracture zone and the presence of undisturbed north-south lineations east of it show strong evidence of differential sea floor spreading in this region. The survey has delineated the extension of the Blanco fracture zone northwestward to about 133° W. It is suggested that Blanco fracture zone began about 15 million years before present. The undisturbed north-south trend of the magnetic anomalies between latitudes 42° N and 48° N and longitudes 133° W and 136° W is interpreted as the interval (22 to 15 my) during which Juan de Fuca and Gorda rises were one continuous structure. West of 137° the Surveyor, Sedna and three minor fracture zones are mapped.

[1]Srivastava, S.P., Barrett, D.L., Keen, C.E., Manchester, K.S., Shih, K.G., Tiffin, D.L., Chase, R.L., Thomlinson, A.G., Davis, E.E., and Lister, C.R.B.: Preliminary analysis of geophysical measurements north of Juan de Fuca Ridge; Can. J. Earth Sci., v. 8, p. 1265-1281, (1971).

[2]Tiffin, D.L., Cameron, B.E.B., and Murray, J.W.: Tectonics and depositional history of the continental margin off Vancouver Island, British Columbia; Can. J. Earth Sci., v. 9, p. 280-296 (1972).

[3]Chase, R.L. and Tiffin, D.L.: The Queen Charlotte Fault Zone, British Columbia; 24th Internatl. Geol. Cong. Sect. 8, Marine Geology and Geophysics, p. 17-27 (1972).

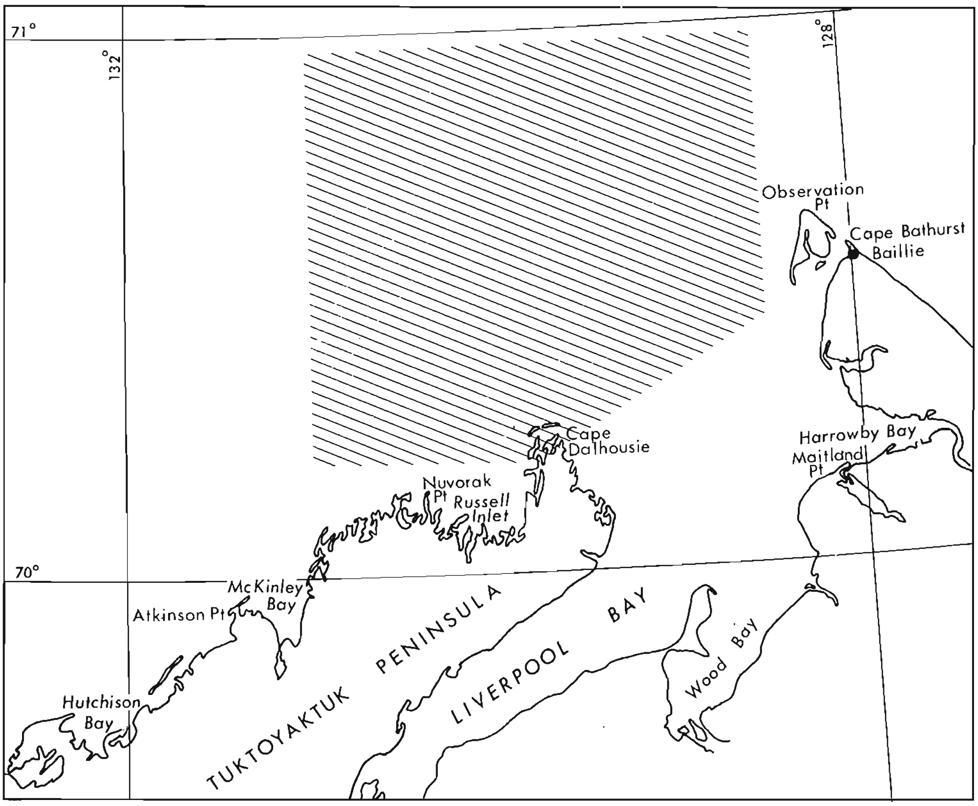
[4]Potter, K., Elvers, D., Srivastava, S.P., Morley, J. and Seidal, D.: Differential spreading of the Juan de Fuca and Gorda Rises as obtained from a detailed magnetic survey; Earth and Planet. Sci. Letters (in press).

58. MAGNETOMETER SURVEY WEST OF BAILLIE ISLANDS

Project 710049

D.L. Tiffin
Regional and Economic Geology Division, Vancouver

A shipborne magnetometer survey was conducted from CHS "Parizeau" during August, 1972, in conjunction with a hydrographic survey of the area west of Cape Bathurst (see Fig. 1). Sea ice prevented towing the sensor initially, and one severe magnetic storm also disrupted readings, but approximately 2,700 nautical miles of data were collected over the area. A station magnetometer located on Baillie Islands near the survey area was operated for the month of August.



59. MARINE GEOPHYSICAL ACTIVITIES ON THE PACIFIC MARGIN

D. L. Tiffin
Regional and Economic Geology Division, Vancouver

A two week co-operative geophysical program in the Strait of Juan de Fuca was completed with U.S. Geological Survey and Geological Survey of Canada personnel in which 1,200 nautical miles of gravity, magnetics and bathymetry records, 960 nautical miles of high resolution sub-bottom profiles and 1,070 nautical miles of reflection sparker profiles were obtained. A Minifix radio location system provided good control over most of the area. Preliminary results of magnetic mapping indicate that major trends in the magnetic field in the Eastern Strait may reflect the extension of the Leech River fault from Esquimalt toward Puget Sound.

A magnetic and reflection profiling survey of the southern part of the Queen Charlotte fault showed oceanic seismic basement (volcanics) rising toward the base of the continental slope and possibly outcropping on a ridge at the base of the slope about 60 kilometres south of the Queen Charlotte Islands. This unusual occurrence can be explained if the area is part of a centre of sea floor spreading activity. The continental margin may be analogous to the Gulf of California where many small spreading segments are connected by short transform faults with the exception that off British Columbia there is no equivalent of Baja California landmass on the western side. A magnetic high over the outcrop area, and seismic activity grouped around it [1] support this interpretation.

[1] Tobin, D. G. and Sykes, L. R.: Seismicity and tectonics of the northeast Pacific Ocean; J. Geophys. Res., v. 73 (1968).

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60. THE LABRADOR SHELF

W. J. van der Linden
Atlantic Geoscience Centre, Dartmouth

At the time of reporting CSS HUDSON is surveying in a systematic way the continental shelf, slope and rise between 54° N and 56° N in the Labrador Sea. The cruise is a joint venture of the Atlantic Geoscience Centre and the Canadian Hydrographic Service. With a trackline spacing of 10 miles the depth to the bottom and the earth's gravity and magnetic fields are measured continuously. At 20-mile intervals a deep seismic reflection system is used to define structural information and the thickness of sedimentary sequences for the top 2-3 kilometres of the earth's crust. Seismic velocity control is obtained from the interpretation of wide angle reflections and refractions by using expendable sonobuoys.

A start was made with the collation, interpolation and evaluation of geophysical information collected in previous years by the Bedford Institute of Oceanography [1], data purchased from geophysical prospecting companies and information supplied by other, both Canadian and foreign research institutions. The Labrador Sea outer shelf and slope are underlain by Mesozoic-Cenozoic and possibly Paleozoic deposits several 1,000 metres thick. These deposits are separated effectively from Precambrian rocks on the inner shelf by an ice-cut marginal channel.

Both the 1972 HUDSON operations and the data compilation are the beginning of an extensive program planned for the next few years which will provide a detailed description and interpretation of the geology and geophysics of the Labrador Sea. Fundamental questions to be answered by the project in totality relate to the age of the Labrador Sea basin and consequently to the formation and build up of the East Canadian continental margin. The apparent difference between the shelf south and north of the projected eastward extension of the Grenville Front poses questions on Canadian Precambrian geological evolution. Attacking those problems, because of its glacial drift cover, its effective separation from Labrador land geology, its geographic setting and climatic conditions may necessitate unorthodox marine surveying techniques for the Labrador Shelf, perhaps requiring emphasis on diamond-drilling operations in the near future.

[1] Grant, A. C.: The continental margin off Labrador and eastern Newfoundland-Morphology and Geology; unpubl. Thesis, Dalhousie University, Halifax, N.S., 1971.

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61. ECOLOGY OF RECENT PLANKTONIC FORAMINIFERA IN THE SURFACE WATERS OF THE BEAUFORT SEA

G. Vilks
Atlantic Geoscience Centre, Dartmouth

During March and April of 1972 a study of the water column and sediments was carried out along the continental slope of the Beaufort Sea between 69° 30'N and 71° 31'N and 130° 00'W and 140° 30'W. Logistics and field facilities were provided by the Polar Continental Shelf Project based at Tuktoyaktuk, N.W.T.

The purpose of this field project was to augment summer field work carried out from CSS HUDSON during 1970 and to provide information on the winter distribution of living planktonic foraminifera in the water column. Thirty-six stations were occupied and at each station plankton was collected from the water of the upper 200 metres, sediments were taken at localities not deeper than 400 metres and standard oceanographic bottle casts were carried out within the upper 300 metres.

The study indicates that under winter conditions the population of planktonic foraminifera in the water column is much reduced. In comparsion to the summer standing crop of 1970, only 0.45 per cent was present in the water column during the winter. Oceanographic conditions were seasonally modified within the upper 10-25 metres, with more saline and cooler surface water during the winter. Below the seasonal layer oceanographic conditions were reasonably similar, where the heavier subsurface water was rising along the continental slope during both seasons.

The field evidence indicates that in the Arctic Ocean planktonic foraminifera are closely dependent on the extent at which the euphotic zone is being illuminated. During the dark season and under a continuous cover of ice and snow, there is a small dormant population of planktonic foraminifera. In the Beaufort Sea the water column is re-occupied very rapidly during the summer when the area is free of ice and the daily insolation is comparable to the tropics.

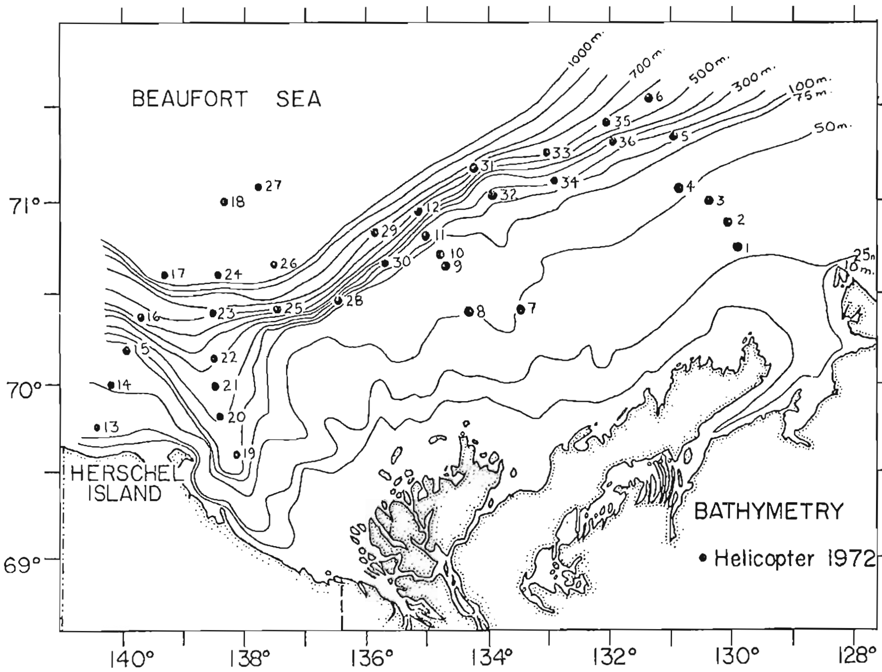

Figure 1. 1972 winter survey station locations.

62. TEST SURFACE ULTRASTRUCTURE OF BENTHONIC FORAMINIFERA AND APPLICATIONS OF SCANNING ELECTRON MICROSCOPY

D. A. Walker
Atlantic Geoscience Centre, Dartmouth

The purposes for conducting this project are:

1. To relate specific ultrastructural features to natural changes in test morphology during ontogeny and to requirements for adaptation to specific habitats and environmental conditions.

2. To relate this information to geological and micropaleontologic interpretations of paleoenvironments and paleoecology of foraminifera.

3. To develop specialized sample preparation techniques in order to improve the quality of the scanning electron microscope image.

4. To develop and improve methods of interpretation of images obtained in scanning electron microscopy.

Specimens of living foraminifera were collected from tide pools for subsequent examination by scanning electron microscopy. Specimens were also collected during a cruise on CSS DAWSON to Chaleur Bay, Strait of Belle Isle and west coast of Newfoundland. Comparative morphology between tide pool and nearshore benthonic foraminifera will ultimately be conducted by scanning electron microscopy.

63. FIELD AND LABORATORY INVESTIGATIONS OF THE LIFE CYCLES, MICROECOLOGY AND SPECIES SUCCESSION OF TIDE POOL FORAMINIFERA OF NOVA SCOTIA

D.A. Walker
Atlantic Geoscience Centre, Dartmouth

The purpose for conducting this project is to supply basic scientific information on the biology of foraminifera, which the micropaleontologist can apply to investigations of recent populations, paleoecology, and paleoenvironments.

Field collections were continued biweekly from tide pools in the Pennant Point area, near Sambro, Nova Scotia. These samples are being processed and analyzed in the laboratory in an effort to describe foraminiferal life cycles in these communities.

Participation in a 10-day cruise on CSS DAWSON involved collection of living benthonic foraminifera from Chaleur Bay, Strait of Belle Isle and west coast of Newfoundland; living planktonic foraminifera were collected from the west coast of Newfoundland and off the continental shelf in the vicinity of Sable Island. A total of approximately 400 living specimens were retrieved and returned to the laboratory for clonal culturing and subsequent investigation of life cycles.

64. MINERAL DEPOSITS

A STUDY OF SULPHIDE AND SPINIFEX DISTRIBUTION OF THE TEXMONT NICKEL DEPOSIT

Project 630037

O.R. Eckstrand and A.R. Miller
Regional and Economic Geology Division, Ottawa

In an earlier report[1], the serpentinized ultramafic mass which contains the Texmont nickel sulphide deposit in the Timmins area of northern Ontario was interpreted as a sequence of superposed ultramafic flows. The basis for this interpretation was the presence of numerous spinifex-textured zones, and their apparent similarity to spinifex-bearing ultramafic flows subsequently documented[2] in Munro Township some 50 miles to the northwest. The reader is referred to the earlier report[1] for relevant descriptions. The most interesting problem raised by these observations was the nature of the relationship between nickel sulphides and spinifex-textured ultramafic flows.

In an attempt to shed some light on this relationship, the Texmont deposit was revisited, 14,000 feet of diamond drill core was relogged, and outcrops in the belt of ultramafic rocks were examined. Recognition of texture and lithology was hampered by intense alteration in much of the rock. A further frustration was caused by partial collapse of the core boxes and consequent loss of drill core during the relogging. However, it quickly became evident that the spinifex zones are not of the Munro Township type, both the crystal habit and the grain size gradation being different. The spinifex zones appear to be conformable with the strike of the ultramafic masses, but continuity of the zones is poor. Some polygonally fractured zones may represent chilled flow tops, but they are not closely underlain by spinifex zones as they are in the Munro Township occurrences. Individual emplacement units could not be distinguished with confidence.

All that may be said of the sulphide-bearing zones is that the sulphides are disseminated, and display intercumulus "bleb" textures where little modified by subsequent shearing and recrystallization. As noted above[1], the sulphide zones are parallel to strike of enclosing rocks. However, no significant sulphide zone was observed in close proximity to spinifex zones, or to polygonally fractured zones.

Intervals of siliceous volcanic and sedimentary rocks that occur within the ultramafic mass appear to represent stratigraphic intercalations rather than xenoliths or dykes.

Tentative conclusions from this investigation are as follows:

1. The ultramafic mass that encloses the Texmont deposit is probably composed of a sequence of flows or shallow intrusions; the upper part of the sequence contains numerous zones of spinifex (see Fig. 3, Ref. 1).

2. These spinifex-textured rocks do not belong to the Munro Township type of ultramafic flows.

3. The nickel sulphides occur in conformable zones of weakly reworked magmatic disseminations, but the magmatic factors that control the distribution of these zones is not yet clear.

[1] Eckstrand, O. R.: Ultramafic flows and nickel sulphide deposits in the Abitibi orogenic belt, Report of Activities, Part A, April to October 1971; Geol. Surv. Can., Paper 72-1, pt. A, p. 75-81.

[2] Pyke, D. R., Naldrett, A. J., and Eckstrand, O. R.: Archean ultramafic flows in Munro Township, Ontario; Geol. Soc. Amer. Bull. (in press).

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65. GEOLOGY OF COPPER AND MOLYBDENUM DEPOSITS IN CANADA

Project 700059

R. V. Kirkham
Regional and Economic Geology Division, Ottawa

Work continued on the general study of copper and molybdenum deposits in Canada and brief visits were made to a variety of deposits in British Columbia and Ontario. Professor F. M. Vokes from the Geologisk Institutt in Trondheim, Norway has also joined the project for one year to update information on molybdenum deposits. He visited many important deposits in the Canadian Cordillera.

In British Columbia the visits by the writer included trips to Western Mines and Twin "J" properties on Vancouver Island, Britannia and Seneca properties near Vancouver, the Thunder and Kim claim groups near Quesnel, and Granduc and Anyox deposits in the Portland Canal area. All of these deposits occur in volcanic terranes and have features in common with volcanic exhalative[1] deposits that are so characteristic of the Canadian Shield and Appalachian regions. However, most of these deposits occur in areas that have undergone significant deformation and metamorphism and insufficient data are available to establish their volcanogenic origins. Nevertheless from comparison with deposits in other parts of Canada a volcanic origin seems probable, but the deformational and remobilization histories of these ores should be studied in order to understand fully the complexities of these deposits.

In the Canadian Shield visits were made to a number of properties that contain porphyry deposits or showings with affinities to porphyry deposits[2]. These include the McCombe property at Minnitaki Lake, the Bochawna Copper property at Lang Lake[3], the Hopkins property east of Lake Nipigon, deposits in the Timmins, Painkiller Lake and Matachewan areas, the Olier property west of Noranda and the Don Rouyn mine at Noranda. These deposits certainly have features in common with typical porphyry deposits in western Canada, but in most areas known mineralization is sparse or restricted in extent and deposits of major economic significance remain to be demonstrated.

In the Atikokan area the old Atikokan Iron, Archibald and Pattison Roberts properties were visited and in the Snakeweed Lake area the Rexdale deposit was visited. In both areas chalcopyrite occurs in close association with iron sulphides and magnetite but without important amounts of other base metals. There is a distinct possibility that these deposits represent syngenetic concentrations of metals that have been significantly recrystallized and rearranged by intense deformation and metamorphism. Layered magnetite and sulphides are common in the Rexdale deposit and occur locally on the

Pattison Roberts property, but in general in the Atikokan deposits the sulphides occur as interstitial blebs and wispy veinlets in magnetite and silicates or as separate massive pyrrhotite and pyrite lenses and pods. Even though the origins of these deposits are somewhat doubtful there is a definite possibility that they are distal products of volcanic exhalative activity[4] not unlike typical Archean iron-formation but containing important amounts of copper and, at Rexdale, silver. Although the combined iron and base and precious metal contents might be low, this type of deposit could be important because large tonnages may be involved, and, as in the case of the Rexdale deposit, there may also be local areas of higher concentrations of base and precious metals.

The Granduc deposit in British Columbia is somewhat similar to the Rexdale deposit in metal content, conformable layered nature and separation from any obvious felsic volcanic centre. It may also represent a distal rather than proximal product of volcanic exhalative activity.

[1] Kirkham, R.V.: Proposed classification of copper deposits; in Report of Activities, Part B: November 1971 to March 1972; Geol. Surv. Can., Paper 72-1, pt. B, p. 58-61 (1972).

[2] Kirkham, R.V.: Porphyry deposits in the Canadian Shield; in Report of Activities, Part A: April to October, 1971; Geol. Surv. Can., Paper 72-1, pt. A, p. 83-87 (1972).

[3] Riley, R.A., King, H.L., and Kustra, C.R.: Mineral exploration targets in northwestern Ontario; Ont. Dept. Mines Northern Affairs, Misc. Paper 47, p. 33-34 (1971).

[4] Ridler, R.H.: Analysis of Archean volcanic basins in the Canadian Shield using the exhalite concept (abstract); Can. Mining Met. Bull., v. 64, no. 714, p. 20 (1971).

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66. GEOLOGY OF LITHOPHILE ELEMENTS

Project 530014

R. Mulligan
Regional and Economic Geology Division, Ottawa

In Ontario, the Kidd Creek mine of Texas Gulf Sulphur near Timmins, the South Bay mine of Selco at Confederation Lake, and the Geco mine at Manitouwadge were visited and samples taken of ores and enclosing rocks. These large zinc-copper-lead-silver massive sulphide deposits contain significant amounts of tin. Proposed recovery of tin from the Texas Gulf deposit will make it the only important tin producer in North America. This and the South Bay deposit are subvolcanic types, associated with rhyolitic volcanic and probably hypabyssal intrusive rocks. The Manitouwadge deposits are in metasedimentary rocks intruded by granite and abundant pegmatite. Granite was sampled between Timmins and the Manitoba lowlands for trace lithophile element study.

Near the Yukon-District of Mackenzie border, the Cantung tungsten mine northeast of Watson Lake and the Amax tungsten deposit at McMillan Pass were studied. A new orebody is being evaluated by drilling at Cantung and intensive drilling is being carried out at the Amax deposit. The Black Diamond tungsten-tin deposit near Atlin, B.C. was examined and the nearby Ruby Creek molybdenum deposit of Adanac was sampled for information as to its tin and tungsten content. The wolframite-rich gold-placer deposit at Canadian Creek, Y.T. was examined and samples taken of the associated granitic rocks and the Nisling alaskite and related (?) volcanic rocks to the south.

The New Brunswick tin deposit at Mount Pleasant was visited and samples obtained of a granitoid intrusion intersected by deep drilling which also indicated new tin-bearing zones. A satellite stock northwest of St. Stephen, N.B., one of several in the belt through the Mount Pleasant deposit, was sampled for trace element content and age determination. Quartz-feldspar porphyries and ores were sampled at the Nigadoo, Keymet and Millstream deposits north of Bathurst, N.B., which contain tin, tungsten, and molybdenum minerals. Muscovite and other peculiar phases of the granite, and adjoining normal biotite granites north and west of New Ross, Nova Scotia were sampled for trace element studies.

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67. A NOTE ON RARE-EARTH OCCURRENCES IN EASTERN CANADA

Project 670028

E. R. Rose
Regional and Economic Geology Division, Ottawa

Numerous occurrences of rare-earth minerals have been reported in Ontario and Quebec, and from a few localities elsewhere in Canada, but marketable ores of rare-earths have not yet been found among them, with the exception of those of the Denison, Stanrock and Rio Algom brannerite-uraninite-monazite deposits in the Elliot Lake district of Ontario, from which rare-earth concentrates, high in yttrium group elements, have been recovered as a byproduct of uranium mining. Certain other occurrences, including those associated with pyrochlore-perovskite-apatite-britholite-magnetite-bearing alkaline intrusion-carbonatite complexes, also found mainly in Ontario and Quebec, may also become important exceptions and sources of rare-earths as byproducts of niobium (columbium) and apatite (phosphate) mining in future.

During the summer of 1972 the writer visited a number of rare-earth occurrences in southern Ontario and Quebec, and attempted to determine to what extent other rare-earth occurrences might be found there and also in the Maritime Provinces. A new method for detecting rare-earths, using Arsenazo III, was employed in the field. Numerous rock formations and mineral occurrences were sampled in order to check for rare-earth content, mainly with negative results, but the detection of faint traces of rare-earth elements in some of these samples suggests that some new types of occurrences may be present in eastern Canada. Some further work is required to check both the validity of the method and the nature of the occurrences before a more complete description of either may be given, and although it is unlikely that any occurrences of mineable grade were detected, the possibility of new types of occurrences seems to warrant further investigation.

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68. GEOLOGY OF CANADIAN LEAD AND ZINC DEPOSITS

Project 650056

D. F. Sangster
Regional and Economic Geology Division, Ottawa

Robb Lake, B.C.

The Robb Lake zinc deposit (see 123°43'W; 56°56'N; G.S.C. Map 1232A) is the first of its type (i.e. zinc-lead in carbonate rocks) found in the eastern Cordillera since the closure in 1957 of the Kicking Horse - Monarch mine near Field, B.C.

Host rock to the Robb Lake deposit appears to be predominantly the Stone Formation (Middle Devonian) consisting of medium- to thick-bedded dolostone with occasional layers of shaly dolostone. The Stone is overlain by about 100 feet of Dunedin Formation carbonates that are in turn succeeded by the Besa Formation (largely shale or shaly limestone).

The mineralized showings occur mainly on the west limb of a large south-plunging anticline. Approximately 12 mineralized outcrops have been found to date; most appear to occur in the Stone but at least one is thought to be in the overlying Dunedin Formation. Those that are found in the Stone occur mainly below a distinctive sandy, mudcracked and ripple-marked unit.

All significant mineralization found to date occurs in one or more zones of brecciated and dolomitized dolostone roughly concordant with bedding in the Stone Formation; in detail, however, the zones may be seen to definitely crosscut stratigraphy. Although various types of "primary" brecciation (i.e. intraformational breccia) can be recognized, zinc mineralization seems to be related only to "secondary" brecciation. Secondary brecciation also takes many forms, ranging from "crackle breccia" (i.e. minimum rotation of Stone dolostone fragments; interstices filled with white dolomite) through recognizable collapse breccia with moderate replacement by white dolomite, through to "pseudo-breccia" representing almost complete replacement of pre-existing dolostone by white secondary dolomite.

The white dolomite breccia zones are in places traversed by essentially vertical, north-south-striking fractures of little or no displacement; some of the better grade material appears to occur near these fractures where they intersect the breccia zones.

Mineralization consists mainly of sphalerite with only local concentrations of galena or pyrite. Everywhere, the sphalerite seems to be related to the white, secondary dolomite. The colour of the sphalerite ranges from honey yellow to black; most common is resinous reddish brown.

Seneca

The deposit (121°57'W; 49°16.5'N; see G.S.C. Paper 69-47) occurs in Middle Jurassic volcanic rocks of the Harrison Lake Formation. The Seneca occurrence is underlain by a felsic pyroclastic unit that occurs at the top of a thick rhyodacite (flows?). Immediate host rock to the deposit is a blanket-like layer of "ore zone fragmental" which lies on top of the felsic pyroclastic unit. The "ore zone fragmental" consists of felsic pyroclastic fragments, sulphide fragments, small veins, etc., and the more massive sulphide zone is found within this unit.

Mineralization consists of barite, pyrite, sphalerite, chalcopyrite, and minor galena occurring mainly as clastic fragments. Microscopic examination of a few polished sections shows that many sulphide fragments have a botryoidal texture and that the groundmass is largely sulphide "dust" so that the resulting rock is largely or entirely sulphide. Host rocks and ore zone dip gently to the east, in the direction of decreasing grain size of sulphide fragments, suggesting a possible source area to the west. Alteration in the ore zone footwall is enriched in pyrite and silica although company geologists have not recognized the typical "alteration pipe" of this type of volcanogenic deposit. Evidence to date suggests the main mineralized zone represents downhill movement of the original massive sulphide deposit shortly after deposition in a subaqueous, volcanic environment.

In announcing the working option on the property of Zenith Mining Corp. (Northern Miner, May 13, 1971), Cominco geologists compared the deposit with the Kuroko ores of Japan. After even a brief examination of the deposit, the writer would definitely agree with the comparison; furthermore, such deposits in Japan and elsewhere are known to occur in clusters and it is not unreasonable to expect that future deposits of this type will be found in the area.

MINERALOGY

69. MICA GROUP MINERALS AND RELATED SILICATES IN CANADIAN MINERAL DEPOSITS

Project 700067

J.Y.H. Rimsaite
Regional and Economic Geology Division, Ottawa

This is a report of progress in a continuing project in which fresh and altered silicate minerals in and associated with ore deposits are being studied in order to document the release of ions during alteration of these minerals[1].

During the summer of 1972, Pb-Zn mines were visited in the District of Mackenzie (Pine Point), Yukon Territory (Anvil) and British Columbia (Sullivan), and specimens containing micas and related minerals were collected for microscopic studies.

Rock specimens were also collected from the Renzy Lake nickel deposit for chemical, isotopic and mineralogical studies. This deposit contains several generations of associated feldspars, amphiboles and micas, including abundant bright green mica which may be indicative of Cu-Ni-Cr mineralization. Microscopic, X-ray diffraction, X-ray spectrographic and electron probe analyses revealed that the green mica rims and replaces phlogopite in and around the mineralized peridotite. The green mica has less potassium than the host phlogopite and alters to green chlorite. Chemical differences between the original phlogopite, bright green mica and chloritized mica are illustrated in Figure 1 and summarized in Tables 1 and 2.

TABLE 1

Electron probe analyses of primary and secondary minerals from the Renzy Lake Ni-deposit

(Analyst G.R. Lachance)

Specimen	SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	K_2O	Cr_2O_3
1. Olivine, Fo_{77}	41.	0.0	0.0	20.	0.2	38.	0.0	0.0	0.0
2. "s-4"*	42.	0.0	0.0	7.4	0.2	41.	0.1	0.0	0.0
3. "s-1"**	36.	0.0	0.1	11.7	0.0	39.	0.0	0.0	0.0
4. Pyroxene	55.	0.1	0.3	12.3	0.4	31.	0.3	1.0	0.0
5. Phlogopite in peridotite	39.	1.1	14.2	6.8	0.0	24.	0.0	9.0	0.1
6. Phlog. surround. peridotite	39.	1.1	13.4	6.7	0.1	26.1	0.0	9.3	0.1
7. Green mica	37.	0.7	13.2	7.5	0.0	25.2	0.0	6.2	0.0
8. Chlorite	45.	0.1	1.7	15.1	0.1	30.2	0.1	0.2	0.0
9. "s-1"**	48.	0.0	1.0	14.8	0.1	26.3	0.0	0.0	0.0
10. "s-2"**	47.	0.0	2.1	20.3	0.3	24.3	0.1	0.0	0.0
11. "s-9"**	50.	0.0	0.5	15.4	0.2	20.9	0.2	0.0	0.0

*pale green serpentine

**bright olive-yellow serpentine

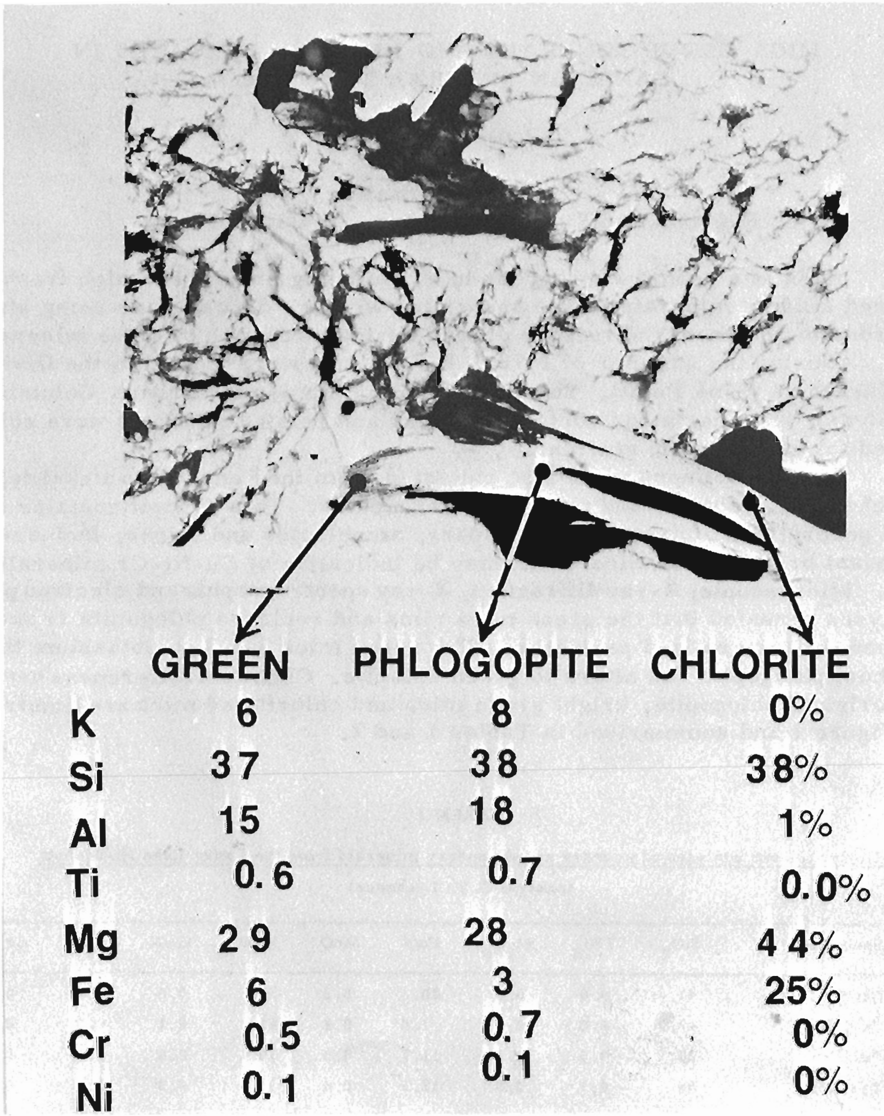

Figure 1. Electron probe analyses of fresh and altered portions of the phlogopite from peridotite, Thompson Nickel Belt, showing the chemical differences between the original phlogopite (centre), green mica (left edge) and chlorite (right). Silica remains relatively constant, K, Al_2O_3, TiO_2, Cr_2O_3, and Ni decrease whereas MgO and FeO increase. Similar trends were also found in specimens from the Renzy Lake deposit (Table 1). Analyst: G.R. Lachance.

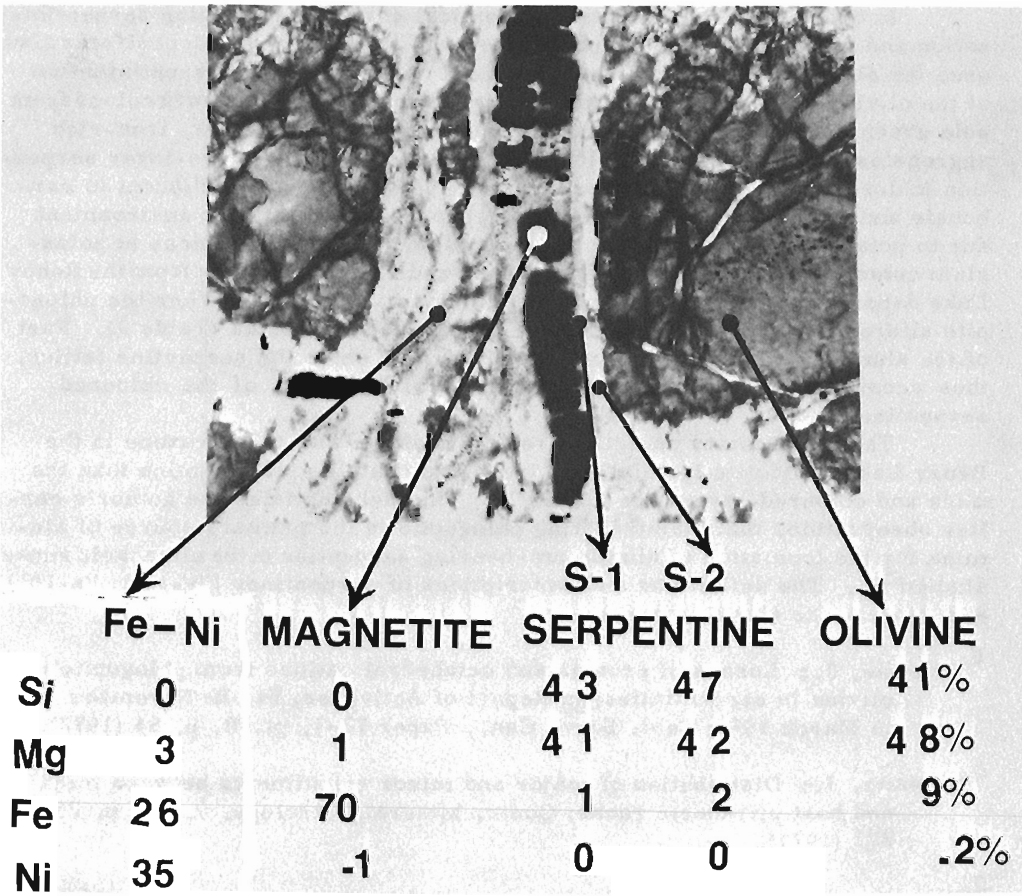

Figure 2. Electron probe analyses of fresh and serpentinized olivine showing chemical compositions of olivine, residual serpentines "s-1" and "s-2", secondary magnetite and Fe-Ni particles which crystalline from the ions released from the olivine lattice. Analyst: A.G. Plant.

TABLE 2

X-ray spectrographic analyses of selected mineral concentrates from Renzy Lake Ni-deposit*

(Analysts G.R. Lachance and J. Gravel)

	Rb, ppm	Sr, ppm	K_2O%	MnO%	ZnO%	TiO_2%	CaO%	BaO%	CuO%	Co, ppm	Ni%	FeO%
1. Pyroxene	<30	<30	<.2	.6	.05	<.1	.4	<.01	1.7	110	.5	20.
2. Phlogopite	345	<30	8.	<.1	.02	1.2	.3	.2	.08	<30	.1	9.
3. Green mica	100	<30	2.2	.3	.3	.5	3.9	.05	.19	<30	<.1	17.
4. Dark amphibole	<30	60	.4	.2	.00	.4	11.	.01	.08	170	<.1	12.
5. Pale amphibole	<30	45	.2	.4	.02	.3	12.	.00	.08	<30	<.1	22.
6. Pyrrhotite									.55	220	1.1	
7. Chalcopyrite									10.	250	0.2	

*The silicates contain minute opaque inclusions.

In order to determine the geochemical environment during serpentinization and mineralization, the peridotite from the Renzy Lake deposit was also used for electron probe studies of chemical changes during serpentinization of the olivine (Fig. 2). The serpentine replacing olivine varies in colour from pale green ("s-1" veinlets and "s-4" rims) to deep olive yellow, iron-rich aggregates. These brightly-coloured aggregates consist of two-layer serpentine (chlorite?), talc, and traces of mica. They crystallize adjacent to carbonate and the green, K-deficient mica, probably in an alkalic environment due to potassium released from the altered phlogopite (differences in potassium contents between the original, green and chloritized mica from the Renzy Lake deposit are given in Table 1, specimens 6, 7, and 8). When the phlogopite alters to green mica and chlorite, it also loses alumina (Table 2). Part of the alumina removed from the phlogopite may enter the serpentine lattice, thus accounting for the relatively high alumina content of the coloured serpentines.

The preliminary analytical results indicate that the pyroxene in the Renzy Lake peridotite is relatively fresh and contains less alumina than the mica and coloured serpentine (Table 1). This substantiates the author's earlier observations that disintegrating phlogopite is the primary source of alumina for the formation of aluminium-bearing serpentine in the ultrabasic rocks studied[2, 3]. The definitions and descriptions of serpentines ("s-1" to "s-10") are given in the above reference.

[1] Rimsaite, J.: Losses of protons and octahedral cations from phlogopite and olivine in serpentinites; in Report of Activities, Pt. B: November 1971 to March 1972; Geol. Surv. Can., Paper 72-1, pt. B, p. 54 (1972).

[2] Rimsaite, J.: Distribution of major and minor constituents between mica and host ultrabasic rocks; Contr. Mineral. Petrology, v. 33, p. 259-272 (1971).

[3] Rimsaite, J.: Genesis of chlorite, vermiculite, serpentine, talc, and secondary oxides in ultrabasic rocks; Discussion; 1972 International Clay Conference, Madrid (in press).

PALEOMAGNETISM

70. PALEOMAGNETISM OF THE HOPEDALE DIABASE DYKES

Project 720075

K.W. Christie
Regional and Economic Geology Division, Ottawa

Oriented cores for paleomagnetic studies were collected from three swarms of diabase dykes in the vicinity of Hopedale, Labrador. A total of 263 cores were collected from 44 sites within a range of 25 miles from Hopedale. These dykes cut Archean rocks and probably range in age from Early Aphebian to Helikian.

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71. PALEOMAGNETISM OF THE DYKES OF WEST GREENLAND

Project 720056

W.F. Fahrig
Regional and Economic Geology Division, Ottawa

The Greenland Geological Survey and Geological Survey of Canada have embarked on a joint program to use the paleomagnetism of basic dykes as a possible correlation parameter between rocks of northeastern Canada and those of West Greenland. As part of this program oriented cores were collected from two areas of West Greenland; namely the Fiskenaesset and Sondre Stromfjord areas. In the Fiskenaesset area, 350 cores were collected from 50 sites (4 swarms) in a zone from Ravns Storo north along the coast about 100 kilometres. The Sondre Stromfjord sampling consisted of 200 cores collected at 28 sites in a zone extending north about 100 kilometres from Kangamuit. The dykes in this zone extend across the Nagssugtoquidian Front and have petrologic peculiarities which make their paleomagnetic study of particular interest.

Eighty cores (10 sites) were also collected from the Amitsoq gneisses near Godhab. These gneisses have yielded the oldest Pb-Pb and Sr/Rb ages known from rocks anywhere in the world and it seemed of interest to determine whether they contain a stable remanent magnetization and if so, to at least determine its relationship to the youngest deformational events in this area.

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72. PALEOMAGNETISM OF THE LAC ST-JEAN ANORTHOSITE

Project 720055

W.F. Fahrig
Regional and Economic Geology Division, Ottawa

Oriented cores for paleomagnetic study were obtained from two areas of anorthosite and related rocks in the Grenville Province. During this program 350 cores were obtained from 48 sites on the Lac Saint-Jean anorthosite and related satellite bodies and 250 from 33 sites on the Sept Iles and Allard Lake anorthosites.

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73. PALEOMAGNETIC REVERSALS IN THE PALEOZOIC OF THE ST. LAWRENCE PLATFORM

Project 720046

J. Foster
Regional and Economic Geology Division, Ottawa

A unique drilling vehicle was outfitted and used for sampling. The drilling vehicle carries an aluminum bucket on the end of a twenty-five foot, hydraulically positioned, wooden ladder. A geologist, standing in the bucket, is able to drill oriented samples from the face of quarry walls which are too dangerous to climb. The bucket and ladder are mounted on an econoline van. This van was outfitted with shelves for the storage and transportation of field equipment for a two-man sampling party.

A drilling technique for recovering oriented cores from unexposed sections below an outcrop was developed. For this, a winkie drill was used to drill long inclined holes through flat-lying sediments. The longest oriented drill core collected this field season was 120 feet in the Ottawa Limestone. This limit was dictated by the amount of drill rod carried. This technique could be extended to about 400 feet of drill core with additional rods on the present winkie drill.

A sampling technique for recovering oriented plugs of unconsolidated Quaternary sediments was developed. This is done with a rubber hammer driving in a square cross-section steel tubing. The tubing is oriented as if it were a drill core, before removal.

Four hundred samples were collected from thirty-five sites in lower Paleozoic rocks of the St. Lawrence Platform. These samples will be measured in the paleomagnetic laboratory during the winter of 1972-73 to apply magnetic methods to stratigraphic correlation.

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74. PALEOMAGNETIC STUDY OF PROTEROZOIC RED BEDS OF WESTERN CANADIAN SHIELD

Project 680012

J.C. McGlynn
Regional and Economic Geology Division, Ottawa

About two weeks were spent in the field collecting cores and oriented hand samples of various geological formations in the Bear–Slave structural provinces in the Northwest Territories. Collections were made from red beds and volcanic rocks of the Cameron Bay Group in the Bear Province and from a carbonatite complex and a few old basic dykes in the Slave Province. This material along with samples collected in previous years under this project will yield data useful in correlating widely separated late Aphebian rocks in the northwestern Shield and will provide data from very old rocks to test the possibility of ancient major crustal movements. This work is being done as a joint project with E. Irving of the Earth Physics Branch of the Department of Energy, Mines and Resources.

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75. THERMOMAGNETICS OF SINGLE MINERALS AND ROCKS

Project 700054

E. J. Schwarz
Regional and Economic Geology Division, Ottawa

With the help of the International Nickel Company and Falconbridge Nickel Mines Ltd., oriented samples were obtained from the Little Stobie, Copper Cliff North, Falconbridge and Strathcona Mines near Sudbury. In addition, oriented samples were collected from sulphide iron-formation and ore deposits in the Timmins area.

The samples are used to determine the distribution of pyrrhotite types and its correlation with wall-rocks of various types. Furthermore, the natural remanent magnetization, the weak-field susceptibility will be determined. The objectives are to see if the pyrrhotite gives raise to characteristic magnetic anomalies at the earth's surface and if the sulphides show a definite fabric. The plan to collect oriented samples from the Kidd Creek Mine near Timmins could not be realized.

PETROLOGY

76. THE RED WINE-LETITIA ALKALINE PROVINCE OF LABRADOR

Project 680071

K. L. Currie
Regional and Economic Geology Division, Ottawa

An area southwest of Seal Lake, Labrador has been celebrated for about a decade as a source of rare agpaitic minerals. In 1968 two large plutons of agpaitic rocks were discovered, one about 5 miles southwest of Letitia Lake near 54°08'N, 62°32'W, and the other on the headwaters of Red Wine River near 53°55'N, 62°40'W. Together with the occurrences previously known, the alkaline rocks form a belt some 40 miles long with a curving, northeast trend. This belt crosses from rocks previously mapped as "basement complex" through the so-called Letitia Lake Group of sheared porphyries and slates, into the lower part of the Seal Lake Group, a Proterozoic sequence of basaltic volcanics and intercalated clastic sediments. The present mapping strongly suggests that the Letitia Lake Group is conformable with the Seal Lake Group, and in fact forms its lower part. The Letitia Lake Group does not lie unconformably on an older basement in the region examined, but is intensely penetratively deformed and recrystallized into the rocks previously identified as basement complex. This deformation has also affected the two alkaline plutons, which apparently originally formed subcircular, or elliptical, layered plutons, the northern one about 2 1/2 miles in diameter, and the southern one about 6 miles in diameter. Deformation has extensively destroyed the northern pluton by tearing off various slices and fragments, and by tectonically intercalating slices of country rocks into the pluton. Where juxtaposition of strongly alkaline and subalkaline rocks has taken place, strong metasomatism has resulted along shearing planes producing the suite of alkaline minerals previously known from this region, notably eudialite and acmite plus various rare sodium-beryllium compounds. In some places areas of this material can be found as far as 12 miles from the pluton suggesting that tectonic transport on this scale has occurred, mainly in a northeasterly direction. Locally, partial melting has occurred during this process, producing complex migmatitic syenite patches, and spectacular, weakly alkaline pegmatites.

The southern pluton is far less affected by tectonic deformation, retaining a subcircular, zoned form, although the margins are strongly sheared, and the textures of all the alkaline rocks are metamorphic rather than magmatic. This pluton shows only feeble and short range marginal metasomatism. The rocks composing it are essentially alkaline amphibolites, mainly composed of arfvedsonite hastingsite, albite, and variable amounts of nepheline and acmitic pyroxene. Most of the rocks are quite basic and some are ultramafic. The recognized remnants of dykes are all very mafic. The most common agpaitic mineral is eudialite, which is locally concentrated, apparently by primary magmatic processes, but preliminary examination suggests the presence of a great variety of other agpaitic minerals including joaquinite, astrophyllite, lamprophyllite, ramsayite, and many others.

77. HARP LAKE INTRUSIVE COMPLEX

Project 670003

R.F. Emslie
Regional and Economic Geology Division, Ottawa

The Harp Lake intrusive complex underlies about 4,000 square miles in central Labrador. In 1972 field work was continued on the complex over a period of about six weeks.

The northwest part of the complex is in contact with quartzofeldspathic gneisses. Medium-grained and locally fine-grained norite occurs at the contact and there is a rapid gradation inward to coarse norite and leuconorite. Angular inclusions of granitic gneiss occur in the norite close to the contact and some inclusions of fine-grained paragneiss were also noted. One large gneiss inclusion was found more than one mile from the contact.

Layering was mapped with dips commonly in the range 10 to 25 degrees, but a clear structural picture has not yet emerged. Areas of 100 square miles or more have nearly constant layering attitudes but across a valley or other lineament an adjacent block commonly has equally consistent dips in a different direction. Possibly some of these attitude changes are the result of folding or discordant primary layered sequences. However, it seems more likely that variations in orientation of layered structures is due to post-consolidation faulting and tilting of blocks possibly due to cooling stresses.

The high-standing hills and ridges tend to be underlain by anorthosite and leucogabbro. Troctolite and leucotroctolite are commonly found on slopes and valley bottoms. These are not inviolate rules but have been noted sufficiently commonly that it seems probable that erosion resistance played an important role in determining rock exposure within the complex.

Several additional large and small olivine diabase dykes were confirmed. These are part of the major east-northeast trending swarm reported last year.

Kennco Exploration has been active in the area for the past two seasons and holds a concession including most of the Harp Lake complex.

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78. PETROLOGICAL STUDIES IN THE VICINITY OF THE KISSEYNEW FRONT

Project 700065

E. Froese and I. Hutcheon
Regional and Economic Geology Division, Ottawa

Mapping in the Snow Lake area (parts of 63K-16E1/2 and 63J-13W1/2) was completed during the summer of 1972. A summary of the geological setting based on work in 1970-71 has been published[1, 2]. Further investigations have led to minor modifications of some contacts and one alteration of greater consequence. Closer examination indicated a monoclinal succession of rock-units in the area between Snow Creek and Wekusko Lake rather than the presence of an isoclinal F_1 fold, as previously suggested. This implies that the pelitic rocks along Snow Creek and those at Anderson and Stall Lakes are not equivalent stratigraphically. Nevertheless, the pelitic rocks along Snow Creek, like other pelitic rocks interlayered with volcanic rocks, could mark a favourable horizon for the deposition of base metals.

[1]Froese, E. and Moore, J.M.: Geological setting of the Snow Lake area; in Report of Activities, Pt. B, November 1971 to March 1972, Geol. Surv. Can., Paper 72-1, pt. B, p. 78-71 (1972).

[2]Moore, J.M. and Froese, E.: Tectonic and metamorphic environment of mineral deposits in the Snow Lake area, Manitoba (abstract); Can. Mining Met. Bull., v. 65, p. 35 (1972).

PRECAMBRIAN GEOLOGY

79. SEDIMENTARY ROCKS OF THE PRINCE ALBERT GROUP DISTRICT OF KEEWATIN

Project 720054

F.H.A. Campbell
Regional and Economic Geology Division, Ottawa

The metasediments of the Prince Albert Group outcrop in a northeast-southwest trending belt west of Committee Bay (NTS 56 O, J). The belt is surrounded by grey quartzofeldspathic gneisses which locally contain large inclusions of metasediments and these are interpreted as post-Prince Albert Group.

Stratigraphic correlation was accomplished by detailed examination at five selected localities, and a tentative facies distribution established (see Table 1). However, top determinations were not possible, due to the degree of recrystallization and the effect of polyphase deformation (see reports by T. Frisch and M. Schau, this publication). Consequently, neither the base nor the top of the Prince Albert Group is presently recognized.

The metasediments of the group include biotite gneiss and schist, garnetiferous biotite gneiss with or without sillimanite, metagreywacke, amphibolite, grey quartzite, white quartzite and minor iron-formation and conglomerate. These rocks occur in varying amounts throughout the lateral extent of the group. However, due to the lack of top determinations, the total thickness of any particular lithology is unknown.

The white quartzite is thickest in the west-central part of the map-area, near Kellett River. It typically outcrops as narrow sinuous ridges which are continuous up to 90 km. The white quartzite thins eastward, and passes laterally into grey quartzite and greywacke. It is typically coarsely crystalline, well foliated, and rarely bedded, this being the only recognizable primary sedimentary structure. The quartzite is remarkably clean at all localities, and contains an estimated 98 per cent quartz. Locally, it is contaminated with small grains of pyrite and/or biotite, and these may be mistaken for gossan zones from the air.

A possible quartzite-pebble conglomerate occurs interbedded with the quartzite at one locality. Compositionally the clasts are nearly identical to the matrix, and could be distinguished only on deeply weathered surfaces. The conglomerate is less than 3 m thick, and could not be traced for more than 100 m.

The conglomerate (?) mapped at location 5 (see Table 1) consists of clasts up to 10 cm which have been strongly flattened in the plane of the foliation. The unit was traced for approximately 600 m, and its thickness remained constant. It is within greywacke, which in turn is in contact with the grey gneisses. The stratigraphic significance of the conglomerate is presently unknown; as it may lie near either the base or the top of the group.

Garnetiferous biotite gneiss or schist and iron-formation are closely associated with the quartzite; they structurally overlie it in the east, but in the west they underlie it. Iron-formation was found at all but one location (Table 1). It varies in thickness from 20 cm at location 3 to approximately

TABLE 1

REGIONAL STRATIGRAPHY OF THE PRINCE ALBERT GROUP*

West 1	2	3	4	East 5
Biotite Schist	Biotite Schist	Biotite Schist	Biotite Schist	Biotite Schist
Greywacke	Greywacke		Greywacke	Greywacke
			Grey Quartzite	
White Quartzite	White Quartzite	White Quartzite	White Quartzite**	White Quartzite**
Garnet-Sillimanite Schist	Garnet Schist	Garnet Schist	Garnet Schist	Garnet Schist
Iron-Formation		Iron-Formation	Iron-Formation	Iron-Formation
Biotite Schist	Biotite Schist	Biotite Schist	Biotite Schist	
Greywacke		Greywacke	Greywacke	Greywacke
Biotite Schist		Biotite Schist	Biotite Schist	
				Iron-Formation
				Greywacke
				Conglomerate (?)
				Greywacke
White Quartzite Facies			Greywacke-Iron-Formation facies	

*Structural repetition and top uncertain.
**Minor amount.

20 m at location 5. The iron-formation consists of alternating lamellae of magnetite and quartzite; rare, magnetite beds are up to 50 cm thick. The greywacke associated with the iron-formation at location 5 commonly contains magnetite porphyroblasts up to 5 mm.

The stratigraphy west of Kellett River appears nearly identical with that outlined in Table 1, except that amphibolite, probably volcanic in origin, is more abundant near the top of the sequence (see M. Schau, this publication).

The metasediments in the area show the effects of at least two periods of isoclinal folding. The early (D_1) folds are tight, invariably overturned, and isoclinal. Their axes generally plunge shallowly south or southwest. These folds affect ultramafic sills and white quartzite beds. Locally these rocks form layers of boudins, especially where they are interlayered with incompetent biotite schist.

The second period of folding (D_2) is also isoclinal and overturned. These folds deform the axial planes of the earlier folds. The f_2 folds strike northeast, and appear to plunge to the east.

The third period of folding (D_3) produced the cross-folds of the f_1 and f_2 axial planes. The f_3 folds are generally upright, open, and plunge shallowly southeast. They commonly have well-developed kink bands on their limbs. Locally, the boudins developed during D_1 appear to have been refolded.

Emplacement of a locally garnetiferous granite and associated pegmatites produced doming of the metasediments and the gneiss in some areas. Small drag-folds are locally associated with these intrusions, especially in the western part of the area. Chevron folds and kink bands near the sediment-gneiss contacts also may be associated with this event.

No minerals of any economic significance were located during the field season. The thickest iron-formation does not appear to be of sufficient extent to be of commercial value.

80. GEOLOGICAL STUDIES IN SOUTHEASTERN MANITOBA

Project 710025

I.F. Ermanovics and Anton Brown*
Regional and Economic Geology Division, Ottawa

In addition to this year's prime objective – that of mapping Berens River W 1/2 – a number of localities that had been mapped in reconnaissance fashion in previous years between lat. 51° to 54° in Manitoba were revisited, (see Geol. Surv. Can., Papers 72-29, 70-29, and 69-42). Additionally, Brown unravelled and mapped the stratigraphy and structure of rocks of the Black Island area and the prominent shoreline lineament of eastern Lake Winnipeg from Rice to Hole River.

Berens River map-area (W 1/2) (lat. 52-53°, long. 97-98°). This map-area of 1,500 square miles was mapped in reconnaissance. On the whole it is underlain by quartz monzonite to quartz diorite; these plutonic rocks are distributed in a northwesterly direction similar to that in the Berens River-Dear Lake map-area (GSC Paper 70-29). Remnants of layered amphibolitized volcanogenetic rocks and quartz-feldspar gneisses occur on the islands in Berens River estuary, along Marchand Creek, and to the north of Poplar River. All these areas displayed pronounced shearing.

Ponask Lake. The magnetic anomaly at lat. 53°51'45", long. 96°22'25" outlines an area comprising fine-grained serpentinized peridotite, blue-green serpentine and carbonate veins. Although the best outcrops occur near a lake along the granite-volcanic belt contact there are other outcrops of serpentinized rocks in swamps east-northeastward along the strike. The mass of serpentinized rock has an outcrop width of 400 feet and a minimum traced outcrop length of 1,500 feet, plunges 35 degrees easterly, and is overlain by 1,200 feet of 2-pyroxene-bearing amphibolitized gabbroic rocks.

Post Kenoran diabase dykes. Twelve sites were drilled to get samples for paleomagnetic pole determinations on Playgreen (lat. 53°55', long. 98°) and Washahigan Lakes. Small dykes (3 inches to 4 feet wide) found during the course of reconnaissance mapping in 1971 emerged in some instances as aphanitic satellite dykelets of larger gabbroic dykes as much as 300 feet wide. Their trends range from 350 to 040 degrees averaging probably 030 degrees.

Washahigan and Pakatawacun Lakes (lat. 53°55', long. 96°45'). Here a set of north-northeasterly striking prominent lineaments extending southward from Molson Lake and cutting east-west trending country rock, are occupied by late Kenoran amphibolite (gabbroic) dykes. The dykes are weakly foliated subparallel to their contacts and presumably occupy zones of late Kenoran normal faulting.

Horseshoe Lake (lat. 52°09', long. 95°48'). An experiment is being designed to test the orientation of the fabric of a late Kenoran massive, leucocratic quartz monzonite body with respect to country rock deformation. Oriented specimens were obtained by drilling 2 1/2-inch cores from outcrop sites. These will be magnetically induced and the magnetic pattern that is so

*Texas A & M University.

produced within the specimen is held to reflect the mineral fabric of the specimen and consequently to give results analogous to those obtained from optical study of quartz fabric.

Manigotogan (lat. 51°06', long. 96°18'). Staurolite, mica- and garnet-bearing metasediments, which form the bulk of the Rice Lake belt at Manigotogan, are being studied petrographically to test whether a temperature gradient is indicated in the mineralogy.

Shoreline geology of eastern Lake Winnipeg from Rice River to Hole River, and the islands westwards to the east shore of Black and Deer Islands (lat. 51°15', long. 96°20'). The lithology has been mapped on a scale of 4 inches to 1 mile. About 4,000 attitude measurements were taken on stratigraphic, gneissic and schistose layering, on mineral streaking and crenulation lineations, on fracture and slaty cleavages, on fold hinges and axial planes, and on boudin and mullion axes. A total of 4,000 fracture attitudes were measured in 23 sample areas and 516 specimens, the majority field oriented, were collected.

Acidic flows and fragmental rocks north of Black Island are overlain by andesitic tuffs followed by andesite flows interspersed with dioritic gabbros. The acid volcanics are interrupted by a unit of gabbroic sills and basalts. This sequence changes southwards to basaltic and basic andesitic volcanics overlain by coarse clastic sediments and by a thin unit of ultrabasic rocks with iron-formation. These rocks are in the greenschist facies of metamorphism. Black Island occupies the axial zone of a fan-shaped, or an upside-down, anticline, with a northeast-southwest axial trace.

Rocks on the south-southeasterly-trending mainland shore are of higher grade of metamorphism, they vary from granitic and quartz-dioritic to amphibolitic in composition; they are metasediments, metavolcanics and rheomorphic rocks, and with minor granitic and gabbroic intrusives. Two units have been traced from the greenschist facies into the higher grade zone eastward. This sequence is isoclinally folded about southeast-trending axes which are subhorizontal in the north and steepen to 30 degrees southwards. The east side has moved relatively upwards along this prominent south-southeast-trending coastline fault and tentative, zircon Pb-Pb age determinations by T.E. Krogh suggest circa 2,945 m.y. and 2,785 m.y. ages for the 'basement' and 'sedimentary basin' respectively, which are situated on either side of this break. Only a minor left-lateral horizontal movement occurred along this fault; however, there was a strong right-lateral movement along it in the area near Hole River in the southeast corner of the map-area where it has given rise to a distinct vertically plunging, fold nose. Para-penetrative kinks and boxfolds on all scales suggest a late north-south compression.

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81. GRANITIC AND ASSOCIATED ROCKS OF THE COMMITTEE BAY AREA, DISTRICTS OF KEEWATIN AND FRANKLIN

Project 720070

Thomas Frisch
Regional and Economic Geology Division, Ottawa

Transportation was limited to a floatplane, and an unusually late and only partial break-up severely restricted field activity, which was envisaged as reconnaissance prior to more comprehensive studies in 1973. Three geologically different areas were selected for study.

Fifteen miles inland from the western shore of Committee Bay, metasedimentary biotite schist of the Prince Albert Group (units 2, 3 and 4 of Heywood[1] and described by F.H.A. Campbell, this publication) is in contact with biotite-feldspar-quartz±muscovite±amphibole gneiss (Heywood's unit 10), the most abundant rock in the area. Southward in a south-trending belt of this schist, interlayers of gneiss on both a major and minor scale become more and more common until schist is no longer present on the surface. In places within this interlayered succession, blocks of schist, not apparently rotated, are enclosed in poorly-foliated to massive granitic rock that grades into granitic gneiss.

In the area of predominantly granitic gneisses (Heywood's units 9 and 10) in Ross Inlet, at the head of Committee Bay, both metasedimentary and meta-igneous rocks are represented: a 15 m-thick quartzite layer with disseminated chalcopyrite and discordant amphibolite layers (probably metamorphosed dykes) was seen. Three phases of folding, the first two tight, the third more open, all oriented about northeast-southwest axes, were recognized. Post-tectonic pegmatites and aplites are widespread.

East-southeast of Cape Sibbald, on the eastern shore of Committee Bay, the Prince Albert greenstone belt (Heywood's units 1 and 4) is intruded by an extensive, locally porphyritic (feldspar), amphibole-biotite granite (Heywood's unit 12). The contact changes from vertical and sharp to gently-dipping interlayers of granite and greenstone sheets. The greenstone belt comprises chiefly amphibolites, some of which are garnetiferous, and banded magnetite-quartzite iron-formation; biotite and chlorite schists and quartzite are subordinate. Dips are generally steep and deformation was intense. Serpentinized ultramafic plugs are common locally within the belt. A large dyke-like body of biotite gabbro, veined by granite, due east of Cape Sibbald, is unmetamorphosed and fresh and carries molybdenite at its contacts.

Metamorphic grade in the areas studied is generally of the amphibolite facies, both inside and outside the Prince Albert belts.

[1]Heywood, W.W.: Geological notes, northeastern District of Keewatin and southern Melville Peninsula, District of Franklin, Northwest Territories; Geol. Surv. Can., Paper 66-40 (1966).

82. THE GEOLOGY OF THE BEAR-SLAVE BOUNDARY IN THE INDIN LAKE AREA, DISTRICT OF MACKENZIE

Project 720052

R.A. Frith
Regional and Economic Geology Division, Ottawa

The Bear-Slave boundary in the Indin Lake area (NTS 86 B, west, long. 114°, lat. 64°) is drawn along the eastern side of a zone of Aphebian sediments (Snare Group), characterized by tight upright second folding. The boundary is along the contact of these rocks of the Bear Province with those of the relatively more stable Slave Province. In the southern part of the area (Mattberry Lake) the boundary is an erosional unconformity represented by basal Snare conglomerate overlying Archean rocks; farther north this boundary appears to be a fault zone or to have been infolded with the Archean. The position of this boundary is virtually unchanged from that shown by Lord[1] and by other workers[2, 3, 4] as the easternmost extent of the Proterozoic in the area.

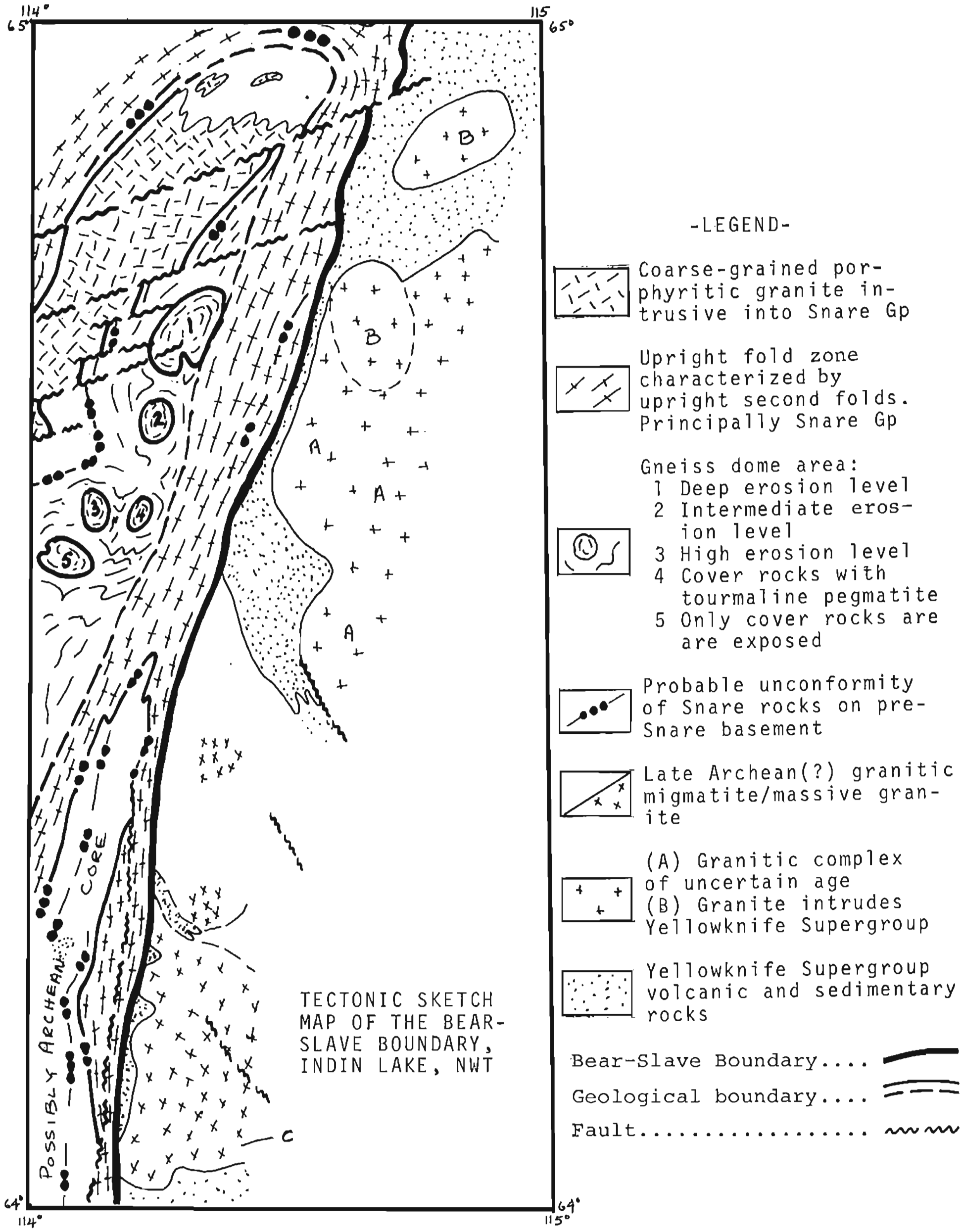
The effects of the Hudsonian deformation east of the boundary in the Slave Province is minimal. Muscovite K-Ar ages, within a mile east of the boundary, retain Archean ages of 2,420 and 2,250 m.y.[5] In contrast to this, west of the boundary, the metamorphic grade increases from the greenschist facies in Archean rocks to upper amphibolite facies in Aphebian rocks over a distance of only a few miles. Also, upthrusting of the Aphebian rocks along north-south fault lines is believed to have taken place.

On the Slave side of the boundary the granite rocks have been separated into several types: a granitic complex of uncertain age, parts of which may be pre-Yellowknife (A, Fig. 1); a post-Yellowknife granite (B, Fig. 1); massive late Archean granites (C, Fig. 1); and late Archean migmatites believed to have formed in part, from Yellowknife volcanic and sedimentary rocks. The ages of these bodies and their relationship to the Bear-Slave boundary are being studied.

In the highly deformed zone west of the boundary the Aphebian rocks are recumbently folded toward the Archean. Away from the boundary, refolding on tightly spaced axes, with steep to vertical axial plane cleavage, has taken place. In the south (Mattberry Lake area) the Aphebian rocks occur only as infolded or downfaulted remnants in a possibly Archean basement. The folding complexity of the zone makes thickness determinations difficult. However, in some areas (Arseno Lake) basal conglomerate occurs along anticlinal fold axes and the major hinge lines are spaced 0.5 to 1.5 miles apart[2]. This suggests that the maximum thickness of the Snare Group in the area is probably less than 4,000 feet.

In the gneiss dome area west of the boundary, the structure is characterized by shallow dipping foliations which wrap around the domes and are folded along north-south trending upright axes. The pegmatite in the granitic portions of the dome is also consistently folded by these upright folds.

The gneiss domes show various levels of erosion. In the deeply eroded dome, a core of massive even-grained granite may be found (No. 1, Fig. 1). Smaller domes, show correspondingly smaller granite cores and the overlying Snare sediments contain pegmatite, the abundance of which decreases away from the core (No. 2 and No. 3, Fig. 1). There are pegmatites also within


114°
65°
115
65°
B
B
A
A
A
1
2
3
4
5
POSSIBLY ARCHEAN
CORE
C
64°
114°
64°
115°
TECTONIC SKETCH
MAP OF THE BEAR-
SLAVE BOUNDARY,
INDIN LAKE, NWT
-LEGEND-
Coarse-grained por-
phyritic granite in-
trusive into Snare Gp
Upright fold zone
characterized by
upright second folds.
Principally Snare Gp
Gneiss dome area:
1 Deep erosion level
2 Intermediate eros-
ion level
3 High erosion level
4 Cover rocks with
tourmaline pegmatite
5 Only cover rocks are
are exposed
Probable unconformity
of Snare rocks on pre-
Snare basement
Late Archean(?) granitic
migmatite/massive gran-
ite
(A) Granitic complex
of uncertain age
(B) Granite intrudes
Yellowknife Supergroup
Yellowknife Supergroup
volcanic and sedimentary
rocks
Bear-Slave Boundary....
Geological boundary....
Fault.................

the granite core suggesting that the granite of the core is, at least locally, older. The presence of basement highs is suggested by the local occurrence of conglomerates and dolomite, which elsewhere in the area are the basal units of the Snare Group. The less deeply eroded domes are recognized by concentric foliations (No. 4 and No. 5, Fig. 1). and by the more frequent occurrence of tourmaline-bearing pegmatite (No. 4, Fig. 1). Toward the north the gneiss dome area wedges out against a large elongated granite mass that intrudes the Snare Group. This granite is very coarse grained, and has potash feldspar phenocrysts up to two inches in length. In the central portions, mineral alignment different from the regional trend is commonly observed. Locally, the granite grades into augen gneisses and migmatites, some of which may be pre-Snare in age.

[1] Lord, C.S.: Snare River and Ingray map-areas; Geol. Surv. Can., Mem. 235 (1942).

[2] McGlynn, J.C. and Ross, J.V.: Arseno Lake map-area, District of Mackenzie; Geol. Surv. Can., Paper 63-26 (1963).

[3] Smith, P.H.: Mattberry Lake, District of Mackenzie, Map 44-1963 (1966).

[4] Ross, J.V.: The structure and metamorphism of Mesa Lake (west half), map-area of Mackenzie; Geol. Surv. Can., Bull. 124 (1966).

[5] McGlynn, J.C.: Basler Lake Granite, District of Mackenzie; in Wanless, R.K. and Loveridge, W.D., Rb-Sr Isochron Age Studies Report; Geol. Surv. Can., Paper 72-23 (1972).

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83. YELLOWKNIFE AND HEARNE LAKE MAP-AREAS, DISTRICT OF MACKENZIE

Project 700015

John B. Henderson, M.B. Lambert and G.R. Peeling*
Regional and Economic Geology Division, Ottawa

Geological mapping of Archean rocks at a 1:250,000 scale in the Yellowknife and Hearne Lake[1] map-areas, begun in 1970[2,3], was completed this year.

Field work was concentrated on the granitic terranes in the Hearne Lake map-area and the north-central part of the Yellowknife map-area not covered in previous field seasons and in areas underlain by volcanic rocks of the Yellowknife Supergroup in the Hearne Lake sheet. Other parts of the area underlain by Archean sediments not previously mapped under this project were also examined. Use was made of a helicopter for a six-week period primarily for traversing the granitic terranes.

The two map-areas contain a section across a northerly-trending Archean basin of supracrustal rocks of the Yellowknife Supergroup. The main part of the basin is occupied by highly deformed, variably metamorphosed greywacke-mudstone turbidites whereas thick sequences of mafic, locally felsic volcanics are found at its margin. Granitic intrusions of several types occur within the basin. The basin is bounded by extensive granitic terranes,

*graduate student, Carleton University.

some of which may represent basement to the Yellowknife supracrustal rocks but most of which exhibit an intrusive relationship.

North and northwest of Yellowknife, outside and to the west of the basin, the granitic terrane is a massive to locally weakly foliated, grey to pinkish grey, equigranular, biotite to biotite hornblende granodiorite. It is generally homogeneous in the southern part except for irregular dykes of pegmatite and aplitic granite.

Towards the north the granodiorite to quartz diorite is intruded by large massive coarse-grained, commonly porphyritic, more felsic plutons about which the granodiorite is distinctly gneissic. Several of these plutons account for the cusp-like shape of the western margin of the bordering volcanic belt.

The large granitic body within the basin southeast of Yellowknife is a generally uniform white to pink massive granodiorite containing extensive areas of mixed rocks (granodiorite and metasedimentary inclusions in varied degrees of preservation). These zones of mixed rocks, which can be traced for several miles, serve to outline distinct plutonic lobes within this large granitic complex. The inclusions, where well preserved, are similar to the sediments of the main part of the basin. Most of the smaller granitic bodies found in the east part of the basin exhibit the same features as the large granitic body, a prominent exception being the complex between Hearne Channel and Blatchford Lake[4]. South of the large granitic complex and separated from it by a thin zone of sediments is a pluton of coarse-grained biotite muscovite granite similar to the granitic rocks in the Duncan Lake–Prosperous Lake area to the north. Like these granitic rocks this pluton locally exhibits scattered patches of uranophane stain on the weathered surface.

Examination of the northern and eastern part of the granitic area between Cameron and Beaulieu Rivers indicates a pattern similar to that described by Davidson[4] for the western and central parts of this granitic area. Large massive coarse-grained granitic plutons intrude less felsic granodioritic to quartz dioritic gneisses. On both the east and west margins of this complex the intermediate gneisses become more intensely cataclastic towards the contacts with the volcanic belt. Observations made this summer tend to confirm the suggestion by previous workers[4, 5] that parts of this granitic area may represent basement to the Yellowknife supracrustal rocks.

The very massive uniform elongate granitic pluton surrounded by volcanic rocks north and west of Beaulieu River has features characteristic of shallow emplacement. Felsic volcanics in the volcanic sequence may represent extrusive equivalents of this body.

East and south of the volcanic belt along Beaulieu River the granitic terrane is of a more uniform character and is more felsic in composition on the whole than the areas north of Yellowknife and between Cameron and Beaulieu Rivers. It consists of massive pink quartz monzonites with minor metasedimentary and metavolcanic inclusions. An extensive north-northwesterly trending zone of extreme cataclasis separates the northeastern part of this area from the mafic volcanic rocks to the west.

The volcanic belts are divisible into two general parts. Mafic volcanic rocks compose most of these belts but felsic rocks form major proportions of the belts south of Payne Lake, on the west side of Sunset Lake, to the south of Tumpline Lake, and on the eastern peninsula of Turnback Lake. In these areas the felsic volcanics form thick pods that abruptly pinch out laterally. Relatively thin units persist laterally from these pods and interfinger or occur as thin layers within the pillowed mafic flows. The succession of felsic volcanic rocks is widest (about 19,500 feet) south of Payne Lake. Thin belts of felsic material occur near the south side of Detour Lake and near the western side of the Cameron River belt. Thicknesses of felsic to intermediate rocks are as great as 1,400 feet in the Cameron River belt.[5]

The felsic volcanic succession comprises buff and pale grey, sparsely porphyritic rhyolite to dacite tuffs and lavas, and pale greenish grey to medium grey quartz-bearing andesites. These rocks generally form massive units in which primary textures have been almost obliterated by recrystallization and shearing. In some places, however, relict eutaxitic foliation and flow layering can be distinguished and is generally parallel to the schistosity. All are generally parallel to the overall trend of the volcanic belts.

Mafic parts of the volcanic belt consist of dark grey to dark green basalt and andesite pillow lavas, pillow-breccias, tuff-breccias and tuffs that are, deformed and metamophosed to amphibolite grade. Pillow lavas are the dominant constituent but tuff breccias and tuffs are common near the contact between mafic and felsic volcanic rocks.

The contact between felsic and mafic volcanic successions is conformable. Southwest of Sunset Lake the contact between mafic pillow lavas and salic welded tuffs is marked by a succession of tuff-breccias about 500 feet thick. In many places, however, amphibolite dykes are along the contact. Metadiabase and metagabbro intrusions make up almost half of the volcanic belt east of Beaulieu River at the northern edge of the map-area. These massive dykes have intruded both the granitic rocks to the east and pillow lavas to the west. In some places granitic rocks have intruded mafic rocks suggesting several ages of intrusion.

The pillow lava succession is almost everywhere deformed: pillows are flattened and stretched in planes that are subparallel to the over-all trends of the volcanic belts. The succession is least deformed in the Cameron River belt where tops of pillows are easily determined. The belt is essentially a homoclinal succession with minor folding along the eastern side. Pillows in other belts in the map-area are generally intensely flattened and stretched-out into thin rods so that the top directions are ambiguous.

An iron-formation in the volcanic belt west of Beaulieu River at the contact with cataclastic granitic rocks to the west, extends for about 9 miles from 112°27'W, 62°57'N to 112°35'W, 62°49'N. It is marked by a very prominent magnetic anomaly. The unit is up to 150 feet wide near the centre and thins out to one or more beds, 2 to 10 feet thick, near its ends. The iron-formation consists of well bedded impure recrystallized chert and of alternating magnetite-rich and magnetite-poor layers (0.5 to 6 cm thick) bearing bluish-green hornblende, epidote and minor hematite and pyrite. One representative specimen of the iron-formation contains 25 per cent magnetite. Layers are locally complexly folded with axial planes of minor folds almost parallel to bedding. A similar iron-formation although much thinner (10 feet) occurs at the base of the Cameron River mafic volcanics at the north shore of Patterson Lake (113°04'W, 62°53'N). Also along the west contact of the mafic volcanic sequence north of Yellowknife a similar chert-magnetite unit up to 50 feet thick occurs at Bell Lake (114°20'W, 62°50'N), to the west of Greyling Lake (114°19'W, 60°41'N) and possibly at other localities along this belt as indicated by small magnetic anomalies.

The sediments in the area, consisting primarily of greywacke-mudstone turbidites, make up the main fill of the basin. A discussion of these sediments, their lithology, metamorphism and structure has been presented previously[3]. Field work this season indicated that the cordierite isograd in sediments in the Campbell Lake area occurs 1 1/2 miles farther west and 1 1/2 miles farther north of its position as presently mapped about the lake[1]. A small area of sedimentary rocks metamorphosed only to greenschist grade occurs north of Jennejohn Lake and west of Upland Lake.

A hundred-foot unit of carbonate and of mixed carbonate and tuff occurs at the contact between the felsic volcanics and sediments three miles east-northeast of Turnback Lake. Between the carbonate unit and the normal greywacke-mudstone turbidites is a carbonaceous, commonly siliceous, mudstone containing disseminated iron sulphides. The sequence is similar to and occupies the same stratigraphic position as the calcareous horizon that has been traced discontinuously from Upper Ross Lake through Detour Lake and Turnback Lake and along which zinc mineralization occurs locally[2,4].

[1]Henderson, J.F.: Beaulieu River map-area; Geol. Surv. Can., Map 571A (1941).

[2]Henderson, J.B. and Elliot, A.J.M.: Yellowknife and Hearne Lake map-areas, District of Mackenzie; in Report of Activities, Pt. A, April to October 1970, Geol. Surv. Can., Paper 71-1, pt. A, p. 133-134 (1971).

[3]Henderson, J.B., Cecile, M.P. and Kamineni, D.C.: Yellowknife and Hearne Lake map-areas, District of Mackenzie with emphasis on the Yellowknife Supergroup (Archean); in Report of Activities, Pt. A, April to October 1971; Geol. Surv. Can., Paper 72-1, pt. A, p. 117-119 (1972).

[4]Davidson, A.: Granite studies in the Slave province; in Report of Activities, Pt. A, April to October 1971; Geol. Surv. Can., Paper 72-1, pt. A, p. 109-115 (1972).

[5]Baragar, W.R.A.: Geochemistry of the Yellowknife volcanic rocks; Can. J. Earth Sci., v. 3, p. 9-30 (1966).

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84. APHEBIAN SUPRACRUSTAL ROCKS OF THE ATHAPUSCOW AULACOGEN, EAST ARM OF GREAT SLAVE LAKE, DISTRICT OF MACKENZIE

Project 660009

P.F. Hoffman
Regional and Economic Geology Division, Ottawa

One month of field work was devoted mainly to mapping, at 1:50,000 scale, Blanchet and nearby islands along the northwest margin of the Athapuscow aulacogen[1], which separates the Slave and Churchill Provinces of the Canadian Shield. Special studies were made of the volcanic and carbonate rocks to further elucidate the evolution of the aulacogen.

Volcanic Rocks and Geochronology

Five distinct periods of volcanism were previously known[2] in the aulacogen – in the Union Island Group, Hornby Channel Formation, Seton Formation, Pearson Formation and Et-then Group (see Fig. 1).

1. This summer, a thick but localized sequence of pillow lavas and pillow breccias, seemingly of intermediate composition, were discovered in the Stark Formation (see Fig. 1) east of Pekanatui Point. The petrochemistry of the Stark flows will be studied to determine whether they are comagmatic with quartz diorite laccoliths that intrude the Stark Formation. If so, the stratigraphic age of the laccoliths will be known and a Rb-Sr isochron utilizing both laccoliths and flow rocks will be attempted. Furthermore, the hypothesis[2] that the huge gravity-slide breccias in the Stark Formation were triggered by doming of the laccoliths during sedimentation will be strengthened.

2. The internal stratigrapy of the Seton Formation, the thickest and most complex volcanic unit in the aulacogen (see Fig. 1), was studied around Seton Island. Five cycles were recognized (see Fig. 2), in each of which thick sequences of unwelded lapilli- and ash-fall tuffs mixed with sedimentary rocks are capped by basic subaerial flows. A Rb-Sr isochron will be attempted utilizing a variety of basic and acidic flow rocks, and comagmatic hypabyssal porphyries.

3. In addition to those from the Seton and Stark Formations, samples of basic flow rocks (72 in all) from the Union Island Group, Pearson Formation and Et-then Group were collected for petrochemical analysis. The analytical data will be used to evaluate a model[1] of the aulacogen as an abandoned intracontinental rift, from which it is predicted that the Union Island basalts be subalkalic, and the Seton and younger volcanics be alkalic.

Carbonate Rocks and Stromatolites

Along the northwest margin of the aulacogen, the Pethei Group (see Fig. 1) undergoes a southward carbonate platform-to-basin facies transition analogous to Phanerozoic reef complexes[3]. The most difficult rocks in the Pethei Group to interpret belong to the intergradational Utsingi Formation of the platform and McLean Formation of the basin (see Fig. 3). They contain digitate cryptalgal structures with a poorly-laminated fenestrate internal fabric, features conventionally considered indicative of subaerial exposure. However, careful study of the platform-to-basin transition (along tens of miles of virtually unbroken lakeshore outcrops of nearly flat-lying beds) reveals that the rocks are in part a sublittoral slope facies deposited between the southern edge of the shallow-water stromatolitic platform (Taltheilei Formation) and the greywacke turbidite tongues (Blanchet Formation) of the basin floor.

An important discovery was made by Malcolm R. Walter (Australia), a participant on the International Geological Congress Excursion A28, on Pethei Peninsula, where the Utsingi Formation in part overlies the Taltheilei Formation (see Fig. 3). At the transition, Walter found units containing the distinctive conically-laminated stromatolite *Conophyton* Maslov and the branched conically-laminated stromatolite *Jacutophyton* Shapovalova, interstratified with non-conical columnar stromatolites. This is the first reported occurrence of *Jacutophyton* in the Aphebian.

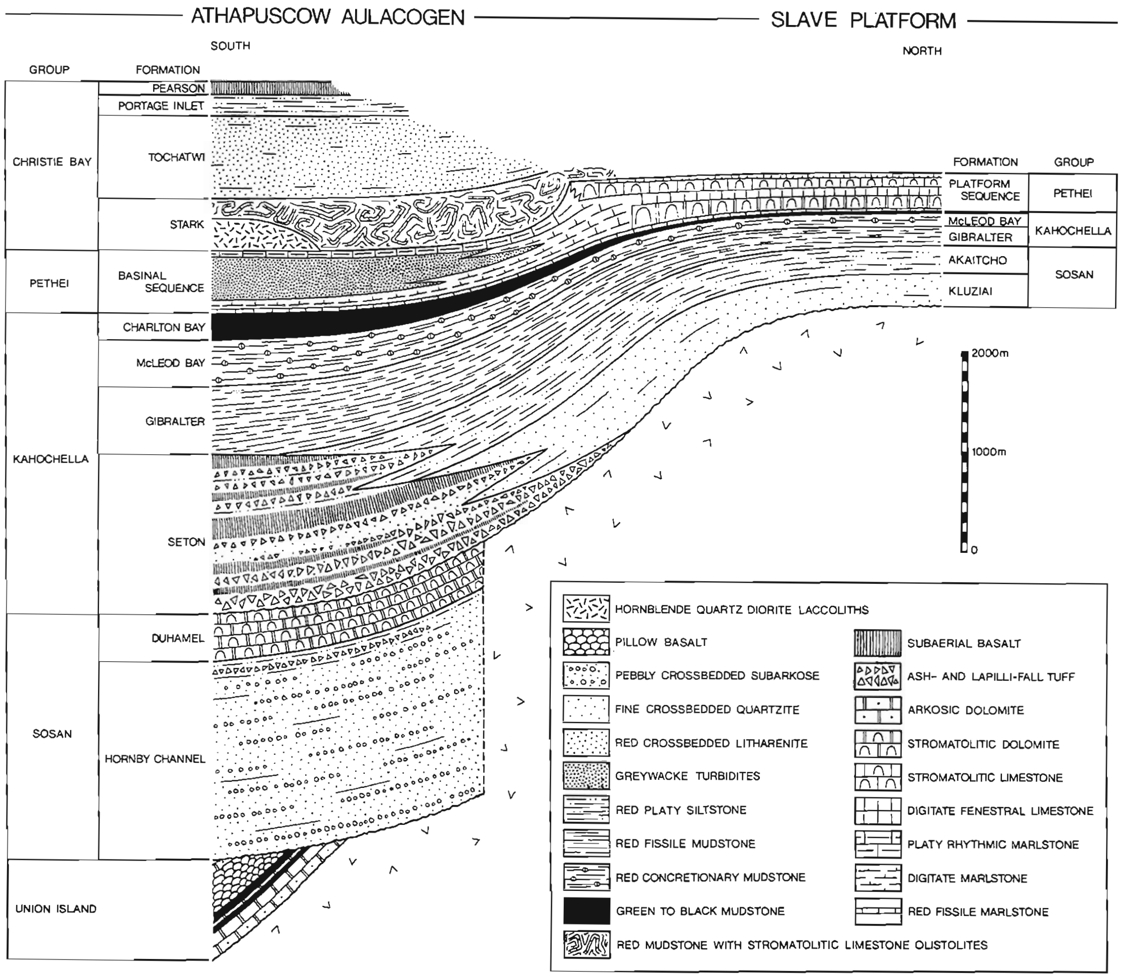

Figure 1

Stratigraphic cross-section of the northwest margin of the Athapuscow aulacogen between Taltheilei Narrows (north) and Hornby Channel (south). Volcanic rocks occur in the Union Island Group, Hornby Channel Formation, Seton Formation, Stark Formation and Pearson Formation. They also occur in the Et-then Group, a thick continental fanglomerate sequence that overlies the Pearson and all older formations unconformably.

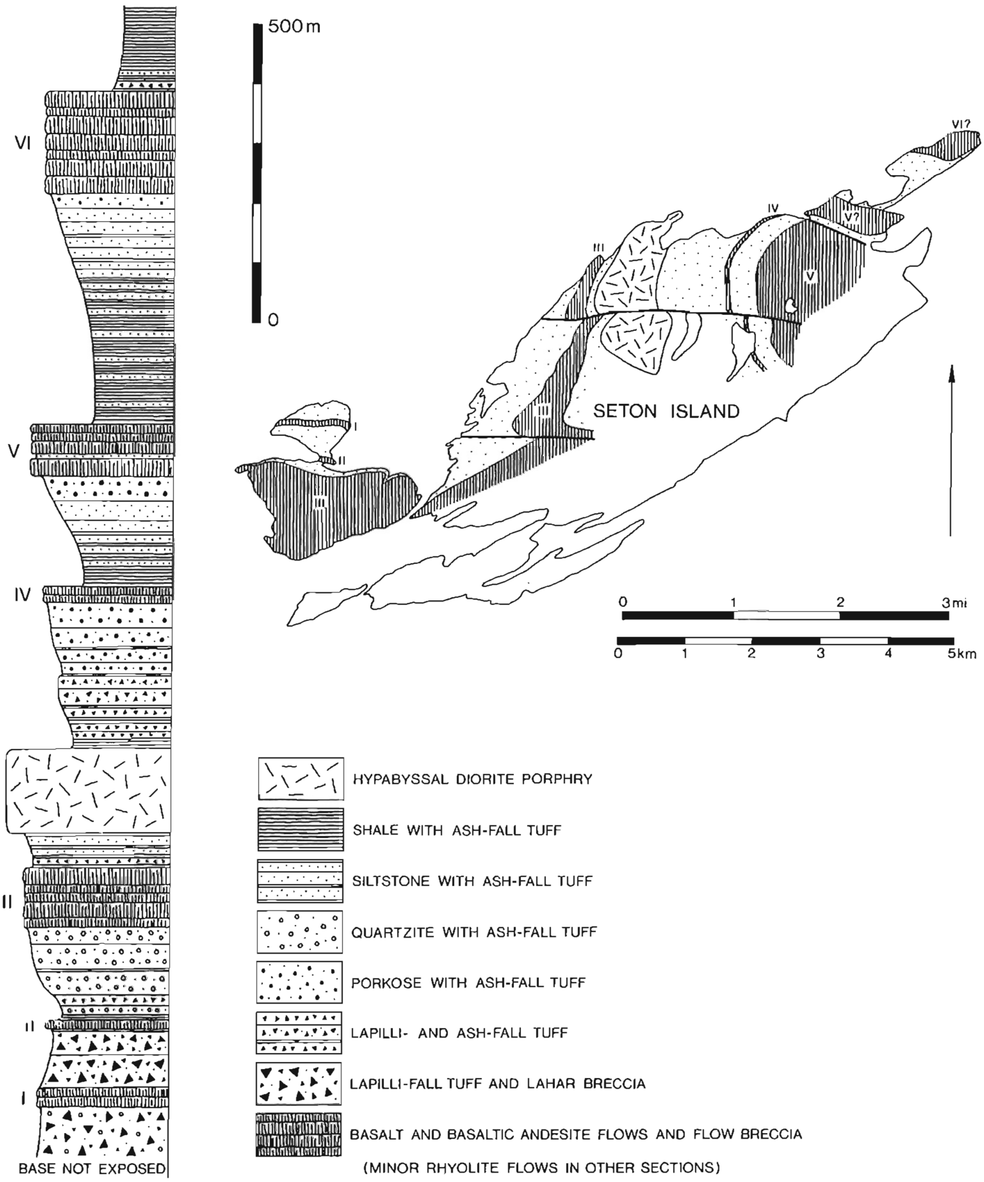

Figure 2. Simplified composite stratigraphic section and sketch map of the Seton Formation as exposed on Seton Island.

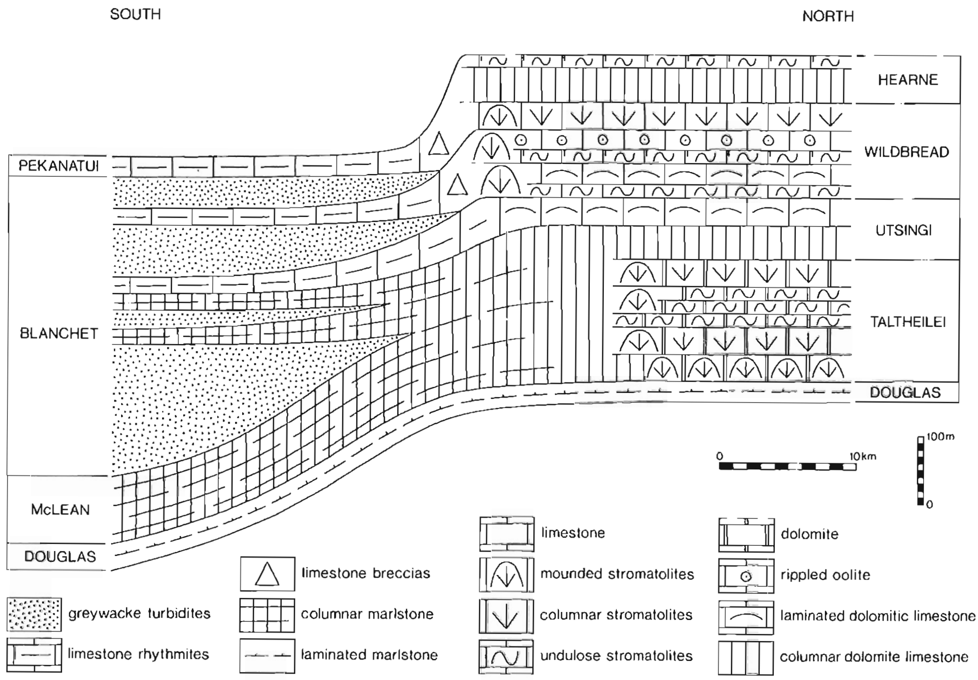

Figure 3. Facies relations and formations of the Pethei Group, showing the lateral transition from shallow-water carbonate platform rocks on north to deep-water terrigenous rocks on the south. The facies transition is continuously exposed around the shores of Blanchet Island.

Basinal Halite Deposition

The importance of salt deposition in deep basins is controversial. Most modern salt deposits occur in very shallow brine pans and many sedimentologists feel that most, if not all, ancient salt beds were similarly formed. However, the facies relations of certain ancient salt deposits are more easily reconciled with a basinal model for the salt.

The Stark Formation (see Fig. 1) consists of red mudstone with chaotically dispersed olistolites of stromatolitic limestone and dolomite. Near the community of Snowdrift, the upper part of the Stark Formation contains a coherent sequence, at least 450 m thick, of mudstone with abundant hopper-shaped crystal casts of halite throughout. This sequence, examined by John B. Henderson (G.S.C.), contains many graded siltstone turbidites of "distal" character but no evidence of subaerial exposure or wave action. Thus, the Stark Formation seems to be an example of salt deposition in relatively deep water.

[1]Hoffman, P.: Evolution of an early Proterozoic continental margin: the Coronation Geosyncline and associated aulacogens of the northwestern Canadian Shield; Roy. Soc. London, Phil. Trans. (in press).

[2]Hoffman, P.: Stratigraphy of the Lower Proterozoic Great Slave Supergroup, East Arm of Great Slave Lake, District of Mackenzie; Geol. Surv. Can., Paper 68-42 (1968).

[3]Hoffman, P.: Proterozoic carbonate platform-to-basin facies zonation, Pethei Group, Great Slave Lake, Northwest Territories, Canada; Amer. Assoc. Petrol. Geol. Bull. (in press).

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85. THE RAMAH GROUP BETWEEN NACHVAK FJORD AND BEARS GUT, LABRADOR

Project 720048

I. Knight*
Regional and Economic Geology Division, Ottawa

The Proterozoic Ramah Group has been delineated and briefly described in previous reports of the area[1,2,3,4,5,6]. Stratigraphic subdivision was made in 1971[7] based upon work of the present author.

Field work undertaken during the summer of 1972, independent of W.C. Morgan's study, has led to a fuller understanding of the stratigraphy and sedimentology of the group. Field work was carried on from a series of two-man fly-camps entirely by foot traverse. Other travel and camp moves utilized a rubber boat. However, the author is grateful for some helicopter support rendered by Dr. Morgan whilst setting up camp at Bears Gut.

The Ramah Group which unconformably overlies Archean crystalline and metamorphic rocks is readily subdivided into several lithologic formations (Table 1) which will be named at a later date.

Stratigraphy

Formation 1 (quartzite)

White, purple, pink and green quartzites and purplish grey and pinkish yellow mudstones and shales compose this formation. It has five units that can be traced throughout the area with very little variation along strike.

The lower and upper white quartzite units, essentially similar, comprise fine to very coarse, moderately to well sorted, crossbedded, quartzose sandstones. Ripples and other small-scale, shallow-water sedimentary structures are also abundant. Argillaceous beds are absent in the lower unit whilst thin intercalations and horizons of shale and alternating rippled sandstone and shale are relatively abundant in the upper unit. Grits and quartzose, small pebble-conglomerates occur in both units and heavy mineral laminae are common near the base of the lower unit.

The lower white quartzite unit is separated from an overlying purple quartzite and shale unit by a 5 to 10 m thick, subaerial, volcanic flow which is now highly altered. The purple quartzites are generally very fine- to medium-grained, muddy to well sorted quartzites. They show large- and small-scale crossbedding and are interbedded with dark, purplish grey, laminated shales and siltstones. The purple quartzite unit is overlain by a

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*Memorial University, St. John's, Nfld.

TABLE 1

Formation	Thickness	Lithologies
Formation 6	200 m	Greywacke sandstones, black shales and mudstones.
Formation 5	128 to 149 m	Black and grey mudstones (now slates) in some sandstone, white quartzites, black limestones.
Formation 4	162 m	Intraformation dolomitic breccia, laminated dololutites, limestones, argillites, dolomitic mudstones and sandstones and shales.
Formation 3	454 m	Colour banded mudstones, silty and sandy mudstones; calcareous mudstones, argillaceous dololutites, dololutites and limestones.
Formation 2	58 to 138 m	Grey sandstones, black quartzites, laminates sandstones and siltstones, mudflow.
Formation 1	118 to 187 m	Upper white quartzites.
	20 m	Purple-grey and pinkish yellow shales and mudstones.
	75 to 111 m	Purple quartzites and purple-grey shales.
	5 to 10 m	Volcanic flow.
	33 to 66 m	Lower white quartzites.
maximum thickness	407 m	
maximum total thickness of Ramah Group	1508 m	Regolith, up to 12 metres thick. Archean basement.

unit of purplish grey and pinkish-yellow shales and mudstones which contain numerous thin lenses and beds of rusty weathering, muddy siltstone and very fine sandstones.

Formation 2 (grey sandstone, black quartzite and laminated siltstone)

This formation is characterized by a tripartite division and by considerable lateral facies variations in both lithology and thickness. The member thickens from north to south. The divisions include a lower unit which in the south consists of grey muddy, fine sandstone with small-scale crossbedding and abundant soft sediment deformation and bioturbation and in the north consists of black, crossbedded, fine quartzites with thin sandstone-shale interbeds which display mudcracks. The black quartzites in the north have a transitional contact with the underlying upper white quartzite unit of Formation 1.

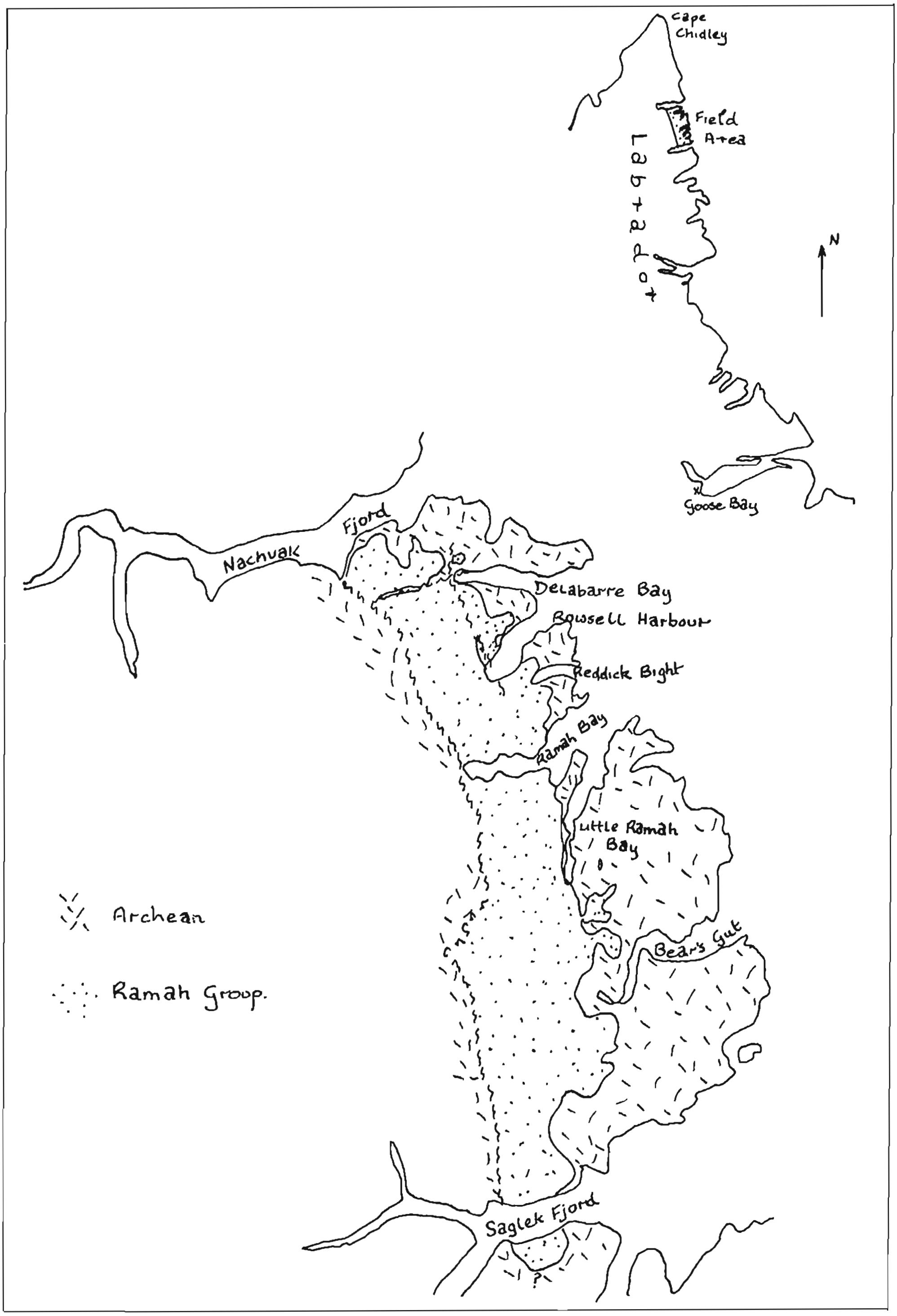

Figure 1. Location map of Field Area, Northern Labrador

The middle unit is composed of distinctive, laminated white, very fine sandstones and of black siltstone with occasional, rusty, fine sandstones which occur as lenses within the laminated facies. It is overlain by the upper unit of grey sandstones and black quartzites which show considerable grain-size and facies variations and includes trough crossbedded, grey sandstones, planar crossbedded, black fine-grained to pebbly coarse-grained quartzites, and numerous laminated sandstone-siltstone horizons in the south and a thick mudflow in the north of the area.

At the top of this formation, there is a distinctive and continuous, yellow, secondary, dolomitic horizon which varies from a slightly to strongly dolomitic sandstone to a finely crystalline dolomite. Its thickness varies from place to place.

Formation 3 (varicoloured slate)

This consists of a thick succession of multicoloured slates which contrast markedly with the underlying coarse clastic rocks. Originally mudstones and silty and very fine sandy mudstones, they are now steel-black, blue-black, green-grey, green, brown, buff and yellow slaty rocks with colour banding of a few millimetres to tens of centimetres. Sedimentary structures are generally small scale, however, large-scale soft-sediment deformation is locally common. The lower part of the member is black, graphitic and sulphurous pyritic shale which is often badly sheared. It passes upward into blue-black and green-grey mudstone which at 45 m from the base of the member contains a thick development of white to black chert. Between Bears Gut and Rowsell Harbour, the chert is underlain by a 2 m horizon of pyrite. Both horizons show considerable evidence for a primary, sedimentary origin and whilst the pyrite is not present north of Rowsell Harbour, the chert thickens considerably. Above the chert, the succession remains argillaceous but upwards there is a gradual increase in the calcareous and dolomitic content of the mudstones which is accompanied by a colour change to brown, buff and yellow. Horizons of yellow, argillaceous dololutites, pure dololutites and limestones occur near the top of the member.

The top of the member appears to grade transitionally upward into the dolomite of the overlying formation midway between Ramah Bay and Reddick Bight but elsewhere the boundary may be sharply defined by the first occurrence of thick and extensive intraformational breccias, equivalent to turbidites of the previous stratigraphic division[7].

Formation 4 (dolomite)

The intraformational breccias that occur at the base of the member vary considerably in style and mode of formation. Soft sediment deformational breccias, secondary post-depositional recrystallization breccias, and breccias produced by the activity of turbidity currents and mudflows all occur approximately at the same stratigraphic level. The turbidite breccias are very coarse and often rich in detrital sand grains and are associated with dolomitic white quartzites and argillaceous dololutites. They show many sedimentary characteristics typical of turbidity deposition. This facies is particularly well-developed locally at Delabarre Bay, Reddick Bight and Little Ramah Bay in the east, and along the western and southern limits of the outcrop of the formation. Locally developed unconformities are thought to underlie these breccias.

The rest of the formation comprises laminated dololutites and limestones interbedded with silvery-grey, calcareous mudstones. Upwards, the dolomitic content decreases within argillites, black limestones and some horizons of dolomitic mudstones. Sandstones and shales occur at Reddick Bight. Sedimentary structures are generally small-scale in all these lithologies but large-scale, soft-sediment deformation is also common. Stromatolitic and gypsiferous horizons previously reported[7] are not present. The former are actually solution pits in limestones and dololutites which are infilled symmetrically and assymmetrically by later laminations. The reported gypsum horizons are actually areas of calcitic, recrystallization which postdate the early post-depositional recrystallization that produced the recrystallization breccias referred to earlier.

The top of the member passes transitionally up into the overlying formation, previously referred to as multicoloured slates[7].

Formation 5 (slate)

North of Ramah Bay, this formation comprises a monotonous sequence of grey and black mudstones (now slates) with an occasional thin sandstone bed. Sedimentary structures are absent or confined to laminations. South of Ramah Bay, however, the formation diversifies and laminated very fine quartzites, some thin-bedded limestones and horizons of concretionary, grey quartzites occur within the mudstones.

The stratigraphy and thickness of these slates is complicated by several, thick, transgressive diabase sills which during deformation acted as competent units between which the fine sediments were squeezed and fractured.

Formation 6 (greywacke sandstone)

This was examined in detail only north of the north shore of Ramah Bay due to lack of suitable exposures elsewhere. The formation comprises grey, very fine to very coarse greywacke sandstone units interbedded with thin black mudstones and shales. The sandstones display massive bedding, grading, convolutions, laminations, ripple-laminations and many other structures typical of clastics deposited by turbidity currents.

The base of the formation appears to grade transitionally up from the underlying slates.

The Unconformity

The unconformity below the Ramah Group everywhere but at Bears Gut is an extensive, flat, planar surface that truncates the underlying gneissic banding of the Archean basement migmatites. The unconformity surface dips gently to moderately westwards in the east and the overlying sediments dip at similar or slightly shallower angles which suggest possible onlap.

Near Bears Gut, the unconformity is irregular with deep, local erosion of the underlying basement and infill of fractures, joints and cavities in the Archean by the Proterozoic Ramah Group quartzites.

A regolith of pre-Ramah Group age effects the basement up to 10 to 12 metres in places, e.g. Bears Gut. It is a zone of buff and rusty weathering wherein granite gneisses display secondary iron enrichment and oxidation, titanium enrichment, leisegang rings, pre-Ramah Group spheroidal weathering, breakdown of silicate minerals and reddening of quartz. Archean basic rocks and diabase dykes intruding the basement are highly decomposed and directly below the unconformity are enriched in magnetite and ilmenite. Jasper and chromite also occur.

Restricted occurrences of conglomerates and breccias composed of white quartz and jasper occur only in the vicinity of Ramah Bay and Reddick Bight where they occupy small depressions in the unconformity surface.

Environments of Deposition

The sediments of the basal quartzite and sandstone members were laid down in shallow marine, intertidal and offshore deltaic environments. Sediments were at first derived from the east but later palaeocurrents have a wide and varied distribution typical of tidal sand deposits. At the time of deposition of Formation 2, however, material was moving both westward and northward.

The finer sediments of Formation 3 were deposited in relatively quiet, deep water which at first and during the deposition of the pyrite and chert horizons had very restricted circulation. It is thought that the basin became shallower with time and this was coupled with increasing content of carbonate in the sediments. The dolomite of Formation 4 represents the period of shallowest basinal conditions. The environment was still quiet but major movements of coarse, dolomitic detritus and sand grains from east to west produced local unconformities in the east and widespread contemporaneous fan deposits in the west. Deeper, restricted basinal conditions occurred whilst the slates of Formation 5 were deposited and the known depositional history of the Ramah Group was terminated with the renewed influx of coarse detritus by turbidity currents derived apparently from the north.

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[2] Kranck, E.H.: Bedrock geology of the seaboard region of Newfoundland, Labrador; Geol. Surv. Newfoundland, Bull. 19 (1939).

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[5] Taylor, F.C.: Reconnaissance Geology of a part of the Precambrian Shield, northeastern Quebec and northern Labrador; Geol. Surv. Can., Paper 68-43 (1969).

[6] Taylor, F.C.: Reconnaissance geology of a part of the Precambrian Shield, northeastern Quebec and northern Labrador; Geol. Surv. Can., Paper 70-24 (1970).

[7] Morgan, W.C.: Ramah Group and Proterozoic–Archean relationships in northern Labrador; in Report of Activities, Pt. A, April to October 1972, Geol. Surv. Can., Paper 72-1, pt. A, p. 125-128 (1972).

86. RAMAH GROUP AND THE CONTACT BETWEEN ARCHEAN AND PROTEROZOIC IN NORTH LABRADOR

Project 710012

W.C. Morgan
Regional and Economic Geology Division, Ottawa

Field work has been completed and the area between Nachvak Fiord and Saglek Fiord has been mapped at a scale of 1:50,000 (14 L/11, /14, 15; parts of 14 M/3, /4, and L/6). Stratigraphic units determined in the Ramah Group[1] have been mapped over much of the belt. Highly deformed and metamorphosed sedimentary rocks of the Ramah Group have been traced for a distance of 25 miles south from Saglek Fiord to Hebron Fiord. The nature of the contact between Archean and Proterozoic has been determined. The contact is variable and may be sharp, gradational or faulted.

[1]Morgan, W.C: Ramah Group and Proterozoic--Archean Relationships in Northern Labrador; in Report of Activities, Part A, April to October, 1971; Geol. Surv. Can., Paper 72-1, pt. A, p. 125-128 (1972).

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87. GIBSON-MACQUOID LAKES MAP-AREA, DISTRICT OF KEEWATIN

Project 720024

E.W. Reinhardt and F.W. Chandler
Regional and Economic Geology Division, Ottawa

This project was designed to upgrade knowledge of the Precambrian geology and to assess the mineral potential of an area previously examined during Operation Baker.[1] The 1972 field season was the first under the present project and geological mapping for publication at a scale of 1:250,000 was completed for the east half of NTS 55 M (MacQuoid Lake) and the west half of NTS 55 N (Gibson Lake). The data were collected by three geologists[2] through both helicopter and ground traverses. Suitable aeromagnetic data[3] were available only for the south halves of the above areas while the field work was in progress. Aeromagnetic coverage[4] is now available for all of the map-area. Outcrop in the southern and western parts of the map-area is sparse but exposure is better in the most geologically complex part (northeast quarter).

The map-area is dominated by Kenoran (?) migmatites and granitic rocks that are derived partly from pre-existing (Archean) lithologies. Typical representatives of the latter are variations of amphibolite and pelitic gneiss both of which contain minerals indicative of relatively high-grade regional metamorphism which was contemporaneous with plutonic migmatization and syntectonic emplacement of granitic rocks. These rocks were subsequently affected by a regionally developed penetrative deformation which is commonly accompanied by partial retrograde metamorphism of lower grade. This later deformation rather than the Kenoran one will probably be reflected in K-Ar mineral dates from the rocks involved. Except for local effects associated with emplacement of later granites (described further on) evidence of major orogenic activity is lacking.

The amphibolites are most abundant northeast of MacQuoid Lake where they form almost continuous envelopes surrounding domal masses of gneissic granodiorite and quartz diorite. The contacts are migmatitic over widths of one hundred feet or more, but away from the contacts the amphibolites are unmigmatized and contain minor interbands of metasedimentary gneiss and some rocks tentatively identified as agglomerate. To the east, within the Gibson Lake area, lesser thicknesses of amphibolite are interbanded with partially migmatized pelitic gneiss and together these rocks define an east-northeastward-trending belt that continues to the east boundary of the map-area northeast of Gibson Lake. Other lithologies that occur in minor amounts within this belt include: hornblende-biotite gneiss, quartzofeldspathic gneiss, calc-silicate gneiss, carbonate, and quartz-magnetite iron-formation. The iron-formation was observed at several locations across the belt and seldom occurs in bands of more than a few inches in thickness although several such bands may be found at a given outcrop. The 'amphibolite-pelitic gneiss belt' measures approximately 8 miles across strike, and rocks within it have an average dip of about 50 degrees to the north. The lithologies defining the belt progressively fade into more granitic migmatites both along strike to the southwest, and across strike to the southeast. The north boundary is delineated by a set of westward-striking faults within the Gibson Lake area and these presumably swing northward in the MacQuoid Lake area.

On the whole, the area lying between these faults and Chesterfield Inlet shows a higher degree of migmatization with substantially less pelitic gneiss and amphibolite. The rocks within this region generally have northerly strikes and steep dips. Elsewhere within the map-area amphibolite and metasedimentary gneiss occur as modified fractions within granitic migmatites. Notable exceptions are: along parts of Chesterfield Inlet, in the vicinity of Blakely Lake (with minor interbanded iron-formation), and at one locality south of Gibson Lake.

Outcrops along Chesterfield Inlet display diverse lithologies and structures. At the north boundary of the map-area between Quoich River and Bowell Islands pyroxene-bearing granulites are associated with leucocratic and mafic garnetiferous rocks. The latter are poorly understood and require further study. On the north shoreline northwest of Round Island, traces of magnetite-bearing iron-formation are interbanded with pelitic gneiss and lesser amphibolite. Deformed pillows were observed in steeply dipping intermediate metavolcanics on the south shoreline near Schooner Harbour. Faulting recognized in this vicinity probably extends eastward along the inlet to connect with a curved fault that follows the west side of Quoich River. Rocks to the south and east of this fault have been involved in two periods of migmatization. Metagabbro, metadiorite and altered ultrabasic rocks occur in minor amounts in a few places along or near the inlet.

Two mappable bodies of mainly metagabbro were found inland south of South Channel (Baker Lake).

Diabase dykes and sills exhibiting marginal cataclasis and replacement of pyroxene by hornblende occur throughout the map-area but are most abundant in the 'amphibolite-pelitic gneiss belt' where their strike is typically easterly. Occasionally these bodies attain thicknesses of several hundred feet and continue along strike up to 4 miles. Younger northwestward-trending diabase dykes cut cataclastically deformed ones and were seen in a few places only.

Post-Kenoran granite and quartz monzonite that lack significant cataclastic deformation were mapped in several parts of the area. In the northeast corner, these rocks occur as irregularly shaped bodies that are partly transgressive and partly concordant; migmatite characterizes the contact zones over much of their length and are particularly prominent where some marked degree of concordancy exists. Other bodies occur at the following approximate locations: to the southwest of Banks Lake, around Gibson Lake, and to the southeast of MacQuoid Lake. These appear more regular in outline and lack extensive migmatitic borders. The late granitic rocks are typically pink, massive, homogeneous, and leucocratic; fluorite occurs in one of the northern bodies. Related pegmatites are of limited distribution and were observed to cut early cataclastic diabase dykes and sills.

Lamprophyre dykes, seldom more than a few inches wide, occur in several localities; the largest known representative is 50 feet thick. The lamprophyre is fresh and undeformed suggesting relatively late (post-late granite) introduction and it may, in fact, be related to the Christopher Island volcanism (discussed below).

In the northwest corner of the map-area poorly exposed clastic sediments and acid to intermediate volcanic and intrusive rocks of the Paleohelikian Dubawnt Group[5] unconformably overlie previously described basement rocks.

The South Channel is the lowest formation of the Dubawnt Group and consists of massive to poorly bedded pebble to boulder orthoconglomerate with rare sandstone lenses. Phenoclasts of foliated granitic rocks are more abundant than those of white quartz and finer grained igneous and metamorphic rocks. The matrix is a hematitic sandstone.

The South Channel Formation passes transitionally upward through intercalations of sandstone and pebbly sandstone into the Kazan Formation.

The Kazan Formation is a fine- to medium-grained feldspathic arenite with rare, sometimes broken, layers of red siltstone. The cement is hematitic and also locally contains carbonate. Sedimentary structures include flaggy to slabby bedding or parting and laminations although some outcrops are massive. Planar and subordinate trough crossbeds indicate that sedimentary transport was to the west.

Massive acid to intermediate volcanic rocks of the Christopher Island Formation form isolated resistant masses standing up to 150 feet above the level of the drift-covered plain underlain by the Kazan Formation. Kazan sandstones show chilling and baking at contacts with the volcanics. The Martell Syenite[5] within the map-area is somewhat similar in appearance to the above volcanics and could belong to the same igneous event.

Apart from local contact effects, the Dubawnt Group is unmetamorphosed and dips westward at from 10 to 30 degrees.

Most of the map-area is blanketed by Quaternary deposits with large tracts covered entirely by boulders or angular blocks. There are also drumlinoid ridges, grassy meadows, and eskers. The glacial topography has been modified in places by beaches which occur at elevations up to 500 feet above present sea level. The last Pleistocene ice advance appears to have been towards the southeast.

Satisfactory evaluation of the mineral potential of the area awaits further compilation. Minor concentrations of sulphides occur along certain horizons within the central zone of amphibolite and pelitic gneiss. The main sulphide minerals are pyrite and pyrrhotite although traces of chalcopyrite were noted in some localities. These sulphide zones are seldom more than a few feet wide and at least locally, follow the stratiform foliation, suggesting an emplacement contemporaneous with that of the host rock. In other places, such as along Chesterfield Inlet, iron sulphide mineralization with traces of chalcopyrite is related to fracturing and is associated with quartz and carbonate. Disseminated iron sulphides were noted in many of the rock samples collected. Traces of molybdenite were found in one outcrop of fluorite-bearing granite. A probable breccia pipe of about 200 feet in diameter is located approximately 2 miles east of Big Swallow Hill in Chesterfield Inlet. The possible genetic relationship of this type of structure to late sulphide mineralization and the uranium showings[6] on Christopher Island (Baker Lake) is worth considering in systematic exploration[7].

The quartz-magnetite iron-formation previously mentioned is unlikely to be presently of economic interest. The thickest zone is about 300 feet across the strike and occurs at 63°33'23"N and 93°30'00"W. Lack of continuity in thickness along strike is to be expected.

[1]Wright, G.M.: Geology of the southeastern barren grounds; parts of the Districts of Mackenzie and Keewatin; Geol. Surv. Can., Mem. 350 (1967).

[2]G.B. Skippen: Collaborated in field work with the authors.

[3]Geological Survey of Canada; Aeromagnetic Maps 7299G and 7300G (1966).

[4]Geological Survey of Canada; Aeromagnetic Maps 6799G to 6802G and 6780G to 6783G (1972).

[5]Donaldson, J.A.: The Dubawnt Group, Districts of Keewatin and Mackenzie; Geol. Surv. Can., Paper 64-20 (1965).

[6]Little, H.W.: Uranium in Canada; in Report of Activities, Pt. A: April to October, 1970; Geol. Surv. Can., Paper 71-1, pt. A, p. 89-90 (1971).

[7]Reinhardt, E.W.: Occurrences of exotic breccias in the Petitot Islands and Wilson Island map-areas, East Arm of Great Slave Lake, District of Mackenzie; Geol. Surv. Can., Paper 72-25 (1972).

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88. VOLCANIC STRATIGRAPHY AND METALLOGENY; RANKIN INLET-ENNADAI BELT, DISTRICT OF KEEWATIN

Project 700052

R.H. Ridler
Regional and Economic Geology Division, Ottawa

Integrated volcanic stratigraphic and metallogenic field studies[1, 2] were continued in the Archean Rankin Inlet–Ennadai Belt. Three main sections were examined and sampled (Fig. 1). Two sections not completed during summer 1971 were concluded. Reconnaissance of geologically pertinent areas was conducted and many mineralized zones examined. Two hundred

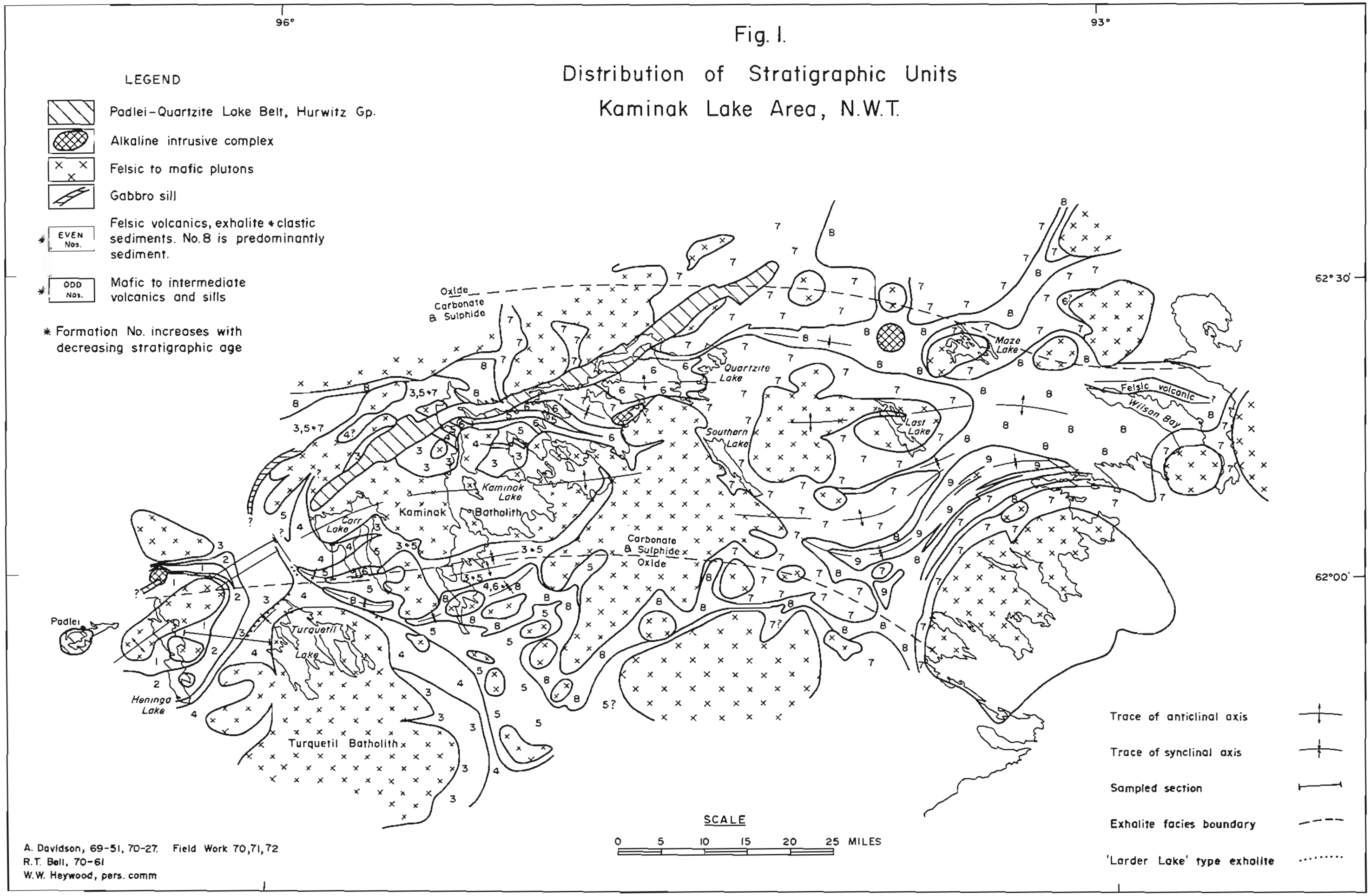

Fig. I.

Distribution of Stratigraphic Units
Kaminak Lake Area, N.W.T.

and seventeen sites were sampled for bulk oxide analysis and fifty for metallogenic suites. R.K. Wanless and R.D. Stevens of the Survey visited the party to initiate a pioneering sampling program designed to put isotopically determined time limits on rhyolite flows of known, different stratigraphic ages. D.F. Sangster assisted for a week in the examination of mineral occurrences in the Turquetil Lake area. Exemplary assistance was rendered by L. Covello (senior) and S. Venskus, V. Bowen and J. Knowles (juniors).

Base camp was established for the period June 23 to August 23 at Turquetil Lake (61° 55'30"N; 95° 50'20"W), approximately eighty-three miles northwest of Eskimo Point, District of Keewatin. Transport was by Bell 47G4A helicopter. The summer's activities terminated the field component of the project.

Volcanic Stratigraphy near Turquetil Lake

Two major volcanic cycles, each possessing at least one large centre of felsic volcanic activity and abundant exhalite are present. The older, or the group formed by units 1 and 2 (Fig. 1), envelopes the batholith centred on north Heninga Lake while the younger, or the group formed by units 3 and 4 (Fig. 1), occupies a complex synclinal structure between the previously mentioned batholith and the Turquetil and Kaminak Batholiths (Fig. 1). Each of the two cycles forms a recognizable group for which a formal name will be proposed.

Units 1 and 2 are intruded by and face away from the batholith centred on north Heninga Lake wherever examined. The contact is discordant, possesses a significant contact metamorphic aureole, and locally displays well developed agmatite. However, on a regional scale the batholith is coincident with the core of the large anticline or dome formed by units 1 and 2, the common relationship observed throughout the Belt. The basal portion of the older cycle (unit 1, Fig. 1) is a sequence of iron-rich basalt flows and gabbro sills and dykes. Individual flows have both pillowed and massive phases. Interflow materials are rare but thin oxide exhalite was noted at one locality. Both texturally and compositionally the sequence appears to be uniform. The maximum stratigraphic thickness observed is 15,000 feet along the Maguse River between Heninga and Turquetil Lakes. However, no accurate measure of the maximum original thickness is available in the area examined due to the discordant lower contact of the succession. The upper contact of unit 1 is defined by the relatively abrupt and distinct change to conformably overlying intermediate to felsic volcanics. The upper phase of the older cycle (unit 2, Fig. 1) is composed of tuffs, breccias, flows, and subvolcanic intrusives and exhalite. There appears to be a gradation from andesitic palagonitic pyroclastics at the base of this upper phase through increasingly more felsic phases to rhyodacite at the summit. Very coarse angular fragments (>2 feet diameter) are present locally. The breccias vary from relatively homogeneous to polymict. Well defined bedding is rare except in the exhalite. Subvolcanic dacitic to rhyodacite intrusives exhibiting plagioclase and/or quartz phenocrysts are found at all levels. There appear to be two significant exhalite intervals, a lower near the base of the upper phase and a higher close to or at the top. The maximum thickness of unit 2 is approximately 15,000 feet just north of the Maguse River between Heninga and Turquetil Lakes. Unlike the extensive mafic lower phase the upper felsic phase thins rapidly to the north and interfingers with and disappears in a penecontemporaneous but "foreign" mafic phase north of the batholith. The two exhalite zones thicken and persist into the adjacent mafic phase. Lack of outcrop and time prevented sufficient examination of the apparently analogous relations to the southwest.

The older cycle appears to be a typical "older Archean" volcanic cycle. The mafic plate although lacking extensive ultramafic complexes does possess at least some very mafic if not ultramafic phases and is entirely basaltic. The upper felsic edifice is predominantly dacitic in composition and apparently lacks any significant ultrafelsic differentiates. On the basis of the available structural evidence for the region, it is the oldest supracrustal group in the portion of the Belt examined to date.

The younger cycle (units 3 and 4) conformably overlies the older cycle to the west and is intruded by the Kaminak Batholith to the east. Wherever units 3 and 4 were examined in the vicinity of the contact they face away from the batholith and the contact is markedly discordant. The basal phase of the younger cycle (unit 3, Fig. 1) is a thick succession of mafic to intermediate pillowed and massive lava flows. Interflow materials are present but rare. The basal portion possesses many iron-rich flows and sills in addition to normal basalts. Iron-rich gabbroic dykes cutting the upper portion of the underlying older group may be feeders for this mafic sequence. Andesite flows and some breccias occur towards the top of unit 3. The maximum thickness of unit 3 is approximately 30,000 feet northwest of Turquetil Lake. However, at the extreme west end of the Kaminak Batholith unit 3 is entirely missing. The upper part of the younger cycle (unit 4, Fig. 1) is a complex of intermediate to felsic breccias, tuffs and flows and exhalite. Rhyolite is prominent in the upper felsic phase. (e.g. at 62°04'20"N and 45°52'30"W; MnO = 0.07, TiO_2 = 0.61, CaO = 3.4, K_2O = 1.7, SiO_2 = 69.8, Al_2O_3 = 14.0, MgO = 1.5, FeO = 3.8, Fe_2O_3 = 0.5, Na_2O = 3.6, P_2O_5 = 0.10, CO_2 = 0.6, H_2OT = 1.7.) Very coarse angular breccias are present locally and at two localities magnesian alteration zones were found stratigraphically beneath relatively thick portions of the exhalite zone. The exhalite zone lies about midway up in unit 4. The maximum thickness of unit 4 exceeds 15,000 feet in the vicinity of Spi Lake and may be the thickest felsic complex in the examined portion of the Belt. Along strike to the north and east this felsic phase thins. To the north it appears to be replaced by a thick conglomerate unit. To the south the group formed by units 3 and 4 may envelope the Turquetil Batholith.

South of Carr Lake the group formed by units 3 and 4 is conformably overlain by another mafic to felsic volcanic cycle (Fig. 1). The mafic phase of this group (unit 5, Fig. 1) is characterized by amygdaloidal basalt pillow lava, interflow exhalite and thick gabbro sills. A large gabbroic sill, at least eight miles long and averaging two thousand feet in thickness and located northwest of Carr Lake may be one of these (Fig. 1). One 250-foot-thick massive rhyolite flow is present. Unit 5 reaches at least 10,000 feet in thickness. It is conformably overlain by several thousand feet of coarse intermediate to felsic flow breccia, polymict breccia and intrusive porphyries (unit 6, Fig. 1) constituting the upper part of the group.

Unconformably overlying the entire volcanic sequence is a complex of varved argillite ("greywacke") and shaly iron-formation (unit 8, Fig. 1). Locally the volcanics and sediments are "back to back" as in the classical Timiskaming case in the Superior Province[3].

Structure

The dominant structural feature of the Turquetil Lake area is a northeast trending regional anticline (Fig. 1). A second major fold, a regional syncline crosses the area in an easterly direction. On the basis of folding of the axial plane of the syncline and crosscutting of the axial plane foliation of the syncline by the axial plane foliation of the anticline, the syncline is interpreted to be the older structure. The syncline must also have been present prior to the deposition of the sedimentary group and been recumbent at least locally. The intrusion of the batholiths probably created the central anticline and brought all the supracrustal rocks to their approximately vertical dips.

Metallogeny

The distribution of the exhalite facies established previously[1, 2] was extended to the west in the area of Figure 1. North of Turquetil Lake a separate area of predominantly sulphide facies was defined; another south of Quartzite Lake, may exist. The sulphide facies so established are contained within the much more widespread and continuous central zone (Fig. 1) of carbonate facies.

"Larder Lake" type of carbonate facies exhalite[4] was recognized in this area and extended west, north and east of Turquetil Lake (Fig. 1). The unit (or units) may be as much as 175 feet thick, is often cut by a variety of quartz veins, possesses micaceous accessories and weathers to an orange-brown rough surface. The fresh surface is grey, beige or green and displays a "fudge" texture, often with finely disseminated pyrite and rarely arsenopyrite. Bedding, either cherty banding or micaceous laminae is present but relatively rare. Carbonate and/or magnesian alteration is found subjacent to the zone at some localities. The zone appears to be folded conformably with the host rocks both on a regional and local scale and possesses the two foliations discussed under "Structure". West of the Turquetil Batholith the carbonate zone immediately overlies the uppermost basalts of unit 3. A probable second "Larder Lake" exhalite zone lies some distance up in the felsic volcanics of unit 4. North of Turquetil Lake the exhalite zone lies within argillaceous sediments. Felsic volcanics lie immediately to the east and basalts to the west. Lack of sufficient "facing" data along this part of the exhalite zone in the core area of the main synclinal structure precludes ready correlation of the zone. A possible magnesian alteration zone at lat. 62°00'40", long. 95°54' suggests a west facing.

Significant extensions of the main zone of exhalite in the group formed by units 3 and 4 were located at 62°14'50"N; 95°15'45"W (mixed facies) and 62°02'25"N; 95°46'20"W (carbonate facies). The latter occurrence is a zone of mostly massive siderite with some chert/carbonate banding, within rhyolite flows and breccias. It attains 75 feet in maximum thickness and lies over a magnesian alteration pipe.

The upper felsic phase of the oldest cycle (unit 2) possesses abundant banded exhalite. A lower exhalite zone was found at 61°51'15"N, 96°17'20"W (oxide); 61° 55'35"N, 96° 11'40"W (oxide) and running as mixed facies for several miles north of Heninga Lake (Fig. 1). The latter occurrence is the most persistent and thickest, locally exceeding 120 feet. An upper exhalite zone was found at 61°48'30"N, 96°17'W where it is banded siderite, chert and magnetite exceeding 200 feet in thickness and extending for several miles. It was also found north of Heninga Lake (Fig. 1) where it is predominantly sulphide facies. No extension of this zone was found on Maguse River at the summit of the oldest group even though the contact with the overlying group is exposed.

In the Wilson Bay area a thick zone of felsic pyroclastics and exhalite has been defined (Fig. 1). The felsic volcanics are tuffs and breccias ranging up to rhyolite in composition. Banded siderite/chert exhalite was located at 62°19'30"N, 92°44'40"W, within this group as well as much disseminated sulphide and probable sulphide pyroclastics. Gold mineralization is present in ore grade at one sampled locality (Table 1) in felsic volcanics north of the main band. This occurrence defines the approximate northern limit of the carbonate (sulphide) central zone to the east.

It appears that exhalite facies may change with time in some localities. In the Turquetil Lake area there may have been a shift of the facies boundaries to the north with time such that an older volcanic sequence with carbonate exhalite is succeeded by a younger volcanic sequence with oxide exhalite, and so on. Another problem is posed by shaly or "Timiskaming" type iron-formation. Shaly iron-formation is widely distributed in association with "unit 8". This unit lies with pronounced unconformity on older volcanics in the western part of the area. Hence, shaly oxide iron-formation is often superimposed "out of context" on the older, purely exhalite facies zone. The consequent difficulties in drawing exhalite facies boundaries is exemplified northeast of Turquetil Lake.

Preliminary Analysis Au/Ag Assays

100 samples from 82 sites were analyzed by a combined fire-assay atomic absorption technique for gold and silver. The sites were mostly varieties of exhalite, but emphasized sulphide-rich types. Duplicates of individuals and sites were run as well as a few multiple samples from individual sites. A representative suite of the gold assays is presented in Table 1.

The range is comparable to that found in the exhalites of the south margin of the Abitibi basin (5), i.e. from a background of less than 5 p.p.b. to ore grades greater than 1,500 p.p.b. The results indicate that the regional and many of the interflow exhalite zones are anomalously rich in precious metals, particularly sulphide and sulphidic carbonate varieties. Oxide exhalite, interflow exhalite in basalt sequences, and shaly "Timiskaming" iron-formation are generally at or near background.

Completion of the Ferguson River Section

The stratigraphic section along the Ferguson River, begun last year[2], was completed. Unit "9" was found to have an additional, relatively thin, zone of felsic volcanics, tuffs and breccias and shaly sediments near its base (Fig. 1). The rest of the unit is basaltic to dacitic, pillowed and massive lava with interflow exhalite. An irregular but prominent gossan was discovered at 62°10'30"N and 93°27'20"W. Unit "9" attains at least 9,000 feet in thickness. To the north is a zone of felsic porphyries and granitoid rocks having an outcrop width of 3,500 feet. Local banding and breccia texture suggests that this unit may be a complex endogeneous dome. It is followed to the north by poorly exposed intermediate to mafic flow rocks. No stratigraphic facings within the felsic porphyries or in the flow rocks to the north were obtained. Since they are located approximately on a regional synclinal fold axis, the orientation of the units remains problematical.

A New Archean Alkaline Intrusive Province

A complex alkaline stock two miles in diameter was discovered centred on 62°00'20"N and 96°24'W. A variety of trachytoid porphyritic syenites; melanocratic, pyroxene (aegerine?)-rich syenites; and a carbonate-rich mafic syenite cut by apophyses of aphanitic pink syenite are the main types noted. All but the last are covered by an unusual looking black lichen. The host Archean volcanics are fenitized near the contact. The stock is unconformably overlain by the Montgomery Lake and Hurwitz Groups of Aphebian sediments (Fig. 1).

The alkaline/carbonatite complex described by Davidson[6] at northeast Kaminak Lake and the poorly exposed alkaline stock discovered by Ridler[2] north of Last Lake, fall on a straight line with the new discovery. This line runs N71°E subparallel to the trend of the Padlei–Kaminak–Quartzite Lake trough of Hurwitz sediments (Fig. 1). Zones of mylonite up to 50 feet wide and subparallel to the foregoing trends were also noted in the vicinity.

It appears that the dominant structural control illustrated by the above is graben tectonics. The alkaline/carbonatite intrusions and the linear Hurwitz Group outliers are at least in part localized along the same tectonic feature or zones of faulting.

Extension of the Aphebian

About one mile north of the north end of Heninga Lake is a previously unmapped outlier of lower Aphebian sediments (Fig. 1). The sequence rests unconformably on Archean basement (volcanics and an alkaline complex) and dips northwest at forty-five degrees. No opposing limit was found to the northwest. To the northeast the outlier is cut off by a north-northwest-trending fault. The limit of the outlier towards Padlei was not defined. The outlier trends parallel to and lies within the Padlei–Kaminak belt trend.

In ascending order the sequence includes highly pyritic Montgomery Lake sandstone; Hurwitz or Montgomery Lake polymict conglomerate; Hurwitz "D" quartzite and a shaly quartzite. The total stratigraphic thickness probably does not exceed 800 feet.

Summary of Work to Date

The stratigraphy of the Kaminak Group of Davidson[6] is similar to the Abitibi Belt. An older volcanic group with a very mafic basal phase and an upper felsic phase culminating in rhyodacite is followed by volcanic groups possessing andesite and rhyolite in addition. Chemically the volcanics are tholeiitic or normal calc-alkaline. Each group appears to have definable territorial limits and relative age, becoming younger to the east. Although Archean alkaline intrusives were found, no volcanic equivalent similar to the trachyte suite at Kirkland Lake was found. Differentiated gabbroic sills with ultramafic phases are present but rare. No ultramafic lava flows have been positively identified. Mafic phases are characteristically massive or pillowed while felsic phases are tuffs, breccias and subvolcanic intrusions. The mafic phases are of great lateral extent while the felsic phases change rapidly in thickness along strike or terminate abruptly. Individual centres of felsic volcanism can thus be defined. Homoclinal thicknesses may approach 50,000 feet while individual volcanic groups may attain 40,000 feet. Major

TABLE I

#	* Au in p.p.b	Rock Type	Setting	Lat. N.	Long. W.
66-71	55 15	Massive pyrrhotite exhalite.	Spot outcrop of sulfide facies within main zone of exhalite near top of unit 4.	62°14'25"	95°10'45"
74-71	145 65	Pyritic banded chert, magnetite, chlorite, exhalite	2 to 6 inch thick interflow in andesite flow sequence within unit 8.	62°09'20"	93°24'15"
84-71	760 430	Pyritic, cherty tuff	2 ft. thick, sulfide exhalite at contact of older rhyodacite breccia and younger andesite pillow lava near top of unit 8	62°10'00"	93°26'10"
99-71	20	Slightly magnetic, pyritic, massive siderite.	Massive carbonate exhalite near top of unit 7.	62°20'25"	93°42'30"
109-71	45	Pyritic chloritite interbanded with chert/magnetite exhalite.	2 ft. thick interflow in lowermost unit 9	62°08'30"	93°30'45"
124-71	320 355	Massive pyrite with some sphalerite and magnetite.	Fist sized piece of float.	62°09'35"	93°10'30"
223-70	20	Pyritic, graphitic slate; trace chalcopyrite.	50 ft. thick interflow sediment in basalts of unit 7.	62°25'00"	94°34'20"
224-70	15	Sugary quartz with laminae of pyrite	Possible 2 ft. thick pod of exhalite in rhyolite pyroclastics of unit 6.	62°21'00"	94°42'20"
228a-70	5	Pyritic, graphitic slate; trace chalcopyrite	5 ft. thick interflow sediment in basalts of unit 7.	62°24'25"	94°36'40"
282-70	5	Banded chert/siderite exhalite; no visible sulfide	1 ft. thick exhalite zone in felsic tuffs of unit 6	62°15'50"	94°59'20"
310-70	260 295	Pyritic, siliceous, massive siderite	Carbonate exhalite fragment in rhyolite breccias towards the top of unit 6	62°15'00"	94°56'30"
338-70	10	Pyritic, cherty laminated tuff	5 ft. band in andesite breccia of unit 7	62°17'05"	94°51'00"
349-70	35	Laminated chert fragments in coarse massive pyrite matrix	Sulfide rich phase of main exhalite zone at top of unit 4	62°14'55"	95°08'00"
1037-71	5	Laminated magnetite with rhombs of siderite	"Shaly" oxide iron formation from unit 8	62°13'35"	93°11'00"

TABLE (cont'd.)

#	*Au in p.p.b.	Rock Type	Setting	Lat. N.	Long. W.
1048-71	250 150	Pyritic, carbonate rich zone	Highly foliated intermediate volcanics, near exhalite zone in unit 8.	62°00'55"	93°39'35"
1049-71	75	Massive siliceous carbonate with disseminated pyrite and arsenopyrite.	Maximum 75' thick carbonate exhalite associated with felsic breccias, and andesite flows near top of unit 8.	62°10'15"	93°24'40"
111-71	240 245	Massive iron sulfides plus chlorite and quartz.	Interflow exhalite, less than 10 ft. thick in large xenolith in agmatite near unit 8	61°58'40"	95°13'45"
1145-71	5	Laminated magnetite	Probable main zone exhalite near top of felsic volcanics in unit 8 (unit 4?, unit 6?)	62°00'10"	95°12'20"
1205-71	4600 6620	Pyritic felsic volcanic	Spot outcrop of felsic breccia in unit 8. Some of the fragments are pyrite. Much carbonate exhalite in vicinity.	62°21'30"	92°42'30"
1296-71	35	Pyritic felsic volcanic	Spot outcrop of felsic breccia near base of unit 8. Some of the fragments are pyrite.	62°23'15"	94°03'50"
2040-71	20	Pyritic siliceous carbonate	Main exhalite zone in unit 8.	62°25'25"	94°19'20"
2047-71	10	Shaly magnetite iron formation	Quartz, biotite schists, meta-sediments perhaps equivalent to unit 8.	61°36'20"	94°16'45"
2068-71	290 275	Pyritic felsic volcanic tuff and breccia.	Near top of unit 6	62°20'10"	94°26'20"
2123-71	10	Disseminated and laminated pyrite in cherty sediment	Interflow exhalite, 30 ft. thick, in basalts of unit 7.	62°08'30"	94°12'45"
2125-71	10	Pyrrhotite rich gabbro	Magnetic high in mafic phase of Kaminak Batholith.	62°08'10"	94°26'40"
2131-71	20	Pyritic interflow	3 ft. thick interflow exhalite in basalts of unit 7.	62°12'15"	93°54'45".

*Two numbers indicates two separate assays of same sample.

zones of exhalite are associated with and often surmount major felsic units. Clastic sediments, principally banded shale/siltstone and associated shaly iron-formation are associated with the main felsic units, follow them or are lateral equivalents and are very widely distributed. Conglomerate is characteristically present but rare, favouring proximity to major accumulations of felsic volcanics. No extensive sedimentary terrains outside the Belt and analogous to the Pontiac Group of the Abitibi Belt have yet been defined.

Structurally, the various groups are characteristically conformable with each other even though pronounced angular unconformities are present locally. Each major volcanic group appears to have a complex batholithic core which intrudes the group. A true basement to the Kaminak Group is yet to be found.

The structural style of the Kaminak Group in the area examined resembles that of the Superior Province in northwestern Ontario characterized by domes and intervening synclinoria. Major folds are persistent for many miles and trend east-west. The presence of angular unconformities within the sequence and accumulating evidence for polyphase deformation preclude a simple "Kenoran Orogeny" interpretation of the tectonic history.

The metallogenic suite of greatest interest in the Abitibi Belt, exhalite, is abundantly developed in the Kaminak Group. Regionally, facies boundaries trend east-west, and define a central carbonate/sulphide facies zone flanked to north and south by oxide. Proximal zones, judged by the presence of underlying alteration pipes, within the main zones are found within centres of felsic volcanic accumulation. Base and precious metals are present in anomalous amounts in the proximal varieties but precious metals are widely distributed in distal varieties as well.

[1] Ridler, R.H.: Volcanic stratigraphy and metallogeny of the Kaminak Group; in Report of Activities, Pt. A, April to October, 1970, Geol. Surv. Can., Paper 71-1, pt. A, p. 142-148 (1971).

[2] Ridler, R.H.: Volcanic stratigraphy and metallogeny of the Kaminak Group; in Report of Activities, Pt. A, April to October, 1971, Geol. Surv. Can., Paper 72-1, pt. A, p. 128-134 (1972).

[3] Thomson, J.E.: The Keewatin–Timiskaming unconformity in the Kirkland Lake district; Roy. Soc. Can., Trans., ser. 3, v. 40, sect. 4, p. 113-124 (1946).

[4] Ridler, R.H.: Relationship of mineralization to volcanic stratigraphy in the Kirkland–Larder Lakes Area, Ontario; Geol. Assoc. Can., Proc., v. 21, p. 33-42 (1970).

[5] Ridler, R.H.: Metallogeny and iron formation, Kirkland Lake–Noranda–Cadillac; Geol. Assoc. Can.–Mineral Assoc. Can., Program and Abstracts, p. 44 (1970).

[6] Davidson, A.: Precambrian Geology, Kaminak Lake map-area, District of Keewatin; Geol. Surv. Can., Paper 69-51, 27 p. (1970).

89. VOLCANIC ROCKS OF THE PRINCE ALBERT GROUP

Project 720062

Mikkel Schau
Regional and Economic Geology Division, Ottawa

The Prince Albert Belt bisects Melville Peninsula and continues in a southwesterly direction past Committee Bay for a hundred miles or more[1,2]. Volcanic rocks appear to be most abundant at either end of the belt. Work (28 ground traverses and a few aerial traverses) concentrated on basic and ultramafic intrusives and the metavolcanic parts of the country rock within the southwest portion of the belt (56 J, K). The sequence of events in this belt is summarized in Table 1 and includes two distinct periods of folding.

The metavolcanic rocks appear to structurally overlie a sequence of metasediments composed of gneissic psammites, garnet-bearing schists, banded iron-formations and a coarse-grained white quartzite; (see F.H.A. Campbell (720054) this publication). Because top indicators were not seen it is not known if this structural relation is an indication of the stratigraphic succession.

Greenstones are not common; a 400-metre stratigraphic thickness is the greatest recorded. Volcanic structures are lacking or strained beyond recognition. Because some iron carbonates are interbedded with centimetre to metre thick greenstone layers it is assumed that at least some greenstones represent past ashfalls. Local breccias may be of volcanic origin but a tectonic genesis due to ductility contrast between greenstone and carbonate layers is more likely. There appear to be chemical differences in the greenstones. Lighter "meta-andesites" form a small proportion of the mainly "meta-basaltic" section. Some of the quartz-sericite schists may be the acid representatives of the volcanic succession. The volcanic rocks were first deformed into doubly but shallowly plunging northeast-trending isoclinal folds with variably dipping axial planes which extend for over a kilometre along the strike of axial planes.

Lenticular ultramafic bodies are found mainly in or near greenstone horizons although a few isolated bodies occur in the gneisses. The bodies in the greenstones have been deformed in the same way as their host rocks. Bodies in the gneisses are not continuous with the structural features of the gneisses although in a few cases the gneissosity is bent around the ultramafic bodies while in others the body is fractured and brecciated, surrounded by a talc or greenschist envelope, and positioned along a lineament.

Ultramafic bodies are probably remnants of a tectonically dispersed sill and dyke complex. The stratigraphic restriction of ultramafic bodies coupled with local discordant contact relations suggests the presence of both sills and dykes. That the ultramafic was once liquid is deduced from an internal layering which is represented by alternate layers of Mg-rich, metre-thick, and of Ca-Mg rich, less than half a metre thick, metamorphic minerals. These layers are at an angle to the major foliation of host rock; divergences are usually about 20 degrees but divergences up to 84 degrees have been recorded. No evidence for an extrusive origin has been recognized even although ellipsoidal bodies with protruding knobs were seen in an ultramafic body, as these cut across the internal layering of the ultramafic bodies and were confined to an isoclinal fold nose. Boudins of layered ultramafic bodies are from a centimetre to 100 m long, and larger ones are suspected.

TABLE 1

Sequence of events of Prince Albert Belt

Material Involved	Event	Physical Nature of Country Rock	Geometry of Product	Product	Time
All rock types	Glaciation, erosion and uplift	brittle		Glacial sediments +Great unconformity	
Basic liquid	Intrusion	brittle	NW-trending vertical dykes	Diabase	No data (1.25 by ?)
Acid liquid	Emplacement	locally ductile	E-W elongated massive stock	Granite (II)	No data
Previous rocks	Hudsonian Orogeny	ductile	upright open folding (steeply plunging and SSE trending)	Medium-grade metamorphic equivalents of previous rocks	~ 1.7 by (K-Ar)
Basic liquid	Intrusion	brittle	NW(??)-trending steeply dipping dykes	gabbro	
Acid liquid	Emplacement	locally ductile	small stocks, dykes	Granite (I) ±gneiss (?)	
Previous rocks	Kenoran or later (Mid-Aphebian orogeny?)	ductile	shallowly and doubly plunging NE-trending isoclinal folds (variably dipping axial planes)	medium-grade metamorphic equivalents of previous rocks	No data
Ultramafic liquid	Intrusion	brittle	sills; few dykes	layered ultramafic bodies	later
Basic liquid	Extrusion	brittle	planar, horizontal flows and ash beds	volcanic rocks	Contemporaneous (with row below)
Sediments	Deposition +Precipitation	brittle	horizontal planar beds	more or less sorted clastic rocks and occasional chemical sediments	Contemporaneous (with row above)

The relationships between gneisses, greenstones, and ultramafic bodies are complex (see Frisch (720070) this publication). Some gneiss was formed before, or nearly at the same time, as the isoclinal folding took place; some gneiss post-dates this event and may be related to the formation of granite (I). Hornblende-bearing gneisses and amphibolites with occasional garnets and epidote are higher grade metamorphic equivalents of the greenstones. However, the reason for the varying grades of metamorphism observed in the region is not known. Thus, some greenschists have actinolite rosettes growing along the schistosity; some gneisses have different biotite flakes oriented parallel to each of two axial surfaces that are at right angles to each other; and oriented acicular minerals are deformed and cut by new aligned minerals suggesting that there were at least two periods of formation of metamorphic minerals.

After gneissification had ceased gabbro bodies as well as a white garnet-bearing, muscovite granite (I) and pegmatite were emplaced. The gabbro bodies occur near or crosscut greenstone-ultramafic complexes and sinuous gabbro dykes cut through the gneisses. Their contacts are sheared and locally sulphide-bearing; the mineralogy is that of a degraded gabbro. Tension gashes and veins in gabbro are felsic or epidotic. The granite engulfed part of the greenstone-ultramafic complex so that large blocks of this complex are now surrounded by granite. All rock types were then redeformed into upright open, south-southeast-trending steeply plunging folds. After this last penetrative deformation a red homogeneous granite body which cuts across the deformed foliation was emplaced. Finally there are the later, fresh, planar diabase intrusions of the Mackenzie swarm; these were not studied.

Scarce copper sulphides were seen near greenstone-ultramafic-gabbro contacts at two localities; both had been abandoned by prospectors in prior years. No nickel minerals were seen. Soapstone is present in a few ultramafic bodies. Iron-formations of the oxide, carbonate, and sulphide facies form useful marker horizons but no deposits with any economic potential were found this season.

The feasibility of using computer filed field notes is being evaluated.

[1]Heywood, W.W.: Geological notes, northeastern District of Keewatin and southern Melville Peninsula; Geol. Surv. Can., Paper 66-40 (1969).

[2]Heywood, W.W.: Geological notes, northern District of Keewatin; Geol. Surv. Can., Paper 61-18 (1961).

90. HISTORICAL EVIDENCE OF LAND USE IN A POLLEN PROFILE FROM OSOYOOS LAKE, BRITISH COLUMBIA

Project 690064

T. W. Anderson
Terrain Science Division, Burlington, Ontario

Pollen analyses were carried out on cores collected by Dr. B. St. John, Canada Centre for Inland Waters, from recent sediments in five lakes in the Okanagan Valley, British Columbia, namely, Okanagan, Wood, Kalamlka, Skaha and Osoyoos. The objective of the study was to identify pollen markers which could correspond to either man-induced changes in the valley or to some dated pollen horizon in the regional pollen record. Dated pollen horizons provide estimates for rates of sedimentation which are essential to staff at CCIW in understanding geochemical input into lake systems.

An abbreviated pollen profile from Osoyoos Lake (Fig. 1) illustrates the general trend in nearly all the lakes. Total pollen concentration is high at the base (33 cm depth), declines to minimum values at 23 cm, and increases to higher values toward the surface. Spruce, pine, hemlock and grass decline sharply at 28 cm, whereas poplar, alder, willow and sagebrush increase to significant peaks at 26 cm.

Investigations into the history of land settlement in the Okanagan Valley reveal a number of key events to which the pollen record may be correlated[1]. Cattle were first trailed into the valley from the south about 1860, and cattle ranching was the most important industry until the early 1890's, so much so, that overgrazing depleted much of the rangeland. Experimental data from areas subjected to overgrazing not only show decreases in the availability of forage bunch grass, but reveal significant increases in sagebrush[2]. Sagebrush has a low palatability value and its dominance at the decline in grass pollen is taken to signify extremely overgrazed conditions about 1890.

By 1892 many ranchers were finding cattle-raising unprofitable and, consequently, turned to wheat growing, dairying and fruit farming. This caused a pronounced change in the flora on the lower valley benches and floodplains through cutting, burning and clearing, the effects of which are apparent in the pollen diagram. Peaks in poplar, alder, willow and weedy herbs (Tubuliflorae and Chenopodiaceae) represent a younger flora which quickly immigrated onto the newly disturbed and burned-over areas. Clearing, land-breaking and faulty application of irrigation-water accelerated surface run-off bringing about a sharp increase in the sedimentation rate in Osoyoos Lake. The minimum point in the total concentration curve could denote such a fruit land boom and poor land management during the years 1890 to 1900. However, a decline in the boom occurred between 1911 and 1920 (the war years) when fewer trees were planted. Sediment influx was minimal at this time, hence the higher pollen numbers between 10 and 15 cm. Not until 1927 did extensive clearing and fruit farming take place around Osoyoos Lake, a fact which may possibly explain lower pollen values at 8 cm. By the early 1950's final stabilization had begun. With increasingly efficient water application

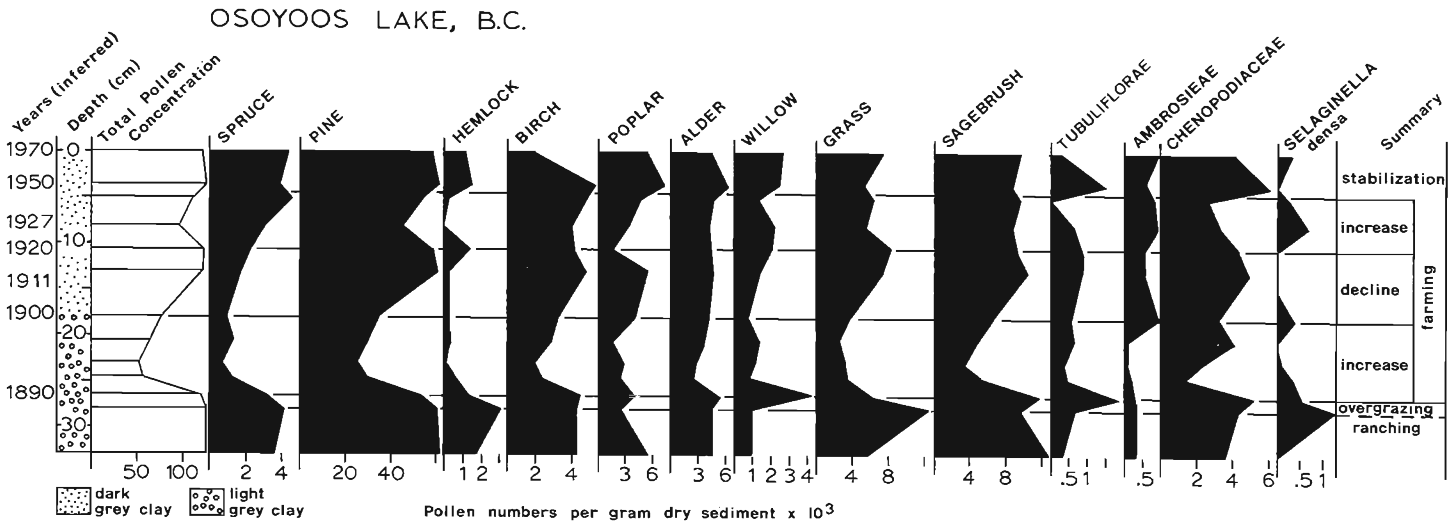

Figure 1. Pollen diagram from Osoyoos Lake, British Columbia.

through adoption of the sprinkler system, downslope seepage and soil erosion were checked. This resulted in higher yields and better markets were obtained. Higher pollen numbers near the surface of the diagram may signify this trend towards better land management.

[1]Ormsby, M.A.: A study of the Okanagan Valley of British Columbia; unpubl. M.A. thesis, Univ. British Columbia, 190 p. (1931).

[2]Tisdale, E.W.: The grasslands of the southern interior of British Columbia; Ecology, v. 28, p. 346-383 (1947).

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91. QUATERNARY PALYNOLOGY, MANITOBA AND QUEBEC

Project 690064

R.J. Mott
Terrain Sciences Division, Ottawa

The 1972 field season involved collecting lake bottom sediment cores in two provinces for Quaternary mapping projects in those areas. The cores will provide samples for radiocarbon, palynology and other paleoecology studies.

In the area being mapped by R.W. Klassen in northern Manitoba (Project 710092), two cores were obtained from small kettle lakes in a large bifurcating morainic ridge about 40 to 50 miles due north of Thompson. One lake (56° 16.2'N, 97° 57.7'W) is at an elevation of slightly less than 1,000 feet while the second (56° 29.5'N, 97° 44'W) is just above that elevation. Both lakes are therefore near or above the highest level of Glacial Lake Agassiz in this area. Samples of basal organic sediments from both lakes have been submitted for radiocarbon dating and should provide minimum dates for deglaciation of the area.

A third lake was cored near Flin Flon, Manitoba (54° 44.5'N, 101° 40.8'W) in an area of Precambrian bedrock. The lake is at an elevation of about 1,000 feet and was not covered by Glacial Lake Agassiz. Carbonates do not occur in either the bedrock or the glacial deposits surrounding the lake in contrast to the abundant carbonates present in the glacial deposits containing the two lakes near Thompson. A date on the basal organic sediments, while providing a minimum age for deglaciation, will also complement the Thompson area dates farther north. Surface samples from the mud/water interface of several lakes were collected in both areas to determine the modern pollen spectra.

Two lake bottom sediment cores were collected in the Sept-Iles area of Quebec for a mapping project by Lynda Dredge (Project 710083). A small kettle lake in a morainic ridge about seven miles northeast of Sept-Iles (50° 17.8'N, 66° 17.5'W) was the site of one core. At an elevation of about 430 feet the lake is at or near the marine limit in the area. The second lake cored occupied a small kettle hole in an outwash delta at the southern end of fiord-like Walker Lake in Sept-Iles-Port Cartier Provincial Park (50° 08'N, 67° 07'W). This lake is at an elevation of 400 feet which is close to the marine limit in the area. Dates on the basal organic sediment from both lakes should provide minimum dates for deglaciation and for emergence from the sea. Surface samples from the mud/water interface of several other lakes were also collected.

Ramsay Lake is a small lake about 3.5 miles north of Eardley, Quebec and is within the boundaries of Gatineau Park. It is at an elevation of 656 feet and was formed where glacial deposits blocked a small valley in the Precambrian bedrock upland. If the lake is below the limit of maximum marine submergence, a radiocarbon date on the basal organic sediment should provide a minimum age for isolation of the basin from the sea and, in either case, the date should be a minimum for deglaciation.

QUATERNARY GEOLOGY: ENVIRONMENTAL AND ENGINEERING GEOLOGY STUDIES

92. TERRAIN PERFORMANCE, MELVILLE ISLAND, DISTRICT OF FRANKLIN

Project 710042

D.M. Barnett and D.L. Forbes*
Terrain Sciences Division, Ottawa

The second field season[1,2] enabled remeasurement of thaw depths and gullying at selected disturbed sites in the Sherard Bay and Drake Point areas. The sites occur on Isachsen sand, Christopher shale and Quaternary alluvium. Three preliminary comments may be made: (i) a general equilibrium of geomorphic processes appears to be rapidly establishing itself in areas no longer subject to vehicle movement; (ii) at Sherard Bay the highest and most poorly vegetated site is actively gullying; (iii) vegetation is re-establishing itself at both Sherard Bay and Drake Point, even in some areas where the ground was churned.

Forbes surveyed, by level, eight disturbance sites at Sherard Bay to obtain a topographic profile enabling seasonal thaw depths to be judged topographically as well as sequentially and relative to climatic data. Weather records were maintained again at Sherard Bay. Low level vertical photography of the whole zone between Drake Point and Sherard Bay was flown by courtesy of the Department of the Environment. This photography will serve both as an inventory of terrain disturbance and as a bench mark against which to judge subsequent changes in the landscape.

[1] Barnett, D.M., and Kuc, M.: Terrain performance, Melville Island, District of Franklin; in Report of Activities, Part A, April to October, 1971; Geol. Surv. Can., Paper 72-1, pt. A, p. 137-139 (1972).

[2] Kuc, M.: The response of tundra plants to anthropogenic habitats in the High Arctic; in Report of Activities, Part B, November 1971 to March 1972; Geol. Surv. Can., Paper 72-1, pt. B, p. 105-112 (1972).

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*Graduate assistant.

93. DISTRIBUTION OF MARINE DEPOSITS, OTTAWA- St. LAWRENCE BASIN

Project 710081

N. R. Gadd
Terrain Sciences Division, Ottawa

Two principal phases of Project 710081 were carried out during the field season of 1972. An inventory of Champlain Sea marine clays and of landslide scars was carried out in the areas of western Quebec west of Lachute. The second phase of the project consisted of a very rapid reconnaissance of major parts of the St. Lawrence and Lac St-Jean basins with the purpose of establishing, within reasonable limits, the position of maximum shorelines of the Champlain and Laflamme seas. The data obtained will be amplified by previously published information and airphoto interpretation. A compilation of such information is in progress. Publication of a map showing revised boundaries of late-glacial Champlain Sea and Laflamme Sea, as well as the pattern of distribution of landslides within those limits, is anticipated.

The general comment may be made that marine limits north of the Ottawa-St. Lawrence system are higher than those in corresponding positions on the south (by as much as 200 feet). The highest known raised marine features are found in the area north of Montreal and similar maximum limit features are found at progressively lower levels both southwest and northeast of there along the 'north shore'. Marine limit features on the south side of the St. Lawrence Lowland are not as clearly defined as those on the north and relationships are less clear. The writer believes that marine limit features are obscured in the area between Lake Champlain and the Chaudière Valley by the fact that maximum marine levels in those areas were associated with drainage along the ice margin of water released from the Great Lakes, Lake Champlain and southern Quebec (south of the Highland Front morainic system). Where flow in this early drainage system was persistent enough to produce current-deposited gravels, the marine faunas were apparently unable to become established and therefore left no records. Positive evidence of marine submergence (i.e. presence of fossils) in some parts of those areas is found at levels well below limits one might project from clearly marked features in, for example, the vicinity of Quebec city.

94. ENVIRONMENTAL GEOLOGY - MOUNTAIN COAL MINING, ALBERTA AND BRITISH COLUMBIA

Project 720083

John E. Harrison
Terrain Sciences Division, Ottawa

The initial phase of a study of the geological, geomorphological and hydrogeological factors affecting mountain coal resource exploration, exploitation and subsequent coal land restoration, was carried out during the 1972 field season. Reconnaissance and data gathering were restricted to the Crowsnest Pass-Elk Valley area of Alberta and British Columbia with the exception of a brief trip to the Canmore area of Alberta. The location and extent of all surface mining activity and most underground mining, both past and present, were mapped in the Crowsnest (82G/10 E and W) Blairmore (82G/9W) and Tornado Mountain (82G/15W) map-areas. Thirteen surface mine locations with over thirty-five individual pits were examined in detail as well as the sites of former activity of fourteen underground mines. Waste rock dumps in each area were examined and data on aspect, profile, stability, associated deposits, composition, active geomorphic processes and vegetation were recorded. Preliminary analyses of these data indicate:

(a) Natural revegetation rarely occurs on slopes in excess of 30 degrees and the probability of successfully reclaiming such slopes without regrading is hampered by downslope creep of the surface material.

(b) Downslope creep, while sufficiently rapid to hamper revegetation, does not move a volume of material sufficient to regrade the slope over an acceptable period of time (less than 50 years). Creep movement tends to shorten the steep slope segments rather than reduce slope angles.

(c) Infiltration on most spoil is sufficiently high that run-off is available to form rills and gullies. The exception is where areas of drainage accumulation occur uphill from the spoil. Slope regrading by running water is therefore not an important process.

(d) Mineralogical and chemical changes at the surface appear minimal although physical breakdown of the softer rock types is rapid in many cases.

(e) Most slope failures are intimately related to moisture, usually in the form of water ponded uphill.

(f) Limited data suggest that failures on active spoil dumps are preceded by an accelerating creep phase offering the possibility of predicting such movements. Investigation of the exact mechanism of failure is continuing.

A limited number of geochemical and sediment samples were collected in the area. Data are not yet available. A small portion of the area, the Michael Creek valley was mapped using a modified Quaternary geology legend to evaluate the feasibility and usefulness of this type of specialized mapping in resource development, reclamation and facilities engineering.

95. TERRAIN PERFORMANCE, CENTRAL ELLESMERE ISLAND DISTRICT OF FRANKLIN

Project 720082

D.A. Hodgson
Terrain Sciences Division, Ottawa

The effects of construction and vehicle operation on a variety of terrain types were observed concurrently with a reconnaissance of surficial materials and landforms (Project 720081). There are two principal areas of activity on the western Fosheim Peninsula.

1. Eureka weather station and airstrip, where poorly lithified, weathered shale (Deer Bay Formation) and marine silts and clays have been disturbed to varying degrees over the past 25 years.

2. The recent extensive oil and gas exploration which includes ground seismic surveys, use of bladed roads and airstrips, and intensive movement around drill sites.

Churning of the surface by vehicles only occurs during the early summer thaw, and the low precipitation and limited run-off retard expansion of disturbed areas by natural processes. However, roads and airstrips are visually prominent and induce vegetation changes so that it is unlikely that they will merge with the surrounding landscape.

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96. GEOSCIENTIFIC STUDIES, NEW MONTREAL INTERNATIONAL AIRPORT REGION

Project 710044

D.A. St-Onge
Terrain Sciences Division, Ottawa

Field work on the geoscientific study of the New Montreal International Airport region was completed at the end of August 1972.

From June 1st to August 30th, 1972, 730 surface samples and over 1,000 borehole samples were analyzed in the field laboratory, Figure 1[1,2]. All the results are stored in a data bank from which they can be retrieved as computer maps or listings. The maps on drift thickness, bedrock topography or on any of the physical properties measured in the laboratory are usually printed at scales of 1:25,000 or 1:20,000; the scale can be modified depending on the user's requirements.

A standard surficial deposits map was also compiled at a scale of 1:25,000.

The results of this project were made available to various planning agencies (BANAIM and SATRA), ecologists (EZAIM) and engineers (CAIM). Programming the work so that results would be computer compatible made them rapidly available and insured that geoscience data would be incorporated in the decision making process related to future land use of the large region surrounding the new airport.

[1]St-Onge, D.A.: Etude géoscientifique, Région nord de Montréal; in Report of Activities, Part A: April to October 1971; Geol. Surv. Can., Paper 72-1, pt. A, p. 149-151 (1972).

[2]St-Onge, D.A., and Scott, J.S.: Geoscience and Ste-Scholastique; Can. Geog. J., v. LXXXV, no. 1, p. 232-237 (1972).

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97. ENVIRONMENTAL GEOLOGY PROTOTYPE STUDY - OTTAWA-HULL REGION

Project 700049

J.S. Scott
Terrain Sciences Division, Ottawa

Mapping of surficial geology at a scale of 1:50,000 was completed by S.H. Richard for the Carleton Place (31 F/1 E), Winchester (31 G/3 W), Russell (31 G/6 W), Thurso (31 G/11 N, south of Ottawa River), Quyon (31 F/9 E) and Wakefield (31 G/12 W) map-areas. J-S. Vincent completed mapping of surficial geology at a scale of 1:50,000 of parts of the Wakefield (31 G/12) and Thurso (31 G/11 W) map-areas east of the Gatineau River and between Ottawa River and 45°37'N Lat.

Some of the significant features of the surficial geology include fossiliferous marine beaches located two miles northeast of Almonte (31 F/1 E). Marine shells (mainly Macoma balthica) collected in 1971 by S.H. Richard from the highest of one of these beaches have yielded a C^{14} date of 11,200±160 yrs. B.P. (GSC-1672). Marine clays, deposits of the Champlain Sea, are of widespread occurrence throughout the areas mapped but are particularly prevalent in areas to the south and east of Ottawa. These clays are generally grey, massive, calcareous and fossiliferous. In the Russell (31 G/6 W) map-area, however, the upper four to twenty feet of the clay beds are noncalcareous, nonfossiliferous and display thick, horizontal bands of burgundy-coloured clay that grade upwards into bands 1 to 2 inches in thickness. The most likely source of red coloration is the large outlier of Queenston shale that is preserved in a downfaulted block of the Paleozoic platform northeast of the Gloucester Fault between Russell and Vars.

Development of methods for the compilation, processing and presentation of geological information with the use of computers has been continued by J.R. Belanger. This work has resulted in the development of the Environmental Geology Information System (EGIS) which is being applied to urban geology data collected for various urban centres of Canada under provisions of the federal government's 1971 Special Employment Plan. A reference manual describing the development of the system and its application for environmental geology purposes is nearing completion.

An inventory of landslides of the region, based on an analysis of aerial photographs, topographic maps and existing geological and geotechnical information was completed by P.T. Hanley. Although the method of analysis limited accurate measurement to landslides greater than 300 feet in width along the slope, and limited slope height evaluation to available contour information, the following general conclusions on the occurrence of landslides were drawn:

1. Landslides occur in three well-defined geomorphological zones: a) along terrace bluffs of the Ottawa River notably the terrace at an elevation of 200 feet; b) along valleys tributary to Ottawa and Gatineau Rivers generally at elevations above the 200-foot terrace; c) along banks of Ottawa and Gatineau Rivers.

2. Landslides are rare on slopes less than 25 feet in height. Above this apparent threshold height no clear relationship exists between slope height and size of landslide.

3. The majority of landslides, and all of these that have regressed a distance greater than 2,000 feet, have occurred in marine clay deposits at an elevation above 250 feet.

4. No apparent relationship exists between the thickness of marine clay and landslide frequency.

5. Sixty per cent of the identified landslides occurred in slopes of marine clay overlain by sand or gravel.

6. Active erosion at the base of the slopes is not a prerequisite for slope failure.

QUATERNARY GEOLOGY: INVENTORY MAPPING AND STRATIGRAPHIC STUDIES

98. CO-OPERATIVE TERRAIN MAPPING SOUTH-CENTRAL BRITISH COLUMBIA

Project 720004

N. V. Alley* and R. J. Fulton
Terrain Sciences Division, Ottawa

The Soils Division of the British Columbia Department of Agriculture is currently engaged in an ARDA-financed lands and soils classification of much of British Columbia. The map-units that they are using are based largely on geomorphology. The Geological Survey of Canada has entered into a co-operative program with them in order to advise them on geomorphology and landform mapping in British Columbia and to provide terrain information for some of the areas they are covering. Dr. N. F. Alley was posted to the Soils Division office in Kelowna to make him available for consultation at all times. During the summer, terrain mapping and preliminary stratigraphic investigations were undertaken in the northern half of the Kelowna map-area (82E/NW) and the western half of the Seymour Arm map-area (82M).

Mapping in the Kelowna area revealed that extensive areas of ice-contact deposits commonly mantle the plateau terrain bordering Okanagan Lake. Thick till overlain by gravel occupies the major valleys. A complex of fans and deltas, which were probably graded to successively lower stands of former glacial Lake Okanagan[1], merge with lacustrine silts in the Rutland, Kelowna and Peachland areas. At least two tills, separated by nonglacial deposits and underlain by more than 50 feet of oxidized gravels, outcrop at several sites along Mission Creek.

Field work was conducted in the Seymour Arm map-area from July to September. Logging and mining exploration tracks were used as access to much of the upland area and inaccessible sectors were traversed by helicopter. Till and bouldery moraine are the dominant Quaternary deposits on the plateau terrain bordering the North Thompson and Adams Rivers. Ice-contact deposits are most common in the valley bottoms and usually overlie till. No multiple till successions were observed, although up to 80 feet of till underlain by at least 60 feet of silt, sand and gravel outcrop at several sites along the North Thompson River near Vavenby. Moraine ridges and hummocks are common within a mile of cirques in Wells Gray Provincial Park, the Shuswap Highland and along the Monashee Mountains. Numerous peat bogs, some containing three volcanic ashes, were cored in these areas. Palynological investigations of several of the cores should aid in understanding postglacial climatic changes and the subsequent events which led to the formation of the moraines.

[1] Nasmith, H.: Late glacial history and surficial deposits of the Okanagan Valley, British Columbia; Brit. Col. Dept. Mines Petrol. Resources, Bull. 46, 54 p. (1962).

*Kelowna, B.C.

99. SURFICIAL GEOLOGY AND GEOMORPHOLOGY OF MELVILLE ISLAND

Project 710041

D. M. Barnett and D. L. Forbes*
Terrain Sciences Division, Ottawa

During the second field season of the project, efforts were concentrated on drilling surface materials to a target depth of one metre using a modified SIPRE core barrel with teflon coating as well as testing a prototype Darry Engineering corer (St. Hubert, P.Q.), both driven by Haynes flexible drive power units. The Darry corer differed from the SIPRE in that it has a uniform diameter inner barrel split longitudinally for ease of core removal, which also confined any thawed material. A drilling stand was used for greater stability and to enable its use by only one person. The potentially greater flexibility was counter-balanced by the slight increase in time spent assembling and dis-assembling the corer. Transportation of the corers was, in part, by Bell '206' helicopter and, in part, by towing on a magnesium toboggan over snow-free terrain using a Honda ATC 90 motor tricycle; the latter mode was remarkably efficient and relatively inexpensive but abused the toboggans.

Each formation [1] was subdivided to include representative sites above and below the local postglacial marine limit (Fig. 1) comprising a well-drained site, a poorly drained site and north and south facing slopes. It was more efficient to dig through the active layer to the frost table and then to core the frozen material as drilling from the surface enabled thawed material to seep around the core and freeze. Site characteristics, pit walls and core were logged on a standard form. Shear vane and penetrometer values were determined on each of the pit walls. Pit samples and core were retained for field determination of moisture content and pH. Moisture content, including ice, was calculated, at approximately 10-cm intervals (depending upon stratigraphy and natural fractures), then selected samples were returned to the laboratory for determination of sand-silt-clay fractions, percentage of organic matter and, where appropriate, Atterberg limits.

The 106 cores sampled materials ranging from weathered Paleozoic to Quaternary sediments. One hundred cores had visible ice in them (terminology as in NRC Technical Memo. no. 79[2]) and, in some, several tens of centimetres of ice occurred in either massive or interlaminated form, sub-parallel with the ground surface. Of the other six cores, several reached lithified bedrock in the active layer, thus precluding the occurrence of ice at that seasonal stage. Occasional vertical ice bands, ice coatings and ice inclusions were observed. Rather more ground ice was encountered here than in the fifteen holes drilled in 1971 [3], however, the magnitude of occurrence is not as great as in the Mackenzie Delta region [4]. Both core logs illustrated in Figure 2 are from above the postglacial marine limit; one is from the generally fine-grained Christopher Formation and the other from the generally sandier Sabine Bay Formation.

One new sample of driftwood (composed of several small fragments) was located 16 km north-northwest of Rea Point at a height of 32 m. It appears similar to a sample from Drake Point at 79 m dated at >41,000 B.P. (GSC-1609) although the considerably lower elevation suggests that a postglacial date is probable.

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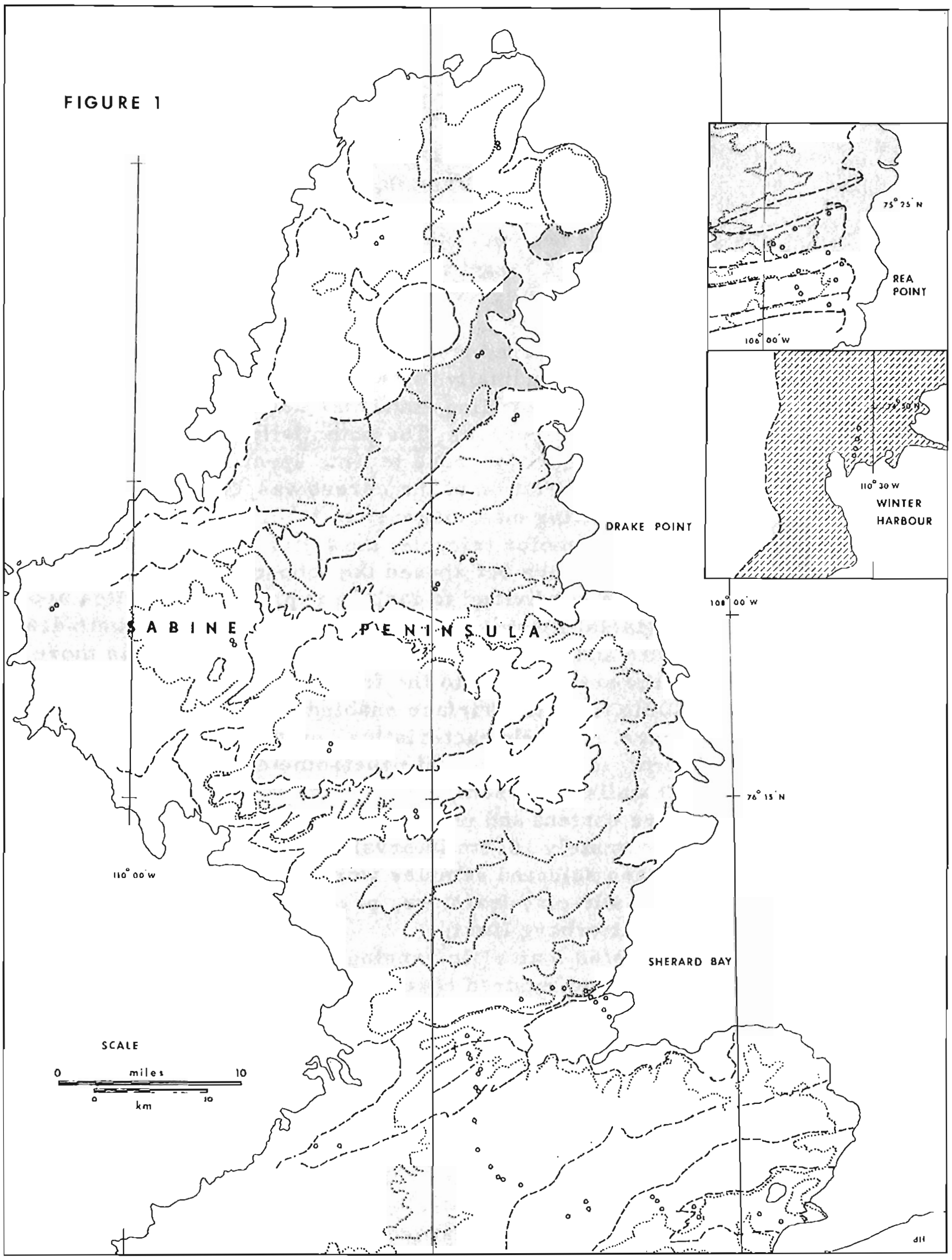
*Graduate student.



------ Approximate formation boundaries (in part after Tozer & Thorsteinsson 1964)

.... Approximate limit of postglacial marine transgression

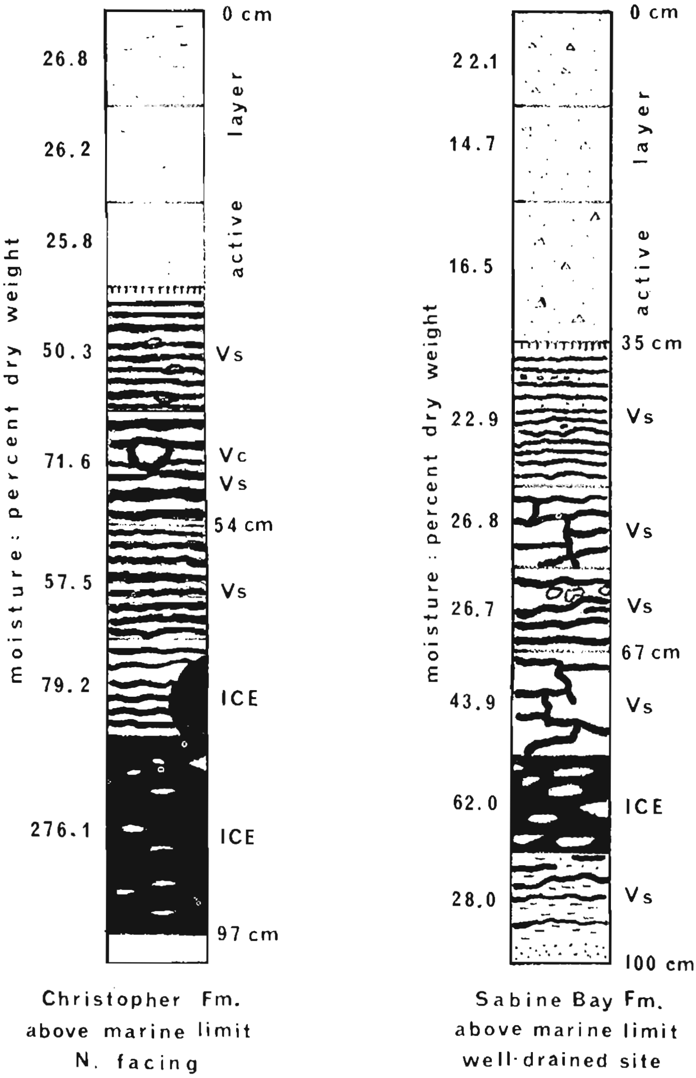
o Core sites

DOMINANT LITHOLOGY:

Shale

Sand, sandstone

Till, till veneer



SAMPLE CORE STRATIGRAPHY

dmb

Vc – ice coatings on particles

Vs – stratified or distinctly oriented ice formations

Figure 2.

The airphoto compilation of the postglacial marine limit on Sabine Peninsula was completed by Forbes and supplemented by field observations. On Christopher, Kanguk and Canyon Fiord Formations, below the marine limit, low-angle slopes (~2 degrees) are considerably more prone to slumping than equivalent slopes in apparently similar material above the marine limit. Analysis of core properties may reveal some clues to the causes of the differences.

[1] Trozer, E.T. and Thorsteinsson, R.: Western Queen Elizabeth Islands, Arctic Archipelago; Geol. Surv. Can., Mem. 332, 242 p. (1964).

[2] Pihlainen, J.A., and Johnston, G.H.: Guide to the field description of permafrost for engineering purposes; Natl. Res. Council, Can., Tech. Memo. 79, 23 p. (1963).

[3] Barnett, D.M. and Kuc, M.: Terrain performance, Melville Island, District of Franklin; in Report of Activities, Part A, April to October, 1971; Paper 72-1, pt. A, p. 137-139 (1972).

[4] Rampton, V.N. and Mackay, J.R.: Massive ice and icy sediments throughout the Tuktoyaktuk Peninsula, Richards Island and nearby areas, District of Mackenzie; Geol. Surv. Can., Paper 71-21, 16p. (1971).

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100. SURFICIAL GEOLOGY, SEPT-ILES - CAP CHAT, QUEBEC

Project 710083

Lynda Dredge*
Terrain Sciences Division, Ottawa

Field work was conducted in 1972 to acquire information about the surficial geology and stratigraphy of the Quebec north shore portion of the Cap Chat map-area. The work is part of a project begun in 1971. The basic elements of the landscape do not differ greatly over the area. A coastal plain of postglacial sediments separates the St. Lawrence River and the Laurentian uplands. The coastal terraces are composed of beach sand and marine clay, and till is the principal surficial deposit in the upland area. This report summarizes the principal findings which supplement or differ from the report given in Geological Survey Paper 72-1, Part A.

Till deposits and ice-flow directions

A sandy, granitic till covers most of the Cap Chat map-area. The ground moraine is up to 6 m deep. It is generally thicker here than in the area mapped in 1971, where large parts of the uplands are devoid of surface sediments. About 35 km inland from the coast, a fragmented end moraine was traced across the upland area (elevation greater than 300 m) for a distance of 75 km. This moraine was probably deposited by ice from the north-northwest. Nearer the coast, in the Baie Trinité map-area, smaller moraines were mapped. Where these forms have been found below the marine limit the upper part of the deposit has been texturally altered. The general trend of these moraines is southwest-northeast.

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*Graduate student.

In the Godbout area farther west a small arcuate valley moraine was also mapped. At the time of its deposition glacial ice was flowing through the valley from west-northwest. The orientation of two "fiord" valleys, Baie St. Nicholas and Mistassini, as well as small-scale abrasion marks also indicate a major ice movement from the west-northwest, in this area.

At the lowest elevations, where bedrock outcrops at Pte. des Monts, cross striae, grooves, chattermarks and roche moutonnée forms give evidence to a late easterly flow.

Field evidence thus suggests that there was a major ice advance from the north-northwest. In the Sept-Iles area, flow continued from this direction. To the west, however, the direction gradually changed until the ice movement was from west to east.

Marine limit

The elevation of the marine limit decreases from 128 m at Sept-Iles where outwash grades into beach sand, to 100 m in the Godbout area about 130 km to the southwest. Intermediate readings were also obtained but, for the most part, the marine limit is difficult to determine because the uppermost terrace of the coastal plain is separated from glacial sediments by a steep bedrock scarp.

Landslides

With the exception of the lower reaches of Rivière Pentecôte, where human influence has resulted in massive bank failures, no active or fossil flow slides were observed beyond the areas mapped in 1971. At Sept-Iles, five small landslides occurred during the summer. The shear strength (using a Geonor vane) for both slide zones and nearby stable slopes was about 3 t/m^2 (700 $lb./ft.^2$), and the remoulded strength was always zero. There was no stiff, fissured outer crust, which was observed in 1971, and there were no changes in shear strength with distance in from the face.

Chronological data

Shell assemblages and samples for dating were collected from silts and clays at eight sites ranging in elevation from sea level to 75 m. In addition, two small lakes were cored by R. J. Mott. These sediment records will provide additional chronological and ecological information.

101. QUATERNARY GEOLOGY, WINNIPEG MAP-AREA (63 H, East Half)

Project 700053

M. M. Fenton*
Terrain Sciences Division, Ottawa

This summer's work included study of the near-surface Quaternary stratigraphy, collecting samples to aid in characterizing the tills and running traverses to further clarify the surficial geology of the area. The two months' field work consisted of (1) drilling ten power auger test holes (3-30 m deep), (2) examining and sampling a number of exposed sections, and (3) collecting near-surface till samples.

Few modifications were made to the surficial geology as described by Fenton[1]. The area is divided into three north-south trending geological units: (i) lacustrine clay in the west, (ii) till partially mantled by lacustrine deposits in the centre, and (iii) a sandy moraine in the east. Preliminary analyses of the data from the test holes and sections suggests unit (ii) may not be continuous.

The shallow (<20 m) stratigraphy is exposed only in the southwestern portion of the area. The examination of a number of river-bank exposures in this region suggest the presence of three distinct tills interbedded with stratified deposits. The uppermost till is silty-sandy, the middle sandy and the lower a clayey-silt.

The sandy till includes more than 5 metres of stratified deposits. The stratified deposits between the middle and lower till vary from coarse sand and gravel to silt and clay.

The middle sandy till has been recognized in test holes in the northern half of the area. The surface till in the northern half is, however, much siltier than the upper till in the southwest. This may be due to either a textural variation or to the absence of this till unit in the south.

[1] Fenton, M. M.: Quaternary Geology, Winnipeg Map-Area (east-half); in Report of Activities, Part A, April to October, 1971; Geol. Surv. Can., Paper 72-1, pt. A., p. 156 (1972).

102. TERRAIN MAPPING IN MOUNTAINOUS AREAS

Project 720057

R. J. Fulton
Terrain Sciences Division, Ottawa

The objective of this project is to devise and test a scheme for classifying and mapping the terrain-Quaternary units in mountainous areas. High relief areas have generally been left blank or shown as areas of rock on Geological Survey of Canada terrain-Quaternary geology maps. This practice was acceptable as there appeared to be little demand for terrain information for these areas. With increasing emphasis on all aspects of the environment and pressure for information on all facets of the land, it is necessary to map and describe terrain-Quaternary units in mountainous as well as in lower relief areas.

*Graduate student

The area around Revelstoke was selected for this pilot study as many of the mountain slopes in the vicinity have been logged and there is access to a wide variety of mountainous terrain. Also, Quaternary deposit information was available from an earlier Geological Survey of Canada project[1]. Field work was completed during the summer in map-areas 82K/12 and 13, 82L/9 and 16 and 82M/1, 7, 8, 9, 10 and 15.

In most low relief areas of Canada, single Quaternary depositional units (areas covered by one geomorphologically and texturally uniform Quaternary deposit) are the only terrain-Quaternary map-units used. In mountainous areas the landforms are either too uniquely complex to permit their being described in terms of a few simple map-units, or individual landforms are too small to be mapped as pure map-units. Two other problems encountered are: surface landform is often a reflection of underlying rock topography rather than an aspect of the unconsolidated material present. Bedrock and unconsolidated components are often so intimately mixed that it is necessary to use map-units that contain both.

In the scheme employed, landforms made of unconsolidated materials are described in terms of deposit genesis, landform and texture. Landforms consisting of consolidated rock are treated in a similar manner, with rock lithology, rock structure and form being the main points considered. Slopes steeper than 30 degrees were mapped as "steep slopes" (S) with U or R as a prefix to indicate whether the landform was cut in unconsolidated material or rock. Where a map-unit consisted of more than one landform unit a compound term, indicating the approximate percentage of each component, was used.

Landform modification due to active and no longer active processes is an important element in mountainous terrain. Consequently a term was included to indicate the type of modification that has taken place. Use of these terms makes it possible to indicate that a steep rock slope has been or is subject to mass wasting, gullying, nivation, or one or more of several other processes which produce characteristics of interest to anyone anticipating using this terrain unit.

During this work brief examination was made of the Quaternary deposit lying in the Columbia River valley north of Revelstoke. From Revelstoke to La Forme Creek the fill appears to be dominantly ice-contact sand and gravel overlain by colluvial fans adjacent to the valley wall and by alluvial fans and deltas at the mouths of main tributary valleys. Locally terraces have been cut in the fill by the Columbia River and veneers of channel gravel and overbank sand overlie the cut surfaces. From La Forme Creek to Downie Creek several units of variable thickness and texture are present. The lowest is ice-contact gravel and sand. Lacustrine silt and sand generally overlies this and appears to be thickest and coarsest at the mouths of large tributary valleys. Variable thicknesses of channel gravel, overbank sand and silt (laid down during river downcutting) and thick gravel and sand fans and deltas (occurring at the mouths of large tributaries) overlie the lacustrine unit. Colluvial gravel and bedrock rubble occur along the valley wall and form wedges that extend into the other units. Many of the slides occurring in the unconsolidated fill seem to be caused by presence of lacustrine silt. A C^{14} date on wood and plant detritus, collected from the lacustrine silt, should make it possible to relate this phase of deposition with the late glacial lake recognized in the Columbia Valley south of Revelstoke[2].

[1]Achard, R.A.: Quaternary geology, Columbia River project reservoirs; in Report of Activities, Part A, April to October 1968, Geol. Surv. Can., Paper 69-1, pt. A, p. 186 (1969).

[2]Fulton, R.J.: Radiocarbon geochronology of southern British Columbia; Geol. Surv. Can., Paper 71-37, 28 p. (1971).

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103. CANADA - NEWFOUNDLAND AND LABRADOR MINERAL DEVELOPMENT PROGRAM
Project 6: Glacial geological-geochemical survey (glacial geology phase)

Project 720028

D.R. Grant
Terrain Sciences Division, Ottawa

During the first field season of this project - the pilot studies phase - surficial geology studies were undertaken in four test areas to expedite the development of geochemical prospecting techniques best suited to the terrain and surface materials (mainly till and muskeg) of Newfoundland. As the companion geochemistry phase (Project 720027) involved sampling surface materials regardless of origin, sampling till at various depths to bedrock, as well as studying modern plants, stream sediment and lake water, the geology phase was concerned with (1) the distribution, stratigraphy, and approximate thickness of till and its various derived marine and glaciofluvial sediments; (2) the nature of subsequent modifying processes such as ablational, meltwater, and colluvial reworking; (3) the direction and sequence of glacial movements in their role as transporting agents of bedrock minerals; (4) general volumetric data on the glacial transport and dispersion of rock detritus from discrete bedrock sources, as well as (5) information on the lithologic contrast between tills and their secondary and tertiary derivatives:

(a) glaciofluvial, late-glacial marine, and modern beach sand and gravel and

(b) "submarine tills", or ice-rafted, stony, marine, shell-bearing clays.

Springdale area

Within a ten-mile radius of the town site, sampling of overburden as well as bedrock clearly illustrated the relationship between mineral development and lack of overburden. Unfortunately, for various reasons, many orebodies are erosionally incompetent and therefore tend to occupy topographic lows. Since there are many large valleys in this area, and most are fault-line lineaments which are deeply filled with till, outwash, and then mantled with marine sediment up to 200 feet, it is reasonable to assume that these valleys offer much promise for future discovery, but present technology is hopelessly inadequate to cope with sampling and development. Aside from the valleys, there are problems in using geochemistry to search for indicators in the drift. Areas of till not covered by glaciofluvial sand and gravel, not reworked by marine action, may still be extensively modified by glacial meltwater streams and sheetwash so that the result is a variably impoverished substrate.

New Bay Pond area

Both geochemical and surficial geological trials were carried out over an area of approximately 10 by 20 miles north of Grand Falls in a volcanic terrane just north of granite and gabbro intrusives. Reasons for choosing this area include its relative ease of access, a recently discovered basemetal orebody that would serve as a target source, apparently unidirectional glacial transport, and a variety of terrain types and till thicknesses. Three weeks were spent (1) photo-mapping and ground-checking a system of terrain classification which can be translated in terms of prospecting parameters; (2) mapping thickness and composition of till; (3) deciphering ice movements; and (4) analyzing the lithologic composition of tills. A significant result of this study was finding evidence indicating glacial transport of a magnitude and direction hitherto unknown.

In addition to the main ice flow to the north-northeast (025 ± 10), as shown by roches moutonnées, crag-and-tail hills, large drift lineations and 50 striation observations, there was a later (latest?) flow to the east (080 ± 30) recorded by superimposed striae. Surprisingly, these were not noticeable in the terrain fabric, except perhaps for a slight curving of till tails. Moreover, these ice-flow markings are distributed in a fan-like pattern, converging on an area of disintegration moraine south of Frozen Ocean Lake. If this radial flow represents the movement of a remnant ice mass, a corroborative direction of retreat is afforded by the trend of side-hill meltwater channels. Moreover, this ice-flow divergence is found to the south and east, but not to the west, of the test orebody. Hence, the interpretation of the geochemical results becomes unnecessarily complicated.

Rock debris transported from the granitic terrane south and west of the test area amounted to 40 per cent of the fragments in the tills only 3 miles "down-drift", and 25 per cent 10 miles away. While this may reflect vigorous erosion and/or duration of flow, no similarly well-developed dispersion fan was downdrift from the orebody.

Daniels Harbour area

Three weeks were spent sampling a previously mapped area of a predominantly carbonate lowland extending 20 miles between Portland Creek and River of Ponds, and 10 miles inland from the coast to the Long Range Mountains. Over 200 samples were analyzed. Earlier interpretation of events was confirmed: (1) no evidence of ice flow from Labrador, only many observations that the only glacial transport was from east to west, i. e. from the mountains to the coast; (2) ice configuration took the form of lobate piedmont glaciers of varying size, sequence and rate of retreat; (3) retreat of glaciers and deposition of stony marine pelite with shell fragments as a sea-bottom deposit accumulated as ice-rafted detritus; (4) penecontemporaneous marine overlap to 300 to 400 feet and, during subsequent regression, reworking of the top several feet of tills and deposition of beach sand and gravel; (5) local eolian modification and final cover of a nearly continuous muskeg; and (6) continuing development of sink holes and related phenomena associated with seasonal water fluctuations in soluble rocks.

Glacial dispersion of rock debris from the granitic terrane onto the carbonate terrain was measured in order to preview what might be found geochemically in terms of metal dispersal from various zinc-copper occurrences in the carbonates. Content of pebbles 5 to 25 mm decreased exponentially from 75 per cent at 1.3 miles distance, to 50 per cent at 2.7 miles, to 25 per cent at 5.0 miles and, to 5 per cent at 8.2 miles. Transport of the Hawke Bay quartzite, from its source under the lowland between the carbonates and the Long Range granites and gneisses, decreases similarly but is less extensive. This may be because the source lies in the area of mainly glacial deposition where the valley glaciers expanded into piedmont glaciers, whereas the granite terrane was the locus of vigorous scour on steep slopes under the expanding ice cap. As expected, the composition of shell-bearing, stony, marine clay interpreted as ice-rafted detritus does not relate to that of the other tills as granite content is 30 to 50 per cent even 10 or more miles from the source.

Clarenville area

A similar program was carried out over an area extending 10 to 15 miles north and south of Clarenville, and from 5 miles inland to 15 miles seaward on peninsulas and islands. The area should yield interesting results as parallel volcanic and sedimentary belts, intruded by granitic plutons, were crossed nearly at right angles by strong unidirectional ice flow showing little divergence of basal or late ice by topographic channelling along meandering fiords. There is, however, a complex interlayering of till phases and of sorted sediments. Huge drumlins occur sporadically, composed of tills mainly of distant derivation. Marine overlap to 100 feet is relatively unimportant as it is restricted, because of steep slopes, to a narrow coastal fringe. Extensive glaciofluvial complexes replace till accumulations in valleys.

Data analysis is largely incomplete and, in any case, will not have the benefit of companion geochemical results which were sacrificed for lack of time.

The value of these pilot studies, in devising techniques applicable to the island as a whole, and the choice of the test areas as a meaningful sample of the bulk of the island's terrain and glacial geological attributes has yet to be assessed and reported.

104. RECONNAISSANCE GLACIAL GEOLOGY SOUTHWESTERN GRINNELL PENINSULA, DEVON ISLAND, DISTRICT OF FRANKLIN

Project 670031

M.G. Grosswald*
Terrain Sciences Division, Ottawa

A reconnaissance survey of the traces of former glaciation and of Holocene changes in the relationship between land and sea in southwestern Grinnell Peninsula (NTS map-sheet 59B) was undertaken between July 19 and August 3 as part of a study of glacial history in the southeastern Queen Elizabeth Islands [1]. Field support and logistics were provided by J. Wm. Kerr (Operation Grinnell). Below are data based on field observations and some conclusions reached on the basis of air photograph interpretation.

The altitude of the upper marine limit was determined in several localities. Near base camp at the head of Barrow Harbour the limit was established at 125 m a.s.l., and at a number of other sites along the coast, from Cape Allard to Cape Hornby, and on Sheills Peninsula, well-preserved strandlines and beach ridges were found up to 110 to 125 m. Somewhat subdued terraces continue up to a level of 150 m or more, at which elevation whole thickened valves and fragments of _Hiatella arctica_ and _Mya truncata_ are still common. These altitudes attest to considerable postglacial crustal uplift of southwestern Grinnell Peninsula, and are higher than those recorded from southern and eastern Devon Island; e.g., the marine limit on the shores of Wellington Channel is about 90 m a.s.l. [2], and that in the Truelove Inlet area of eastern Jones Sound is 76 m [3].

Samples for radiocarbon dating were collected from the following localities:

1. the head of Barrow Harbour, 76° 36'N, 95° 33'W (shells up to 110 m a.s.l.; peat at 51 m; wood at 28 m);
2. a flight of raised beaches 6 to 7 m northwest of Stewart Point, 76° 23'N, 95°37'W (shells up to 150 m);
3. southwest and central Sheills Peninsula, 76° 14'N, 95°17'W and 76° 17'N, 95°01'W (shells up to 150 m; driftwood at 21 m).

Dating of the samples will provide the time of deglaciation and the pattern of postglacial crustal movements.

Although some authors had suggested previously that Grinnell Peninsula showed no evidence of having been glaciated [2,4], glacial features proved ubiquitous, being represented by features resulting from erosion by ice and from meltwater activity. Morainal deposits are much less common. The peninsula is characterized by a system of U-shaped troughs with hanging tributaries and a variety of other glacial elements such as steps where ice was converging or diverging, sills, and basins. Lateral drainage channels, col gullies, and captured streams are also widespread. In addition, there is evidence indicating the presence of large bodies of dead ice during the final stages of glaciation.

*Institute of Geography, Academy of Sciences of the U.S.S.R., Moscow; with Terrain Sciences Division as an Exchange Scientist, May 1972 to February 1973.

The occurrence of rounded summits and watersheds suggests the former existence of a continuous ice sheet with differential ice movement rather than a network of valley glaciers. The ice sheet seems to have been very thick over both the central and marginal parts of the peninsula. This conclusion as regards the periphery of the peninsula is inferred from the many indications of former divergence of ice flow in close proximity to the present-day coast (suggesting conditions of ice impounding rather than thinning out), from the lack of former nunataks, and from the glaciated valleys that cross bays and straits or trend parallel to the coast. It appears that the ice sheet formerly covering the peninsula was coalescent with and dammed by a major ice stream that is believed to have filled Penny Strait and Queens Channel. Such an interpretation is in keeping with the general character of the submarine topography[5].

[1]Blake, W., Jr.: Studies of glacial history in Arctic Canada 1. Pumice, radiocarbon dates and differential postglacial uplift in the eastern Queen Elizabeth Islands; Can. J. Earth Sci., v. 7, p. 634-644 (1970).

[2]Roots, E.F.: Devon Island physiography; in Geology of the north-central part of the Arctic Archipelago, Northwest Territories, Y.O. Fortier et al.; Geol. Surv. Can., Mem. 320, p. 164-179 (1963).

[3]Barr, W.: Postglacial isostatic movements in northeastern Devon Island; a reappraisal; Arctic, v. 24, no. 4, p. 249-268 (1971).

[4]Prest, V.K.: Quaternary geology of Canada; in Geology and Economic Minerals of Canada, ed. R.J. Douglas; Geol. Surv. Can., Geology Rept. no. 1, 5th ed.; p. 676-764 (1970).

[5]Pelletier, B.P.: Development of submarine physiography in the Canadian Arctic and its relation to crustal movements; in Continental Drift, ed. G.D. Garland; Roy. Soc. Can., Special Publications, no. 9, p. 77-101 (1966)

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105. QUATERNARY GEOLOGY HALIBURTON-BURLEIGH FALLS AREA, ONTARIO

Project 700093

E.P. Henderson
Terrain Sciences Division, Ottawa

Striae and associated ice-flow features indicate ice movement of about south 24 degrees west over the northeastern (Wilberforce) and south 19 degrees west over the southeastern (Burleigh Falls) parts of the area. These flows are in close agreement with previously recorded ice movements in the intervening Gooderham-Apsley[1] region and in the Marmora-Coe Hill[2] and Madoc-Bancroft regions to the east. In the southwestern part of the area, striae and some drumlins show a more westerly flow, with considerable variation in direction from place to place. This agrees with Gravenor's[4] findings to the south, where he ascribes this swing to the west to spreading out of the Lake Simcoe ice lobe.

Glacial deposits, underlain by Paleozoic and Precambrian rocks, are the most widespread unconsolidated materials in the area. The ground moraine is characteristically thin and discontinuous, but locally attains considerable thickness on the flanks of hills and in drumlins. Thicker till occurs in the Dummer moraine[5] which lies across the southern part of the mapped area in a belt up to 12 miles wide and trends 15 degrees north of west, approximately at right angles to adjacent ice flows. Total relief in the Dummer moraine may exceed 100 feet.

Glaciofluvial deposits are present generally as isolated kames or short esker segments but, in two river systems, form long series of ice-contact and associated valley-train deposits, separated by intervening lake basins or stretches of narrow bedrock valley. The longest series of such deposits was traced down the Irondale-Burnt River drainage. These two valleys carried meltwater to Kinmount from the east and north respectively, where they joined to flow south into an expanded glacial version of Cameron Lake. Trenching by the modern rivers has left terraces along these valleys that generally lie 10 to 30 feet above the rivers but which, in a few places, may be considerably higher, such is the case of the terrace on the east side of Burnt River just south of Kinmount, which lies over 60 feet above the river level. Less extensive but more massive deposits lie in the Gull River drainage, particularly around Minden and from Maple Lake to Eagle Lake. Sand and gravel are derived from kame and esker deposits in several places, but principally come from outwash gravels along the Irondale-Burnt River and Gull River drainage routes. Large pits have removed only a fraction of the easily exploited material which appears to be present in these deposits.

Apart from a few very local low-lying deposits adjacent to some of the modern lakes, lacustrine sediments are confined to the Burnt River valley from Cameron Lake to Union Creek. They were deposited in an extension of Cameron Lake when it formed part of the Fenelon Falls outlet for proglacial Lake Algonquin. Subsequent postglacial tilting has contributed to withdrawal of the lake from the Burnt River valley.

There are indications of ice readvance, or at least of a fairly lengthy pause in its retreat, in the vicinity of the town of Haliburton. Thicker than normal till covers the hills both north and south of the town, and extensive exposures of rock are uncommon. This, together with areas of stony morainic hills east of Lake Kashagawigamog and thick outwash in adjacent valleys suggests that cessation of retreat or readvance allowed much greater accumulation of glacial and glaciofluvial deposits here than elsewhere. The latter interpretation is further supported by areas of very sandy till east and south of Kinmount, which were probably derived from a readvance over outwash and ice-contact deposits. In addition, two sections near Union Creek expose two or three feet of till overlying outwash.

[1] Henderson, E.P.: Quaternary geology, Gooderham-Apsley area, Ontario; in Report of Activities, Part A, April to October, 1971; Geol. Surv. Can., Paper 72-1, pt.A, p. 84-85 (1972).

[2] Henderson, E.P.: Quaternary geology, Kingston, Ontario; in Report of Activities, Part A, April to October, 1970; Geol. Surv. Can., Paper 71-1, p. 167-168 (1971).

[3]Henderson, E.P.: Quaternary geology, Kingston (north half), Ontario; in Report of Activities, Part A, April to October, 1969; Geol. Surv. Can., Paper 70-1, pt. A, p. 176-178 (1970).

[4]Gravenor, C.P.: Surficial geology of the Lindsay-Peterborough area, Ontario, Victoria, Peterborough, Durham, and Northumberland Counties, Ontario; Geol. Surv. Can., Mem. 288 (1957).

[5]Chapman, L.J., and Putnam, D.F.: The physiography of southern Ontario; Univ. Toronto Press (1951).

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106. BEAUFORT FORMATION, WESTERN QUEEN ELIZABETH ISLANDS

Project 640004

L.V. Hills*
Terrain Sciences Division, Ottawa

Field work was designed to collect material from the lignite beds on Banks Island for insect studies to be conducted by Dr. J. Mathews, re-collect leaf litter from the lignite bed on Banks Island, and to examine and collect lithologic and palynologic material from Brock, Ellef Ringnes and Meighen Islands.

With the exception of collecting on Meighen Island, which was snow covered, all field objectives were accomplished. Two field observations which contribute significantly to the overall interpretation of the Beaufort Formation were: (a) the discovery of cones of *Pinus* cf. *P. strobus* type and 5 needle fascicles in the upper 2 feet of the lignite bed on Banks Island, and (b) tree stumps in growth position on Ellef Ringnes Island.

The former is important in evaluating the relationship of the fossil to its possible modern equivalent *Pinus strobus*. These fossil cones and needles were not transported, indicating that they grew at the site of deposition. This would indicate that the species grew on an organic substrate which is not generally true of the extant species *P. strobus*. However, examination of cone scale morphology in progress would indicate that morphologically the fossil is most closely related to *P. strobus*. The latter observation confirms the inference, based on palynological evidence, that conifers grew as far north as Ellef Ringnes Island.

Laboratory work consisted of (a) a morphologic analysis of the *Juglans* nuts collected on southwestern Banks Island has been completed and a paper by L.V. Hills, J.E. Klovan and A.R. Sweet is in the final stages of preparation, (b) a morphologic analysis of the fossil and extant white pines is well advanced, and (c) stratigraphic sections and mineralogic analyses of samples collected from Prince Patrick, Brock and Ellef Ringnes Islands are in progress.

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*University of Calgary.

107. SURFICIAL GEOLOGY AND GEOMORPHOLOGY OF CENTRAL ELLESMERE ISLAND

(Parts of 49 D, E, G, H, 340 B)

Project 720081

D.A. Hodgson
Terrain Sciences Division, Ottawa

Oil and gas exploration in the eastern Sverdrup Basin has created a requirement for maps of surficial materials and landforms as a basis for land-use planning and regulation. Sample areas were examined this summer as a prelude to detailed airphoto interpretation and further field checking in 1973. Field work was restricted to the Fosheim Peninsula west of the Sawtooth Range, with the exception of a week at the head of Vendom Fiord which lies on a possible pipeline route to Makinson Inlet. The writer and an assistant occupied seven camp sites, moving to a site by fixed-wing aircraft and travelling within a 15-mile radius of the camp on Honda A.T.C.'s – the latter a successful if gruelling method of transport.

Although there is evidence that the whole area has been glaciated, very possibly during the last continental maximum, bedrock weathered to various degrees is the dominant surface material and exercises most control over the form of the landscape. Lithologic (not necessarily stratigraphic) units will form the basis of many map-units. Most exploration activity to date has taken place on the Eureka Sound Formation, which presents a wide variety of surficial materials including sand, coal fragments, silt and clay. There is a massive fill of fluvial and deltaic silt, clay and sand within the Slidre River valley to an elevation of at least 60 m. Crossbedded sands with large accumulations of well-preserved (not carbonized) wood were noted overlying, or faulted within, the Eureka Sound Formation at several localities near Romulus Lake. Deposits resemble the Beaufort Formation.

Glacial deposits are more significant at the head of Vendom Fiord. Bedrock is mantled by a bouldery till, thicker end and lateral moraines, and by coarse alluvial fans. It is hoped to make a detailed reconstruction of post-glacial events in the area after determining the age of marine pelecypods, plant material and driftwood found between sea level, the marine limit (maximum 70 m) and the ice cap.

Limited subsurface information was obtained this year, however it is evident that many of the very widespread polygonal trenches are underlain by substantial ice wedges. Ice partings or lenses, up to 50 per cent ice by volume, are present in at least the upper two metres of most frozen fine-grained materials. Segregated ice was also noted within lithified shales and coal.

Retrogressive flowslides with two patterns were recorded. Rotational-translational slides, leading to flows, are common on marine and deltaic silts and clays. Broad, shallow, translational slides were occasionally noted on thinly vegetated shales and coal of the Eureka Sound Formation, and on shale of the Christopher Formation with the failure occurring in icy sediments. Fine-grained (and some coarser deposits) are saturated and unstable during the early summer thaw, but with the low precipitation they rapidly dry out and little mass-movement occurs during the remainder of the year.

108. QUATERNARY GEOLOGY INVENTORY LOWER NELSON RIVER BASIN (53M, 54C, D, 63O, P, 64A, B)

Project 710092

R.W. Klassen and J.A. Netterville
Terrain Sciences Division, Calgary

Inventory mapping of the surficial deposits in the project area begun last year[1] was completed. Field work entailed ground and aerial observations in selected localities within various map-units delimited on the basis of air-photo interpretation and plotted on photo mosaics on a scale of 1:125,000. Ground control (average 1 site per 100 sq. mi.) was directed primarily towards determining (1) the general lithology and local morphology of non-organic map-units, (2) the Quaternary stratigraphy of the map-area and (3) the nature and thickness of organic deposits.

Geological mapping in this region is hampered considerably by the nature of the vegetation and the widespread occurrence of permafrost. Boreal forest that consists of closed or scattered stands of trees occurs on and between extensive areas of peat and fen that cover most of the low relief terrain. The peat is usually between 4 feet and 9 feet thick and the ground is perennially frozen 1 to 4 feet beneath the surface to a depth of more than 12 feet (maximum penetration depth of hand-operated sampling device). Casual inspection of numerous sampler cores (3/4 in. x 6 in.) indicates the usual ice content of peat and mineral sediments is about 5 to 25 per cent. It increases downwards towards the contact with the underlying mineral sediments where ice lenses about 1 foot thick commonly occur. The ice content of clays generally decreases downward below the peat. A radiocarbon date of 6490 ± 170 years B.P. (GSC-1738) was obtained from the bottom of a peat bog 5 feet deep in the north-central part of the map-area.

Glaciolacustrine clay and silt are the most common non-organic surficial sediment in the map-area. The lacustrine sediments are fairly continuous within a broad belt some 50 miles wide and 120 miles long straddling the Grass and Burntwood Rivers. Smaller lacustrine basins occur within the Canadian Shield bedrock terrain[1] in the western part of the map-area, in the morainic terrain in the north-central part, and in drumlinized terrain in the southeastern part of the map-area. The lacustrine sediments are commonly 5 to 15 feet thick, but local thicknesses are highly variable and may be considerably greater.

Most of the drumlinized terrain in this region (53M, parts of 54D and 63P) is gently undulating with less than 20 feet of local relief. It is underlain by fairly loose, coarse-textured till. Precambrian bedrock outcrops are fairly common in this terrain and the till is fairly thin in places. It is likely that the till locally thickens to 50 feet or more, for the buried bedrock topography probably has local relief in the order of 50 to 100 feet. Drumlin crests are commonly water-eroded and a lacustrine clay veneer occurs on the drumlin flanks and in inter-drumlin areas.

Morainic terrain in the north-central part of the map-area (54D and 64A) consists largely of broad belts of ice-contact deposits, including prominent esker ridges and kames that stand more than 200 feet above the surrounding plains. The surfaces are well drained and generally underlain by fine sand which, in places, appears to make up the entire landform. Gravel seems to make up a minor part of the morainic terrain although elsewhere isolated clusters of kames, particularly those along former meltwater channels, are high in coarse bouldery gravel. Morainic hills of much lower relief in the northwestern part of map-area 54D and the northeastern part of map-area 64A are mostly till.

A distinctive beach ridge complex at about 400 feet a.s.l. trending roughly north-south along the eastern margin of map-area 54D and the northeastern margin of map-area 53M marks the western limit of "marine terrain"[1] in the eastern part of the map-area. This terrain, covered by an almost unbroken blanket of peat (6 to 12 feet thick) and fen, primarily seems to be a plain of eroded till locally veneered with marine silt and clay less than 5 feet thick. Silt, sand and gravel, in places 100 or more feet thick, are exposed along the Hayes River and along parts of the Nelson River below the confluence with Limestone River. These sediments are related primarily to the river valleys and are not representative of the sediments underlying most of the lowland.

Multiple tills are exposed along the larger river valleys and escarpments in 54C, in the eastern part of 64A and the northeastern part of 53M. At least three (probably four) tills are exposed in places along the banks of the Gods River. In places the two oldest tills are separated by 10 to 20 feet of stratified sediments, including wood and peat radiocarbon dated as >41,000 years B.P. (GSC-1736). Thin sediments devoid of organic detritus commonly underlie the youngest till. Two tills are commonly seen elsewhere in the eastern part of this region although, in places along the lower Nelson River, a succession of three distinct till units form the bulk of the 200-foot river cliffs.

Stratified sediments forming the banks of the Hayes River and parts of the Nelson River include glaciofluvial, deltaic and alluvial deposits. The Hayes River valley below the confluence with the Gods River is relatively young as indicated by a radiocarbon age of 4890±140 years B.P. (GSC-1745) from wood 27 feet below the top of an 80-foot bank.

[1] Klassen, R.W.: Quaternary geology inventory, lower Nelson River basin; in Report of Activities, Part A, April to October, 1971; Geol. Surv. Can., Paper 72-1, pt. A, p. 166 (1972).

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109. STRATIGRAPHIC AND ENGINEERING STUDIES OF UNCONSOLIDATED SEDIMENTS IN CENTRAL LAKE ERIE NEAR ERIEAU, ONTARIO

Project 680055

C.F.M. Lewis, A.E. Wootton*, and J.B. Davis**
Terrain Sciences Division, Ottawa

In recent years, much concern has centred on pollution in the Great Lakes and on the role of sediment as a record of recent environmental change and control on water quality. There is a growing demand for physical and engineering sedimentary information also, particularly by those who are concerned with shore and lake bed management, coastal and offshore structures, pipelines, communication cables, powerlines, dredging, etc. Such applications of sediment information are best made in the context of the total environmental system and require, among other things, that all information be available concerning the sedimentary processes and the regional geological history that led to the formation and development of the sediment deposits.

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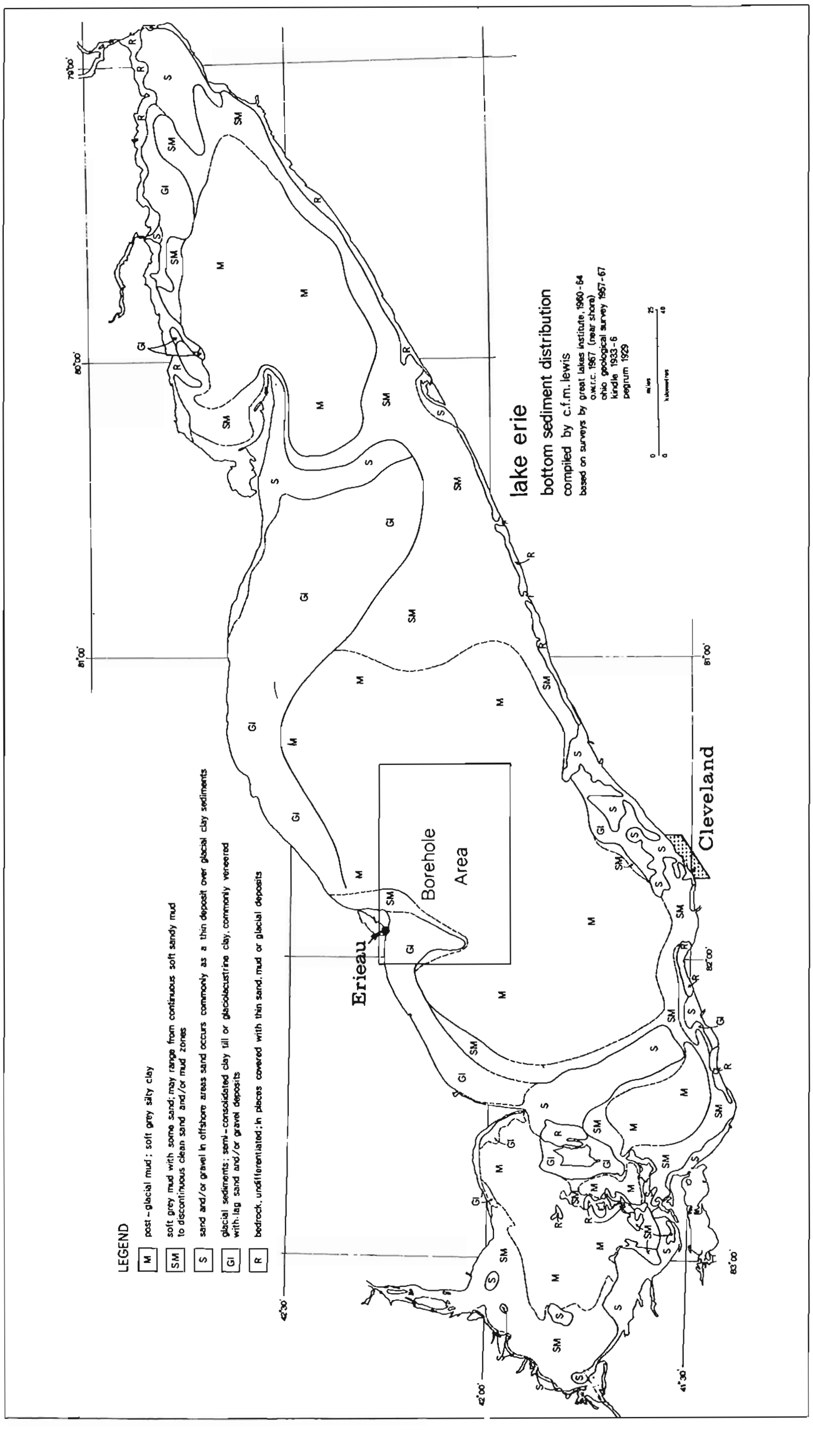
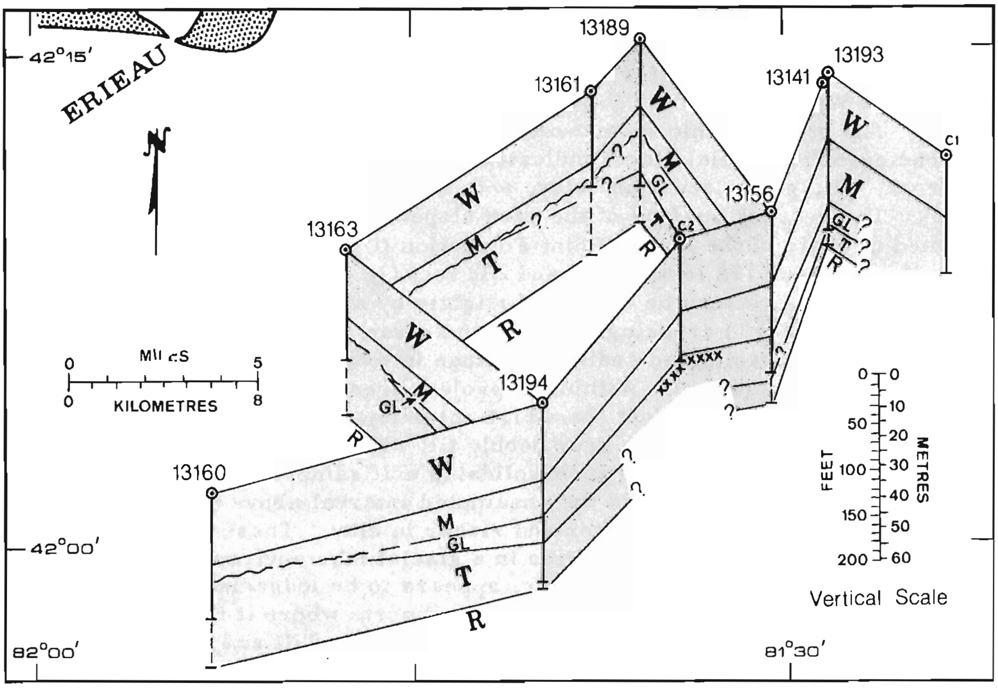
* A.E. Wootton, The Consumer's Gas Company, Toronto, Ontario.
** J.B. Davis, Golder Associates, Mississauga, Ontario.


LEGEND
M post - glacial mud; soft grey silty clay
SM soft grey mud with some sand; may range from continuous soft sandy mud to discontinuous clean sand and/or mud zones
S sand and/or gravel in offshore areas sand occurs commonly as a thin deposit over glacial clay sediments
Gl glacial sediments; semi-consolidated clay till or glaciolacustrine clay, commonly veneered with lag sand and/or gravel deposits
R bedrock, undifferentiated; in places covered with thin sand, mud or glacial deposits
lake erie
bottom sediment distribution
compiled by c.f.m. lewis
based on surveys by great lakes institute, 1960-64
o.w.r.c. 1967 (near shore)
ohio geological survey 1957-67
kindle 1933-6
pegrum 1929
Borehole Area
Erieau
Cleveland
79°00'
80°00'
81°00'
82°00'
83°00'
42°30'
42°00'
41°30'



The authors combined interests and resources in this study to sample the sequence of mud sediments occurring in central offshore Lake Erie (Fig. 1). This study area is one in which The Consumer's Gas Company has experienced difficulty in locating adequate bearing strata for jack-up drilling rigs. Deep sampling in the area is also of interest to the Geological Survey and Canada Centre for Inland Waters for their current studies of regional Quaternary geology in the Great Lakes. The overall objectives for this program were:

1. to determine the stratigraphy of lake deposits, to bedrock if possible, in terms of their lithic, physical, chemical, mineralogical and fossil properties, in order to increase our understanding of sedimentological processes and Quaternary events that controlled Lake Erie's development;

2. to measure and interpret the engineering properties of fine-grained lake sediments with particular reference to their bearing capacity for offshore structures.

At three of the ten sites sampled, piston cores were obtained from tug and barge operations conducted by The Consumer's Gas Company during December 1971 and January 1972. The remaining sites were cored from June to September 1972 from NORDRILL (a drill ship under charter to The Consumer's Gas Company) using a Benthos gravity corer, an Alpine piston corer, Shelby tubes and a large-diameter sleeve sampler. The NORDRILL sites were subsequently drilled into bedrock as conventional exploratory tests for natural gas. Piston core recovery was continuous with penetration up to 55 feet (17 m); Shelby and sleeve samples were collected in 2 to 5 feet (.6 to 1.5 m) lengths at intervals of 5 to 20 feet (1.5 to 6 m), usually to refusal, at sediment depths up to 110 feet (34 m). Generally, the cores bottomed in till or glaciolacustrine clay. Messrs. A. Zeman (Golder Assoc.) and P. Wallace (GSC) have undertaken most of the sampling and laboratory work to date with the aid of technical facilities supplied by Golder Associates and Canada Centre for Inland Waters.

The stratigraphic framework as interpreted from preliminary data (X-radiographs and field logs) indicates a four-unit sequence composed of bedrock, till, glaciolacustrine clay, and mud (Fig. 2).

The bedrock surface of the area slopes gently to the southeast and is formed of shale of the Kettle Point Formation (Upper Devonian). This surface lies between 178 feet (54 m) and 232 feet (71 m) below lake level (570 feet [174 m] a. s. l.); it may be dissected slightly by a minor northeast-trending depression (valley?) crossing the eastern sector.

The unconsolidated sediments range in total thickness from 99 feet (30 m) to 151 feet (46 m). Within the project area their upper surface is flat and lies uniformly 80±3 feet (24.4±1.0 m) below lake level.

A compact, brownish grey pebbly till with a calcareous clayey silt matrix comprises the lowest unconsolidated unit sampled (Fig. 2) although lower units may be present in the unsampled interval above the bedrock surface. Parts of the till are softer and richer in clay. These facies probably result from slumping and deposition in a glacial lake environment near an ice front. Most of the deposit, however, appears to be lodgement till. The till surface in this locality rises to the west and north where it forms the proximal flank of the buried Erieau cross-lake moraine[1,2]. Till and moraine are considered Late Wisconsin in age and were probably deposited during the Port Bruce stadial[3] about 14,000 - 13,500 years ago. Data from one borehole (13163, see Fig. 2) show water contents in the till ranging between 20 and 35 per cent (per cent of dry weight) and unit weights ranging between 120 and 130 lb./cu. feet.

A glaciolacustrine unit conformably overlies the till in the southern and eastern parts of the sampled area. The unit is composed of laminated brownish grey clay with random sand grains and pebbles. Various types of laminations occur such as varved clays and crossbeds, and including thin regular units up to 2 cm in thickness. The whole glaciolacustrine unit is tentatively correlated with glacial Lake Arkona and subsequent lakes of the Mackinaw interval and Port Hudon stadial in the Erie basin. Deposition probably occurred between 13,300 and 12,500 B.P. These clays are extremely low in strength and generally have high water contents ranging from 30 to 65 per cent.

A prominent erosional unconformity truncates the glaciolacustrine and till sediments at approximate depths of less than 100 feet (30 m) below lake surface. The unconformity is overlain by postglacial lacustrine muds and is correlated with the low-level Early Lake phase[1,4] (about 12,500 years B.P.). Nearshore wave abrasion in this transgressive lake phase is believed to have cut the unconformity.

The unconformity is of engineering significance because it is usually associated with relatively higher strength materials. The glacial sediments are commonly overlain with thin lag sands and gravels. The clay and till surface itself is somewhat strengthened, presumably due to dewatering and consolidation during the low level Early Lake Erie phase when these sediments may have been subaerially exposed.

Farther offshore, at slightly greater depths (about 120 feet [37 m] below lake level), the non-eroded, glaciolacustrine clay surface is composed of an unusual oxidized crust, e. g. , at core 2. Its colour resembles the orange Fe Mn oxidized zones commonly found near the surface of Holocene Great Lake muds. The crust has a markedly reduced water content (about 40 per cent) and has a substantially greater shear strength. Hence, this feature is of considerable engineering importance in the sequence of low strength clays. Research is continuing to determine the nature of the oxidized crust. At present, two mechanisms are being considered with respect to its origin:

1. subaerial exposure with dehydration and oxidation when the glaciolacustrine clay surface was exposed above lake level during the low level Early Lake Erie episode;

2. oxidation and deposition of migrating Fe and Mn ions at the clay surface while it was exposed for an extended period to oxygenated bottom water prior to mud deposition.

The uppermost unit of postglacial mud is composed of a uniform sequence of faintly laminated, grey, silty clay with blebs of black FeS(?) scattered throughout. The mud is an extremely soft, low-strength material with water contents ranging from less than 60 per cent at depth to over 200 per cent at surface. Within the sampled area it ranges in thickness from 20 feet (6 m) to 60 feet (18 m).

Preliminary pollen studies [5] indicate the muds were not deposited uniformly throughout postglacial time. The pollen record at site C2 indicates a missing pine zone and implies that mud sedimentation began less than 8, 000 years ago. The inferred hiatus in sedimentation corroborates the idea of long-term oxidation of the underlying glaciolacustrine clay surface as described above.

Samples from Core C2 were submitted to Dr. K. M. Creer (Lamont-Doherty Geological Observatory and University of Newcastle) for paleomagnetic analysis in order to:

1. provide material for Dr. Creer's study of Late Quaternary history of the geomagnetic field and

2. assess the potential of paleomagnetic variation measurements for establishing a chronology in uniform Great Lakes sediments.

The preliminary results show no field reversals. However, interesting cyclic variations in inclination and intensity were easily resolved in the holocene mud section and hold great promise for the existence of a magnetic signature in Lake Erie sediments that may be correlated from place to place.

Engineering, stratigraphic, paleontological, and paleomagnetic work is continuing on the materials collected this season. Reports on various aspects of this study are planned for the future.

[1] Lewis, C. F. M., Anderson, T. W. and Berti, A. A.: Geological and palynological studies of Early Lake Erie deposits; Proc. 9th Conf. Great Lakes Research, Great Lakes Div., Univ. Michigan, Ann Arbor Publ. (1966).

[2] Sly, P. G. and Lewis, C. F. M.: The Great Lakes of Canada, Quaternary geology and limnology; Field Excursion A43 Guidebook, 24th Int. Geol. Cong. (1972).

[3]Dreimanis, A. and Karrow, P.F.: Glacial history of the Great Lakes – St. Lawrence Region, the classification of the Wisconsin (an) Stage, and its correlatives; 24th Int. Geol. Cong., Sec. 12, Quaternary Geology, p. 5-15 (1972).

[4]Lewis, C.F.M.: Late Quaternary history of lake levels in the Huron and Erie basins; Proc. 12th Conf. Great Lakes Research, Intern. Assoc. Great Lakes Res. (1969).

[5]Anderson, T.W.: Personal communication; Geol. Surv. Can., Burlington, Ontario (1972).

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110. QUATERNARY GEOLOGY, CHARLIE LAKE, BRITISH COLUMBIA

Project 710085

W.H. Mathews*
Terrain Sciences Division, Ottawa

Field investigation in the Charlie Lake map-sheet took place during half of June and most of July. Field mapping of surficial geology was completed. The most significant findings are:

1. At the junction of Halfway and Peace Rivers, one and a half to four miles northwest of Attachie, and on Farrell Creek, nine miles west of Attachie, lenses of coarse diamicton of Cordilleran provenance are found in three to four hundred foot lacustrine beds underlying the principal till sheet, which is attributable to the last, late-Wisconsin, glaciation. The diamicton is considered to have been deposited by, or sloughed from, ice of an early advance from the mountains to within two miles of Attachie. On the other hand, an occurrence of advance outwash directly beneath the principal till sheet on the south bank of Peace River 17 miles southwest of Attachie is of eastern provenance and suggests that Laurentide ice advanced to this vicinity following a somewhat earlier and temporary advance of Cordilleran ice.

2. A single, virtually continuous, till sheet was deposited at the climax of Late Wisconsin glaciation. In the southwest part of the area it is characterized by a small but significant fraction of slate and schist fragments derived from rocks near, and west of, the Rocky Mountain Trench; in addition, it contains the ubiquitous detritus of quartzite, chert, and sandstone from the Rocky Mountains and of volcanic rocks from the Omineca area. Till of this composition extends eastward to a boundary zone which extends north and northwest from about the mouth of Wilder Creek (13 miles east of Attachie) past Mile 91 on the Alaska Highway, to upper Blueberry River. Eastward from this boundary zone, slate and schist become very scarce to absent whereas detritus of red granite and gneiss, which is very rare throughout the area to the southwest, becomes common. The boundary is considered to mark the junction of Cordilleran and Laurentide ice; the breadth of the boundary zone which can be several miles, may possibly record shifts in the position of this junction during the time of till deposition.

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* University of British Columbia.

3. Shoreline gravels, generally with very weak topographic expression, are concentrated in several swarms, near elevations of 2,750, 2,650, 2,300 and 2,150 feet. The "2300 level" swarm includes several individual beach lines separated by zones in which gravel is scarce or absent (Fig. 1). Differences in the vertical interval within which beach gravels of this swarm can be found at various sites are attributable to the development, or lack of development, of individual strandlines, but a westerly increase in altitude of almost 160 feet along an east-west line over a distance of 78 miles is believed to be due to glacioisostatic tilting. Observations on a 22-mile-long north-south line near the Alberta border could be interpreted to indicate, but do not prove, a similar southward rise in beach levels. The westerly component in the rise of the water plane, no less than 1.2 and perhaps 2.0 feet per mile in the Charlie Lake area, contrasts with a rise to the east of nearly 2 feet per mile in the Great Slave Lake area and suggests that loading by Cordilleran ice has dominated over that by Laurentide ice in the isostatic tilting of the Charlie Lake area.

4. A blanket of glaciofluvial sand overlying postglacial lacustrine beds along Halfway River, from the western boundary of the Charlie Lake map-sheet to a point a few miles east of Attachie, was deposited during a stand of Rocky Mountain ice postdating the last of the lakes to have been dammed back into this area by retreating Laurentide ice.

[1] Craig, B.G.: Glacial Lake McConnell and the surficial geology of parts of the Slave River and Redstone River map-areas, District of Mackenzie; Geol. Surv. Can., Bull. 122 (1965).

111. TERRAIN INVENTORY AND QUATERNARY GEOLOGY OF THE ASHCROFT MAP-AREA, BRITISH COLUMBIA (92I NW)

Project 720058

J.M. Ryder* and R.J. Fulton
Terrain Sciences Division, Ottawa

Field work on this project was completed during the summer with the Quaternary geology and landforms of the Thompson, Fraser and other major valleys being mapped at a scale of 1:50,000 and information being gathered from the rest of the area to provide a basis for airphoto interpretation of regions inaccessible on the ground. The eastern two thirds of the area lies within the Thompson Plateau of the Interior Plateau of British Columbia and consists of rolling upland areas separated by large valleys. The local relief and degree of dissection of the "Plateau" surface increases westward. The western third of the map-area includes parts of the Clear, Marble and Camelsfoot Ranges of the Interior Plateau and a small section of the Coast Mountains.

The bedrock valleys of the Thompson and Fraser Rivers are partly filled with glacial, glaciofluvial, glaciolacustrine and fluvial sediments that are complex both stratigraphically and structurally. There is stratigraphic evidence of at least two glacial stages during which earlier fill was partly excavated from the valleys. During the non-glacial interval following each, the valleys were refilled in part. Postglacial dissection and terracing of the valley fill by major rivers, the development of alluvial fans, landslides and other colluvial features have given rise to the present valley landforms. The Mazama ash (6,600 years B.P.) provides one useful stratigraphic marker but datable material which would further illuminate the Quaternary history was not found.

Till of the final (Fraser) glaciation covers most of the uplands and the shallow "upland" valleys. It forms an almost continuous veneer over the plateau surface of the eastern part of the map-area, where only the steeper valley-side slopes are drift free. Constructional till landforms are confined to localized areas, most notably the southern half of the Hat Creek Valley where well-developed till ridges and associated glaciofluvial features occur. The area of till-covered upland decreases westwards as local relief increases. Alpine glacial forms occur above 6,000 feet elevation in the Coast Mountains. Below this level, slopes are mainly of bedrock or colluvium.

* University of British Columbia.

QUATERNARY GEOLOGY: TRACING MINERAL DEPOSITS

112. TILL INDICATOR TRAIN FORMED BY GLACIAL TRANSPORT OF NICKEL AND OTHER ULTRABASIC COMPONENTS: A MODEL FOR DRIFT PROSPECTING

Project 690095

W. W. Shilts
Terrain Sciences Division, Ottawa

Samples of surface (lodgment) till were collected from exposures in the Thetford Mines - Lac-Mégantic region. The sampling plan was designed to work out the anatomy of the trace-element and mineral train that extends southeastward from Thetford Mines. It was also hoped that the results could help clarify any complications in interpretation of the train, particularly those caused by late-glacial, northward movement of ice in the Thetford Mines area[1].

Samples were collected from fresh exposures along streams and in roadside ditches. Because of abnormally high rainfall and flooding just prior to the sampling, exposures were exceptionally clean and abundant. Lodgment till was sampled at most stations, but some samples are thought to have been taken from the 1 m-thick colluvial mantle that commonly overlies lodgment till on the steep slopes of this region. Although the colluvium is highly weathered, it is usually derived from downslope movement of till, and is thus similar to it in many aspects of composition and texture.

The -250-mesh (-63μ) fractions of all samples have been analyzed for Cu, Zn, Pb, Ni, Cr, Co and Ag using atomic absorption techniques after hot HCl-HnO_3 leach. Table 1 shows the ranges of concentrations for these elements. In addition to these analyses, the percentage of magnetic minerals in heavy-mineral separates (S.G. > 3.3) is being determined and trace-element concentrations will be determined on magnetic-mineral, heavy-mineral, and -2 μ fractions of selected samples.

Figure 1 is a preliminary drawing of the distribution of nickel for the -250-mesh fraction of till. A well-defined indicator train stretches over 40 miles (~64 km) from Thetford Mines toward the southeast. The trace-element train is similar in detail to the surface-boulder train (Fig. 2). Chromium dispersal[2,3] is similar to that for nickel and ultrabasic boulders and pebbles. Percentages of sand-sized magnetic minerals and sand- and clay-sized serpentine are also distributed in similar patterns.

Chamberlain[4], Eckstrand[5], and Nickel[6] report that the ultrabasic rocks of the Thetford area contain uniform amounts of nickel in the 2,000 ppm range. In highly serpentinized facies, the nickel is evenly divided between serpentine and rare iron-nickel alloys such as awaruite. The pre-serpentinization minerals, olivine and enstatite, were thought to contain most of the primary nickel.

It is interesting to note that, in the most nickel-rich portions of the indicator train, nickel values are as high as 950 ppm. After subtracting a regional background value of 40 to 50 ppm it is evident that close to half (9/20) of the finest portions of some till samples have been derived from the ultrabasic rocks. These high values are detected only to distances of a little more

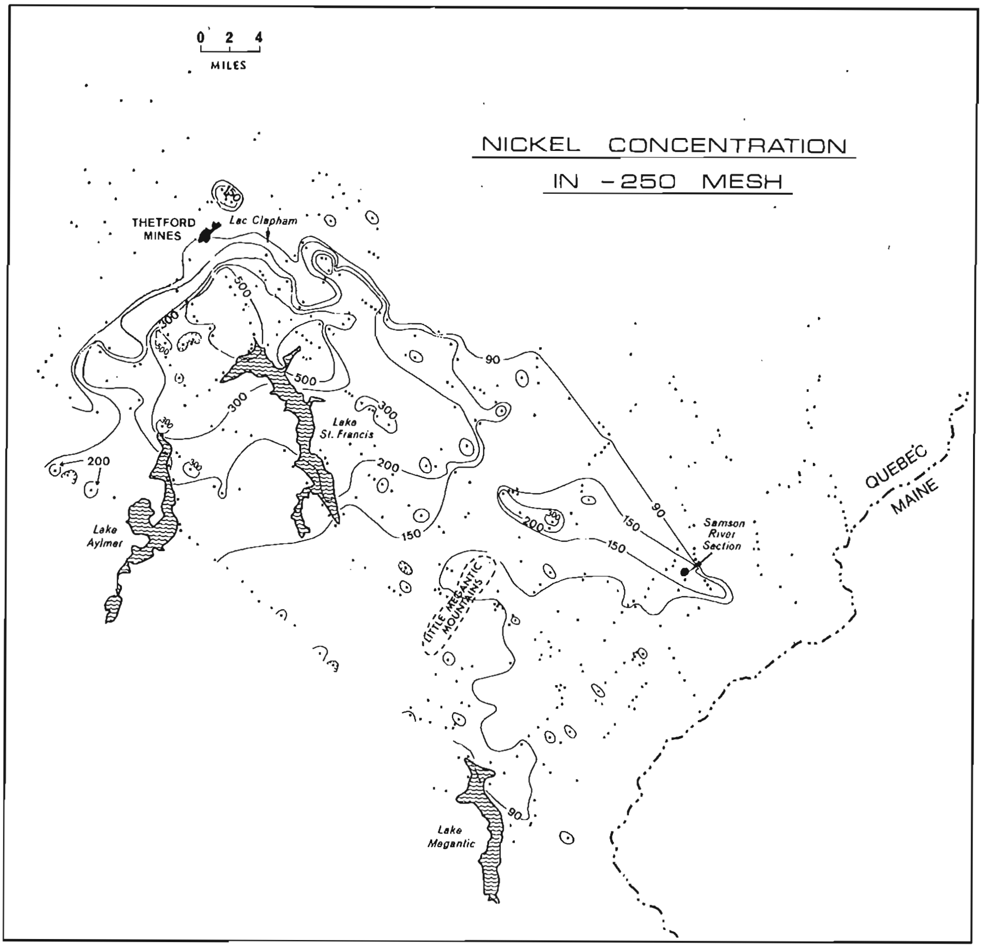

Figure 1. Glacial dispersal of nickel in -250-mesh (63 μ) fraction of till; note that nickel train is traceable over 40 miles (~64 km), is finger-shaped, is best developed where widest outcrop was exposed to glacial erosion, and is interrupted by Little Megantic Mountains' ridge. Stippled areas are ultrabasic outcrop. Contours represent ppm Ni.

than a mile (1.6 km), beyond which they drop off rapidly. At distances of 40 miles, nickel values are still in the range of 150 to 170 ppm which means that, even at this distance, 5 to 6 per cent of the finer portions of the till were derived from ultrabasic rocks.

Figure 3 is a profile of nickel values for three till units exposed in a section located at the axis of the indicator train, about 40 miles from the ultrabasic source area. The two upper units are members of Lennoxville Till, known to have been deposited by a glacier that flowed southeast[7]. The high nickel values of the upper unit reflect its fabric, which points toward the main ultrabasic outcrops at Thetford Mines. The lower member has markedly

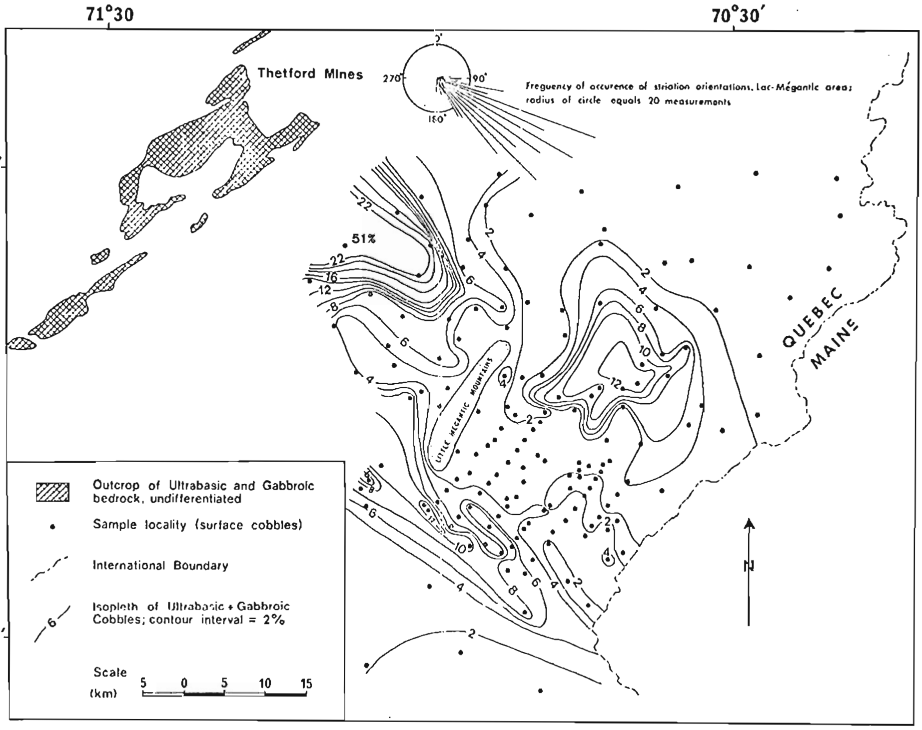

Figure 2. Glacial dispersal of ultrabasic and gabbroic surface erratics. Note striking similarity of pattern to that Ni.

lower nickel content consistent with its fabric which is oriented north-northwest — an azimuth that crosses only small, discontinuous, ultrabasic bodies northeast of Thetford Mines.

The Chaudière Till was deposited by a glacier that flowed over the Samson River from the northeast, changing direction to flow from northwest late in the Chaudière glacial episode[7]. The upper surface of Chaudière Till at this section is striated by ice that was flowing from the direction of Thetford Mines, but the very low nickel contents confirm that the bulk of it was deposited by ice that flowed from northeast and that flow from northwest was not of sufficient duration to transport ultrabasic indicators to the site.

Study of this section emphasizes the necessity of having accurate stratigraphic information when interpreting geochemical data on drift sheets. In this case, thick lake sediments clearly separated the physically similar till sheets but, in other areas, the tills may lie directly on one another with no obvious break.

In conclusion, several aspects of the pattern shown in Figure 1 are important to note as guides for future drift prospecting studies:

(1) The dispersal patterns are "finger-shaped" and actually seem to narrow in the down-ice direction.

(2) Patterns of surface-boulder concentrations and nickel concentrations are similar.

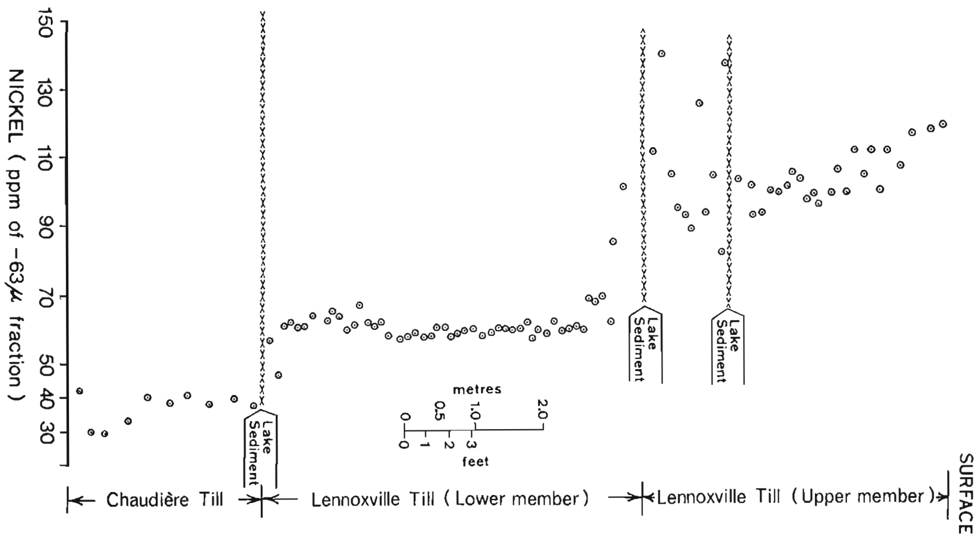

Figure 3. Vertical variation of nickel among three till sheets in a stratigraphic section located near the axis of the ultrabasic indicator train. Section is located about 40 mi. (~ 64 km) from Thetford Mines (see Fig. 1). Lake sediments separating till units are not figured. Only their relative locations are noted. Points in Lennoxville Till are averages of two samples at same level and separated laterally by ~ 2 m.

(3) The nickel fan is well defined and is traceable for over 40 miles (~ 64 km).

(4) Nickel values drop off rapidly in the down-ice direction but, after the initial drop from ~ 45 per cent ultrabasic debris to 5 per cent ultrabasic debris, values stay close to 5 per cent for a long distance. The rate of down-ice dilution of the ultrabasic components is, therefore, logarithmic.

(5) Till contains a maximum of ultrabasic debris at, or slightly down-ice, from the down-ice edge of the source area and not necessarily over the source rocks themselves.

(6) The Little Megantic Mountains, a major topographic high lying athwart the regional direction of glacier flow, have effectively blocked ultrabasic components causing a gap or void in the dispersal pattern.

(7) The strength of the fan seems to be related directly to the width of the outcrop across which the glacier moved (given areally uniform nickel content for the ultrabasic source rocks).

In addition to these seven points, several other preliminary observations may be made on the basis of data not presented here:

(1) Because of variable degrees of weathering of the till exposures and because of the high probability that some samples of colluvium and alluvium were taken, the -250 mesh fraction is best to use in this type of program.

This is because even the slightest oxidation of the normally pyrite-rich till of this area destroys pyrite and probably most other sulphides as well. This makes reasonable comparison of heavy mineral suites from oxidized and unoxidized samples impossible. Oxidation was found to have little effect on the -250-mesh fraction, however. The clay in this fraction probably adsorbs most of the cations released by weathering of the labile minerals, so that there is little net loss of the elements studied.

(2) Anomalously high nickel values and high percentages of ultrabasic erratics occur at the northernmost part of the train, just southeast of a small ultrabasic outcrop in Clapham Lake. The source of these components is difficult to assess as the anomaly is cut off from the Clapham outcrops by samples with low values.

(3) Late-glacial northward ice flow, described by Lamarche[1] for the Thetford area, has had virtually no effect on the distribution of nickel values or ultrabasic erratics.

Uses of this study

The principal value of Figure 1 is that, by changing scales, the nature of dispersal trains from sources of various sizes can be envisioned. It may be reasonable to assume that if the width of the source is scaled down by a factor of 100 (i.e. .04 mile, or $\sim$200 feet in this case) the length of the detectable parts of the train for this tenor of nickel would be on the order of 0.4 mile or about 2,100 feet. Naturally, higher amounts of a trace-element in the source will take a longer distance to be diluted so that the length of a train is not only proportional to the size of the source but to trace-element concentration in the source and the ease with which the source can be eroded by ice.

Table 1

Range of observed concentrations of seven trace-elements in till and ultrabasic rock — Thetford Mines - Lac-Mégantic area

Element	maximum range in ultrabasic train (ppm)	average range outside ultrabasic train (ppm)	ultrabasic mine spoil (ppm) (2 samples)
Ni	70-950	30-50	1650-2100
Cr	50-260	18-50	610-870
Co	21-64	11-25	62-77
Cu	18-50*		7-20
Zn	60-90*		26-30
Pb	15-25*		13-16
Ag	0.4-1.2*		1.2-1.4

*More than 95 per cent of these values fall within this range (analysis of about 500 samples).

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[5] Eckstrand, O.R.: The nickel potential of serpentinized ultramafic rocks; Can. Mining J., v. 92, no. 4, p. 40-45 (1971).

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113. PROSPECTING FOR DIAMONDS IN NORTHERN ONTARIO - A SUGGESTION

Projects 710080; 690045

R.G. Skinner
Terrain Sciences Division, Ottawa

It has commonly been asserted that northeastern Ontario is the source of the Great Lakes Diamond fan[1,2]. The Moose River basin of the James Bay lowlands has been considered an attractive area for diamond exploration due, partly, to the occurrence of a kimberlitic lamprophyre at Coral Rapids on Abitibi River. However, the thick cover of glacial and marine sediments has discouraged the use of a common prospecting technique, that of tracing kimberlite indicator minerals.

The Cretaceous Mattagami Formation of the Moose River basin should not be overlooked as a possible source of placer diamonds. The Mattagami Formation consists of continental beds of gravel, sand, clay and lignite deposited as a clastic wedge. It was probably once a feldspathic or arkosic deposit, similar to the Sextant Formation, an arkose of Lower Devonian age in the same area. The Mattagami Formation is geochemically very mature, consisting of kaolin and quartz — the end members of weathering. Cretaceous gravel beds observed along Adam Creek, northeast of Smokey Falls, consist of silica pebbles, some of which are extremely angular, and many with vugs. The vugs are believed to have been occupied by less stable minerals such as mafics or feldspars. Very angular, amoeboid-shaped quartz and silica grains were observed in thin sections of the silica sand from McBrien Township. Many quartz grains have flat, cleavage-like surfaces due to an original contact with a cleavage surface or crystal surface of some less stable mineral. Most grains are coated with a thin film of kaolin. It is suggested that the unstable minerals in the original arkose have been slowly altered to kaolin, which has been illuviated down through the interstices of the sand. The kaolin may have accumulated preferentially in less permeable, fine-grained zones in the clastic wedge resulting in bands of kaolin-rich sand.

The Mattagami Formation is unconsolidated. In some places it is under hydrostatic pressure and will flow up a well if drilled into[3,4]. This feature could be utilized in sampling large volumes of the sand in a search for diamonds. It is conceivable that very fine grained diamonds have illuviated down to the kaolin bands and have collected there. This might be a method of testing for diamonds in the deposit. Exploration for diamonds in these sands will require that large volumes be sampled and processed. This might be economic if the silica sand and kaolin were beneficiated at the same time. Meanwhile, the first diamond in these deposits is yet to be found.

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[2] Satterly, J.: Diamond: USSR and North America: a target for exploration in Ontario; Ont. Dept. Mines, Misc. Paper 48 (1971).

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114. GEOMORPHOLOGICAL PROCESSES AND TERRAIN SENSITIVITY, BANKS ISLAND, DISTRICT OF FRANKLIN

Project 640004

H. M. French*
Terrain Sciences Division, Ottawa

A number of studies related to thermokarst processes, both natural and man-induced, were initiated in Eastern Banks Island and at Sachs Harbour. Previous geomorphic process studies were also continued.

Eastern Banks Island

Attention was concentrated upon the morainic areas between Johnson Point and the Thomsen River. The aim of this project is to identify the principal present-day processes operating on this terrain, paying particular attention to naturally occurring thermokarst phenomena and processes. A map of terrain sensitivity is being prepared based upon a consideration of both terrain conditions and present-day geomorphic processes.

The dominant processes operating in the study area appear to be (1) mass-wasting, (2) fluvial, (3) thermokarst. Evidence for both thermal erosion and thermal subsidence (thermokarst) can be found. Numerous semicircular thermokarst erosional scars, similar to those described by Lamothe and St-Onge[1], reflect the presence of localized ground-ice bodies of, as yet, undetermined origin. The scars appear to be randomly located in areas adjacent to kettle lakes and depressions with no preferred orientation. Both active and stabilized features can be recognized, and some are several acres in extent. In addition, many of the small stream valleys are asymmetrical, with steeper slopes facing towards the west and northwest. These slopes are often characterized by numerous active mudslumps and thermokarst scars. Two active thermokarst scars were monitored during the summer.

Rates of retreat of the headwall above the ice face, and movement within the scar are presented in Table 1.

It appears that maximum activity of the scars is in early July and that in late summer, as the ice exposure becomes buried beneath slumped material, rates of change decrease. The data suggests that retreat of the headwall, and thus the enlargement of the scar, is in the order of 20 to 30 feet each summer. Airphoto interpretation, together with a consideration of the average dimensions of many of these features, suggests also that the majority of scars become stabilized within 20 to 30 summers of their initiation.

Patterned ground features include non-sorted stripes and circles in the lowland areas adjacent to lakes. On the coarse-grained morainic materials comprising the uplands, high centred polygons, commonly 30 x 60m in diameter, dominate the terrain and form shallow baydjarakh fields. Small irregularly-shaped thermokarst ponds, some of which remain throughout the summer, occupy the depressions formed at the junction of adjacent polygons. Where badland topography exists in close juxtaposition to polygon terrain, fluvial erosion has operated preferentially along ice wedges (thermal erosion)

*University of Ottawa

TABLE 1

SCAR	HEADWALL RETREAT			MUDFLOW MOVEMENT	
	Period of observation	Av. rate of retreat (ft./day)	Over all retreat (ft./day)	Period of observation	Av. rate of cork movement (ft./day)
1	June 30 - July 10	0.39	0.32	June 30 - July 10	0.76
	July 10 - July 23	0.37		July 10 - July 23	0.53
	July 23 - Aug. 3	0.27		July 23 - Aug. 3	0.41
	Aug. 3 - Aug. 13				
2	July 15 - July 28	0.41	0.36	July 15 - July 28	0.72
	July 28 - Aug. 12	0.31		July 15 - Aug. 12	0.42
				(July 28 - Aug. 12	0.16)

to form striking baydjarakhs over 30 feet high and with side slopes in excess of 40 degrees. Detailed mapping of these patterned ground and thermokarst features has been undertaken. Thermal characteristics of the active layer are also being investigated, using thermocouples and soil and surface thermographs, in a variety of different terrain conditions, both natural and man-induced.

As mass wasting is the most widespread process in the area, experiments were initiated to measure its rates. Badland topography and areas of rapid fluvial dissection are limited to fine-grained outwash or lacustrine sediments. In these areas, wooden dowels are being used to investigate the nature and rate of slope development.

Sachs Harbour

a) Mass-wasting studies

Tin foil markers and painted pebbles, installed in 1969[2], were re-examined. The aim of these experiments was to establish the rates of mass-wasting characteristic of slopes of extremely low gradient and developed in unconsolidated materials. Table 2 presents data, for five localities, on sub-surface movement rates for slopes of 2 degrees over the three year period 1969-72. On these slopes the over all average rate of movement p.a. is 1.56 cm. Predictably, the highest rates occur in the surface layers and, with increasing depth, the rate of movement decreases.

TABLE 2

Date of installation: 28.6.1969 | Date of resurvey: 17.6.1972

Site	Depth 2cm	8cm	15cm	30cm	Av. total movement (cm)	Av. p.a. movement (cm)
1	5.8	4.9	4.7	4.2	4.9	1.63
2	4.9	4.6	4.9	4.5	4.7	1.56
3	4.0	4.2	4.2	4.5	4.2	1.40
4	4.9	4.7	5.4	4.3	5.3	1.76
5	5.6	5.6	3.9	2.1	4.3	1.43
Column averages	5.3	5.0	4.6	3.9	4.7	1.56

Data for surface pebble movements on the same slopes are presented in Table 3. The average p.a. surface movement is greater than the subsurface movement, emphasizing the importance of the rillwash and surface sheetwash components of mass-wasting. Other similar studies, on slopes of varying angles, are being continued to obtain longer term results.

TABLE 3

Slope angle	Original no. of pebbles 1969	No. pebbles identified 1972	Av. total movement cms	Av. p.a. movement cms
2°	120	79	7.15	2.57

b) Terrain sensitivity and thermokarst studies

Several acres of disturbed terrain adjacent to the Sachs Harbour airstrip are being observed. A thin veneer of glacial sands and gravels, which overly silts and sands, was stripped and removed during the construction of the airstrip in 1962. Thermokarst subsidence has occurred subsequently on both sides of the airstrip. The thermokarst terrain is characterized by irregular hummocky topography, standing water and pools, and a number of small, interconnected linear depressions. The hummocks are commonly 10 to 15 feet in diameter and give a relative relief of between 3 to 5 feet to the terrain. Air photographs reveal the depressions to follow broad patterns similar to the ice-wedge polygons of adjacent undisturbed areas.

Detailed levelling of selected areas of thermokarst has been undertaken with a view to ascertain the rate of change of thermokarst topography. Thermocouples have been installed to investigate the thermal regimes of disturbed and undisturbed terrain. The thickness of the active layer in different terrain conditions was also determined at various intervals during the summer. Sample depths are given in Table 4.

TABLE 4

Date of observation (1972)	Undisturbed terrain (in.)	Airstrip shoulder (disturbed) (in.)	Disturbed terrain (stripped) (in.)
17 June	20.0	13.0	7.5
16 July	26.0	28.0	28.0
7 September	32.0	36.0	35.5

Surficial geology mapping and a general geomorphological reconnaissance was also begun in the surrounding area as a first step towards an environmental geomorphology study of the Sachs Harbour area.

[1] Lamothe, C., and St-Onge, D.: A rate on a periglacial erosional process in the Isachsen area, N.W.T.; Can. Geog. Bull., v. 16, p. 104-113 (1961).

[2] French, H.M.: Geomorphological investigations: Northern and Southern Banks Island, District of Franklin; Report of Activities, Part A, April to October, 1969; Geol. Surv. Can., Paper 70-1, pt. A, p. 190-192.

QUATERNARY GEOLOGY: SURVEYS AND TERRAIN PERFORMANCE - MACKENZIE VALLEY

These projects are part of the Environmental Social Program Northern Pipelines, of the Task Force on Northern Oil Development, Govenment of Canada

115. THE STABILITY OF NATURAL SLOPES IN THE MACKENZIE VALLEY

Project 720068

J.A. Code
Terrain Sciences Division, Ottawa

A study of the stability of banks of the Mackenzie River and its tributaries within the plains region was carried out between Fort Providence and Fort Good Hope. Slopes were mapped according to an engineering-geological classification which is intended to convey information, applicable to engineering purposes, which relates stability to the geology and the geometry of the slopes. A tentative and abbreviated version of the classification is given in Table 1. Erosion of the river banks is accomplished by a range of types of mass movement and mass transport. The most significant mass movement, from an engineering standpoint, involves Quaternary and Cretaceous sediments. In order to indicate the importance of the scale of these failures they are initially classified either as relatively small active layer failures or as the larger, retrogressive types which characteristically involve the movement of much larger quantities of material. Although the latter type would present a more immediate threat to such nearby facilities as roads, pipelines or structures their occurrence is somewhat predictable as they are associated with certain geological and topographic settings which can be avoided by construction activity.

TABLE 1

Map Unit	Age of Deposition	Characteristics of Slope Erosion
D	Devonian	Failure mainly by rockfalls
K_A	Cretaceous	Low slopes (<100 ft.) erode by rockfall, slopewash, gully erosion, shallow slumping
K_L	Cretaceous	High slopes (>100 ft.) fail by large scale slumping of entire bank usually near the toe
Te	Tertiary	Slopewash, infrequent slumping
Q_S	Quaternary	Stable riverbank, usually 15 degrees or less
Q_A	Quaternary	Active layer failures, mainly shallow flows, detachment slides, solifluction or creep, slopewash and gullying
Q_L	Quaternary	Large scale retrogressive slumping - mainly confined to glaciolacustrine sediments in high slopes (100+ ft.)

In conjunction with this project, the role of groundwater in the various types of mass movement is being investigated by Dr. A. Lissey of Brock University, under contract to the Geological Survey. Initial investigations in a study to determine quantitatively the common failure mechanisms associated with landslides in the Mackenzie Valley were carried out by Dr. N. Morgenstern and Mr. E. McRoberts of the University of Alberta also under contract with the Geological Survey.

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116. EROSION IN A PERMAFROST ENVIRONMENT

Project 690054

J.A. Heginbottom
Terrain Sciences Division, Ottawa

The experiments reported previously[1,2,3] were inspected and resurveys were undertaken. The experiment to monitor changes in ground surface elevation and the thickness of the active layer, begun in 1969, was concluded. The experimental sites have been resurveyed twice each year for four years, and the effects of the repeated presence of the surveyors has introduced considerable disturbance itself. This has now reached the point where the reliability of future surveys would be doubtful. Several other surveys of the effects of the 1968 forest fire on ground surface elevation and the thickness of the active layer were made in different topographic situations. The data from all these surveys is still being analyzed. The other experiments reported on previously are being continued.

In September, Dr. A. Lissey installed 31 piezometers in a bulldozed plot at Manipulation Site 1[2]. They were grouped in three nests of ten plus a single piezometer. Each piezometer within a nest was screened at a different depth. The vertical distance between screens was set at 10 cm and the deepest piezometer within a nest was completed at a depth of 100 cm. One nest was located in the centre of a pre-existing mineral soil hummock whereas the other two were located within the organic material separating hummocks. The singer piezometer was located in undisturbed terrain upslope of the bulldozed plot.

After stabilization, slug tests were run on seven piezometers. These tests suggest that the organic material has a high permeability, that the clay till comprising the hummocks has a less permeability and that the permeability of the till decreases with depth. Readings of the stabilized water levels taken every two hours for 48 hours in all piezometers showed that, as freezing of the soil occurs, the water-table drops and a vertically upward hydraulic gradient is established within the saturated zone. This suggests that, as the freezing front progresses downward from the ground surface, groundwater moves up towards it. All the piezometers will be read on a weekly basis to monitor groundwater behaviour in the active layer throughout each season of the year.

By learning of the behaviour of groundwater in the active layer we hope to gain some understanding of the importance of water movement as a heat transfer mechanism in the thermal regime of the permafrost active layer.

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117. TERRAIN SENSITIVITY AND MAPPING MACKENZIE VALLEY TRANSPORTATION CORRIDOR

Project 710077

J.A. Heginbottom and P.J. Kurfurst
Terrain Sciences Division, Ottawa

A five-week drilling program was carried out in the Norman Wells area (96E) by P.J. Kurfurst in March and April 1972. The main objectives of drilling were:

1. To provide subsurface information on surficial deposits and to verify the boundaries of the surficial deposits map[1].
2. To obtain frozen core samples of different surficial materials for laboratory determination of the ultrasonic-wave propagation and for thermal properties test.
3. To obtain chip samples of surficial deposits and bedrock for laboratory determination of their engineering properties.

During the drilling operation, which was supervised by R.M. Isaacs, a new technique for coring frozen materials was developed. A truck-mounted Mayhew 1000 rotary drill rig was used for drilling and coring and a specially equipped truck with Revco freezers was used for preliminary preparation, handling and storing of core and chip samples obtained (R.M. Isaacs, Project 700094).

Forty holes, ranging from 15 to 200 feet in depth were drilled at twelve different sites along Canol Road and on and off winter roads and seismic lines around Norman Wells. Each site was located within a different surficial geological map-unit ranging from till plain and lacustrine and glaciolacustrine deposits to glaciofluvial, eolian and organic sediments. The underlying bedrock, when encountered, was shale and siltstone. Several holes were drilled at each site in both undisturbed and freshly disturbed areas to obtain comparable samples. Some 150 feet of frozen core and 100 chip samples were collected for further tests.

Materials of each surficial geological map-unit have a different character and variable ground ice content. Peat is generally of low strength, highly compressible with moderate to high ground ice content; it is commonly unfrozen (fen) to depths of more than 6 feet. Clay, which is commonly mixed with silt and overlain by sand with a discontinuous organic cover, is generally highly plastic, with moderate to high ground ice content in the form of a reticulated network of segregated ice. Silty to clayey till, underlain by bedrock, has moderate ground ice content with segregated ice occurring as thin seams and thicker lenses. Ground ice content in sand and gravel is generally low or not present in the coarser deposits and low to moderate in finer sediments. Little ground ice is found in bedrock except in shale where a network of small ice-filled fractures was encountered at depths of from 100 feet to 150 feet.

Seven thermistor cables between 50 and 200 feet in length were installed at different sites to provide continuous record of air and ground temperatures at different depths. Shallow seismic surveys were carried out at these sites to determine the depth and properties of permafrost.

In May and June 1972 six weeks were spent in Saskatoon at the Department of Geological Sciences, University of Saskatchewan, where extensive use was made of their electronic equipment and of the facilities of the Rock Mechanics Laboratory. Specially designed transducer holders, a loading frame and electronic equipment were used in the controlled-temperature chamber to measure the ultrasonic-wave velocities of frozen core at temperatures ranging from +30 to +20 degrees F.

Some 25 representative samples of soil and rock materials from the Norman Wells area were tested to compare laboratory results with the seismic velocity measurements obtained in the field and to determine the ice content in different materials. The ultrasonic-wave velocities were recorded for each material. They varied from very low (peat - 5,000 ft./sec.) to very high (clay - 13,000 ft./sec.). Preliminary results indicate that decrease in temperature or increase in ground ice content results in much higher ultrasonic-wave velocities. All data are being evaluated and will be made available early in 1973.

During the summer of 1972 one week was spent around Inuvik and Tuktoyaktuk studying ground ice features of the area and investigating terrain disturbance at several drill sites. Six weeks were spent in the Norman Wells area studying the response of various soil and rock materials to different types of natural and man-made disturbances. Emphasis was placed upon thorough study of the Canol Road and the Oscar Creek areas. Canol Road is one of the oldest major roads built in the N.W.T. and, with the network of access roads, camp areas, borrow pits and airstrips, represents an ideal example of various types of man-made terrain disturbances and resulting changes in different materials. Oscar Creek area, containing two abandoned well sites and recently built winter roads, seismic trails, and staging areas, represents the most recent major terrain disturbance in the area.

A number of old and new drill sites were investigated. Some time was devoted to extensive soil sampling and mapping of the permafrost and thickness of the active layer. The increase in active layer thickness due to the terrain disturbance of the drilling operation was observed to be between 50 and 100 per cent compared with relatively undisturbed areas farther from the well-head; this can result in gullying and terrain subsidence.

Excessive compaction and/or removal of the vegetation cover by natural or other processes can lead to terrain subsidence, severe gullying, and ground ice and thermokarst slumping. Ice-rich clays and silty clays on hillsides and sloping banks are most prone to disturbance which can result in superficial mudflows and large flow slides.

J.A. Heginbottom examined terrain disturbance associated with oil exploration activities around the southern half of the Mackenzie Delta (NTS 106 M-N). Eight abandoned oil well sites were visited and at each one the aftermath of drilling and associated activities, which included airstrips, seismic trails, access roads, campsites, and staging areas was examined. The oldest site visited was abandoned in 1960, the most recent one in January 1971.

The disturbance immediately surrounding the well-heads and slush-pits is quite apparent. At most sites gravel and/or wood chips had been spread to minimize thermal disturbance. Wood chips can be quite effective for this purpose for at Attoe Lake 1-06 well-site, on 20 June 1972, the ground was thawed for only 10 cm below a 25-cm thick layer of wood chips, compared with 60 cm under burned ground and 42 cm under unburned ground well away from any disturbance. In general, the depth of thaw was greatest near the well-head, and decreased to the edge of the clearing. The depth of thaw was normally about 50 per cent greater in the well-head area compared with undisturbed terrain.

The three airstrips examined had suffered little disturbance other than removal of tree vegetation. The site requirements of a temporary airstrip - smooth, level ground - mean that they are often sited on terraces of granular, i.e., non-frost susceptible, material or on broad organic deposits. Neither are prone to severe deterioration following the initial clearing.

Seismic trails were examined in about 15 locations on slopes of various angles and geological materials. The amount of disturbance appears to be due primarily to differences in original mode or construction of the trails — in cases where the humus and vegetation mat was removed, thawing and thermokarst have occurred. In other cases, only the removal of the trees indicates that any activity has taken place. Similar conclusions may be drawn from the access trails which were examined in nine locations.

Figure 1. Gullying guided by and concentrated in vehicle tracks. Tree River, N.W.T. Rod is 4 m long. (GSC Photo no. 202095)

Other activity sites examined included two river crossing sites, a borrow pit and four camp areas. The camp areas were similar to the well-head areas in most respects. The borrow pit and the river crossing sites were in gravel deposits and the disturbance subsequent to the initial activity appears minor. One exception to this is gullying being guided by, and concentrated in, the vehicle track marks on the trail between the borrow pit and the well-head area where the gravel was used (Fig. 1).

[1] Hughes, O.L.: Preliminary drafts of five surficial geology maps of Mackenzie District, N.W.T.; Geol. Surv. Can., Open File no. 26 (1970).

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118. SURFICIAL GEOLOGY AND LAND CLASSIFICATION, MACKENZIE VALLEY TRANSPORTATION CORRIDOR

Project 710020

O.L. Hughes, J. Pilon, and J. Veillette
Terrain Sciences Division, Calgary

The objective of the project, continued from 1971[1], is to provide inventory surficial geology and permafrost distribution data pertinent to pipeline construction, road building and other land-use activities that might take place in the Mackenzie Valley Corridor.

Field work was devoted mainly to: (1) field checking of 1:125,000 scale photo-interpretive maps, prepared in advance of field work, of map-areas 106E (N 1/2), 106F (N 1/2), 106L, 116H (part), 116I, 116N (E 1/2), 116O, 116P; (2) drilling shallow holes with light-weight coring drills to provide engineering data on the geological materials and contained ground ice; 109 holes averaging about 9.5 feet in depth were drilled. Bedrock lithology was examined at numerous localities to augment bedrock geology data available from existing reconnaissance maps.

Some important features of the Quaternary geology are: (1) map-areas 106E (N 1/2), 106F (N 1/2) and 106L lie mostly within the limits of Laurentide glaciation. The remaining areas are mostly unglaciated[2]; (2) a broad, irregular belt of mostly low relief hummocky moraine extends along the east flank of the Richardson Mountains. The moraine is locally overlain and, in places, underlain by glaciolacustrine sediments. The sediments and, locally, the till of the hummocky moraine have high ice contents and are potentially highly unstable; (3) much of the 106L map-area is underlain by Cretaceous shale that has been deeply dissected postglacially. Valley walls along major streams and tributaries are highly subject to detachment slides, especially following fires, and large rotational slides are common; (4) glaciolacustrine sediments with locally high ground-ice content, and which are potentially highly unstable, occur along the lower reaches of Snake River, along Peel River between Snake and Wind Rivers and the lower reaches of Wind and Bonnet Plume Rivers; (5) extensive lacustrine and glaciolacustrine sediments in Bell Basin, Old Crow Basin and along Porcupine River have locally high ice content and are likewise potentially unstable[2]; (6) except in areas of basin sediments and of fluvial sediments bordering major streams and tributaries, landform and surficial deposits of the unglaciated area are largely determined by structure and lithology of subjacent bedrock. Map-units distinct from those used in the glaciated area were adopted to distinguish the wide range of landforms and surficial deposits found within the area.

S.C. Zoltai of Canadian Forestry Service and W. Pettapiece, Department of Agriculture, were attached to the field operation. Zoltai determined the relationship of vegetation to surficial geology, landform and permafrost conditions, and Pettapiece studied the relationship of soil development to the same factors. D. Delorme and L. Kalas, Inland Waters Branch, Department of the Environment, collected modern ostracods and mollusca, plus environmental data relevant to the collections, as background data for future paleoecological studies.

[1] Hughes, O.L., and Hodgson, D.A.: Quaternary reconnaissance, Northwest District of Mackenzie; in Report of Activities, Part A, April to October, 1971; Geol. Surv. Can., Paper 72-1, pt. A, p. 165-166 (1972).

[2] Hughes, O.L.: Surficial geology of northern Yukon Territory and northwestern District of Mackenzie, Northwest Territories; Geol. Surv. Can., Paper 69-36, 11 p. (1972).

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119. ENGINEERING GEOLOGY MACKENZIE VALLEY TRANSPORTATION CORRIDOR

Project 700094

Ralph M. Isaacs
Terrain Sciences Division, Ottawa

In March and April 1972, ten drill sites in the Norman Wells-Canol Road area were drilled with a Mayhew 1000 truck-mounted rig supplemented with an air to air heat exchanger, both supplied and manned by Big Indian Drilling of Calgary, Alberta.

With the assistance of P.J. Kurfurst, and after considerable experimentation, a combination of core barrel and drill bit was found which would give relatively undisturbed cores of frozen sand and silt, i.e., a 5-foot Valley Tool Machine core barrel with a short nose cone to the inner core barrel and a 6-tooth wide insert bit with no core catcher. Cores of clay of acceptable quality could not be obtained by using air as a drilling fluid. Very good quality cores were obtained, however, with the use of chilled diesel fuel in conjunction with a V.T.M. core barrel equipped with a 12-tooth narrow insert bit, which made the core diameter slightly smaller than the inner core barrel, a core catcher and an inner core barrel whose nose cone projected to just behind the inserts. The barrel and bit configuration used for air drilling of sand and silt also proved successful for drilling with diesel fuel of these materials.

Most of the core (about 150 feet) was obtained, however, with a 3-inch split-spoon driven by a 350 lb. hammer. The standard split-spoon will not give acceptable core except by chance but, by ensuring that the inside diameter of the shoe is identical to the inside diameter of the barrel, the quality of the core can be improved considerably.

Very limited drilling of the Canol Road, at about 6 1/2 miles along the road from the Mackenzie River, indicated that permafrost immediately beneath the road may have disappeared entirely or has degraded to a great depth. This seems substantiated by recent shallow seismic work by J.A. Hunter (Project 680037) and, as it may be very significant in the design of roads and pipelines in the north, it should be investigated during the next field season.

The cores and chip samples from several holes were kept in Revco freezers throughout the drilling operation and were flown back in the freezers to Ottawa in a YS-11 aircraft modified to keep its cabin temperature at about 0°C.

Most of the cores have since been photographed and logged in a cold room in Ottawa and, at present, classification and thermal tests are being performed on them.

In July, some three weeks were spent installing additional thermistors in the Canol Road area and at sites drilled in the 1971 field season in the Sans Sault-Fort Good Hope region.

Additional data acquisition systems in environmental boxes were also installed at the latter sites.

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120. GRANULAR RESOURCE INVENTORY - MACKENZIE VALLEY

Project 720085

D. E. Lawrence
Terrain Sciences Division, Ottawa

The object of this study is to provide information on the availability and quantities of natural construction (bedrock and unconsolidated) materials in the Mackenzie Valley and Delta. Emphasis is being placed on areas where there may be a shortage of these materials relative to anticipated demand, e.g., settlements and along proposed highways and pipeline rights-of-way. This study is being produced for the Department of Indian and Northern Affairs.

In co-operation with a similar project (G.V. Minning, Project 720086), over forty maps at a scale of 1:250,000 of areas between the Alberta border and the Beaufort Sea will be assessed. The information for each map-area is presented in the form of a report with a tabular summary of the estimated quantity and quality of materials, a black-line map showing areas of surficial deposits and, where applicable, a bedrock geology map. These maps and reports will be completed by March 1973 and will be available through the Department of Indian and Northern Affairs.

Data for the inventory are derived primarily from surficial and bedrock geology maps produced by various officers of the Geological Survey of Canada. Most of the bedrock geology maps are in unpublished manuscript form whereas the surficial geology maps are available on Open File (copies may be examined at Geological Survey of Canada offices).

Field work during July and August 1972 was devoted mainly to assessment of the granular deposits as sources of construction material. Field checking of these deposits was carried out by a two-man helicopter-supported team concentrating in the following NTS map-areas: 96 C, D, E, F; 106 G, H, I, J, M, N, O; 107 B, C.

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121. SOME ASPECTS OF PERMAFROST GROWTH MACKENZIE DELTA AREA, N.W.T. (107 B, C, D)

Project 680047

J. Ross MacKay*
Terrain Sciences Division, Ottawa

Rate of Permafrost Growth

The rate of permafrost growth, in the bottoms of naturally drained lakes in saturated sands is estimated to be:

$$z \approx 3\sqrt{t}$$

where z is the depth of permafrost in metres; t is time of permafrost growth in years; and the mean annual ground temperature is -10°C. This field derived equation is in reasonable agreement with computations based upon the Neumann solution for the freezing of soils with a phase change. The depth of permafrost in silty or clay soils, with segregated ice, would be less by as much as 50 to 100 per cent.

Lake Bottom Heave

In continuous permafrost, the bottom sediments of lakes deeper than the winter ice thickness will always have a talik, which may or may not be through-going. When such lakes are drained, either naturally or artificially, permafrost will aggrade downwards on the exposed lake bottoms. Therefore, the lake bottoms must heave, unless pore water escapes at depth through a continuous talik. In the extreme case, localized "heave" produces a pingo with its ice-core but, in most instances, lake drainage results in a widespread heave of the lake bottom, and thus escapes notice. Precise levelling on bench marks, established across drained lakes, shows that lake bottom heave does occur, that differential heave permits an estimate as to the extent of ice segregation at depth and that in one lake, which drained an estimated 150 years ago, heave is still occurring. Thus, lake bottom heave may be a construction factor in artificially drained lakes.

Pingo Growth

The growth of closed system pingos has now been measured for three years by precise levelling of non-heaving bench marks. The pingos range in height from 6 to 18 m. For this height range, preliminary studies suggest that the following identity holds:

$$H_2 = \frac{b^2}{\Delta H}$$

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*University of British Columbia

where H_2 (in cm) is the height of the pingo as measured from the bottom of the ice-core, i.e., about 4/3 the apparent pingo height; b is an empirically derived parameter related to thermal conductivity and diffusivity which indicates the nature of the freezing process; and ΔH (in cm) is the measured annual growth at the top of the pingo. The available evidence suggests that: (a) if $b > 150$, water is injected faster than it can be frozen; (b) if b lies between 100 and 150, a "pure" ice-core is growing by basal freezing; (c) if b lies between 50 and 100, segregated and pore ice are growing below the ice-core, and permafrost has closed beneath the pingo; and (d) if $b < 50$, the growth of the pingo is due to volume expansion associated with the growth of pore, and some segregated, ice well below the ice-core.

A Simple Meter to Measure Upward Freezing

Laboratory experiments have shown that a vertical migration for particles can take place in front of a moving plane[1]. For example, if the freezing front moves vertically upwards, sand particles placed on top of ice may be carried upwards, against gravity. This principle has been used, in the field, to measure the upward rise of the frost table, above permafrost, during the fall freeze-back. Transparent water-filled acrylic tubes, inside rigid PVC tubes, have been installed vertically to depths well below the top of permafrost. After the water has frozen in the acrylic tubes in the winter, sand grains and small (e.g., 1 cm diameter) pebbles have been seeded onto the ice in summer. During the summer thaw the sand grains and pebbles descend with the downward-thawing ice surface. However, in the fall freeze-back, the larger pebbles remain in situ, but most of the sand grains and some smaller pebbles are uplifted. A maximum uplift of 17 cm has been measured. With proper care in construction, this simple method might serve to monitor long term changes in the depth of the thaw zone of the active layer and the rise of the permafrost surface beneath areas of artificial fill.

[1] Corte, A.D.: Vertical migration of particles in front of a moving freezing plane; J. Geophys. Res., v. 67, p. 1085-1090 (1962).

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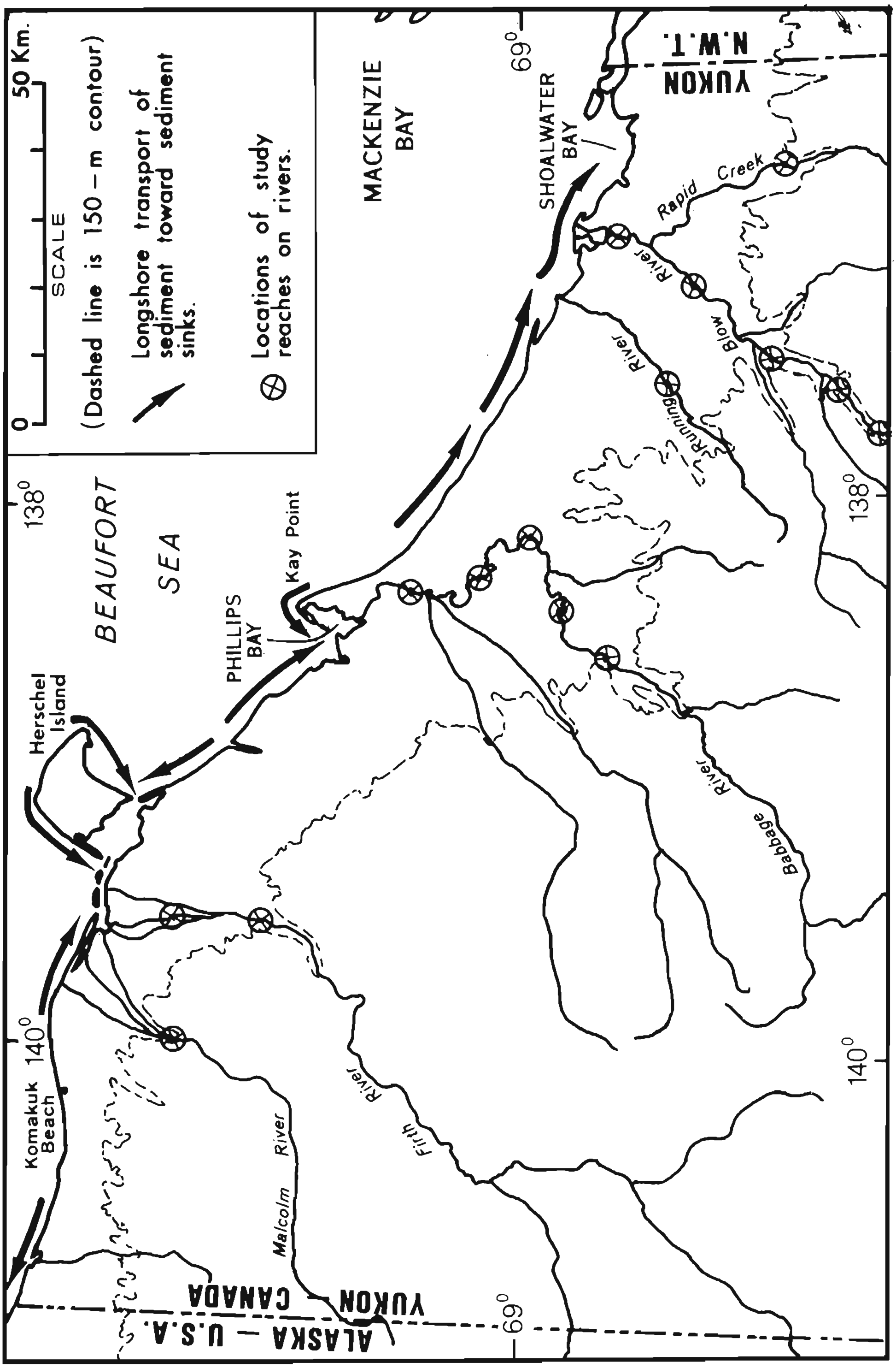
122. SEDIMENTARY AND GEOMORPHIC PROCESSES, YUKON COASTAL PLAIN

Project 720079

B.C. McDonald and C.P. Lewis
Terrain Sciences Division, Ottawa

The major objective of this project is to examine the modern sedimentary environments of the coast and rivers of the Yukon Coastal Plain (Fig. 1) from the Mackenzie Delta, west for about 180 km, to the Alaska border (part of NTS 117 S.W. and 117 S.E.). The study focuses on the types, magnitudes and frequencies of erosional and depositional processes presently active in the area. This information, in turn, will be used to assess their potential impact on various human activities.


SCALE
0
50 Km.
(Dashed line is 150 – m contour)
Longshore transport of sediment toward sediment sinks.
Locations of study reaches on rivers.
BEAUFORT
SEA
MACKENZIE
BAY
SHOALWATER
BAY
PHILLIPS
BAY
Kay Point
Herschel
Island
Komakuk
Beach
YUKON
N.W.T.
ALASKA — U.S.A.
YUKON — CANADA
Rapid Creek
Blow River
Running River
Babbage River
Firth River
Malcolm River
138°
140°
69°

Field work in the summer of 1972 was broken into two components:

1. Major Rivers. These are of particular interest because of the variety of types, from braided through to full meandering, found along the Yukon coast. As well, a large number of river reaches fall somewhere between the braided and meandering states (i.e., braided but with a dominant low water channel) and their hydraulic characteristics are thus difficult to predict without field measurements.

Selected reaches of the Rapid, Blow (five reaches), Running, Babbage (five reaches), Firth (two reaches), and Malcolm Rivers were studied in some detail (Fig. 1). Data collected at each reach included: water discharge; water temperature; suspended and dissolved load concentrations; a slope of water surface and of floodplain (if present); channel cross-section characteristics; and size of material in channel bars, beds and banks. General observations were made on mass movement, permafrost features, river terraces and channel stability. In several locations stake networks were installed to enable measurement of bank retreat, and painted lines and chains were placed to provide data on channel bed scour.

Reaches of other coastal plain rivers and additional reaches on those rivers mentioned above were examined in much less detail. Emphasis was on description of channel patterns and of permafrost features (e.g., aufeis, ice wedges, massive ground ice), and on estimates of apparent channel bank and bed stability.

2. The Coast. The coast was examined on a reconnaissance scale, with more detailed study at selected localities. Echo sounding was carried out in near-shore areas in the vicinity of Kay Point - Phillips Bay and off the mouths of the Firth and Malcolm Rivers. Information on the stratigraphy of the delta of Babbage River was obtained from shallow drillholes and hammer seismic study. A number of measurements were made of the position of the frost table in spits and of the cross-sectional forms of beaches and spits. The stability of the shore zone in terms of marine sediment transportation and deposition, and in terms of style and rate of coastal retreat, was evaluated.

The coast can be conveniently subdivided into major sources and sinks of sediment with intervening areas of near equilibrium where relatively small-scale depositional features protect the coastal cliffs from wave attack. Sediment carried to the coast by rivers and erosion of coastal cliffs are the major sources of sediment. Where coastal cliffs are directly exposed to wave action, the cliffs are wasting back at locally spectacular rates of several metres in one collapse (e.g., near Kay Point). Generally, however, the rate is considerably less. Measurements at the monument on the Yukon-Alaska border indicate that, since 1912, the coast has retreated 43 metres. The coastal cliff there is 6.5 metres high and is underlain by frozen silty clay. It is characteristic of the roughly straight section of coast extending eastward to Komakuk Beach.

Sediment is accumulating in the area between Herschel Island and the mainland, in Phillips Bay, and in Shoalwater Bay on the west side of the Mackenzie Delta (Fig. 1). Although most of the sediment is transported toward these sediment sinks by longshore currents, sand waves and rip-current channels indicate additional components of sediment normal to the shore.

123. GRANULAR MATERIAL INVENTORY - SOUTHERN MACKENZIE VALLEY

Project 720086

Gretchen Minning, J. A. Rennie and J. L. Domansky
Terrain Sciences Division, Calgary

An inventory of granular resources available from unconsolidated materials and bedrock was undertaken for eleven map-areas (1:250,000) in the southern Mackenzie Valley. This project will provide the Department of Indian Affairs and Northern Development with geological data for planning highway, pipeline and other construction projects. Information was drawn from published and unpublished Geological Survey reports and maps and unpublished drilling results of industry and government agencies. Field investigations during the summer of 1972 also provided basic data.

A report and two maps (scale 1:125,000) for each of these eleven areas will outline the distribution and physical characteristics of sources of granular material and give an estimate of the volume of granular material available in unconsolidated deposits. Sufficient quantities of naturally occurring gravel and sand-size material are of greatest use for construction projects, although silt and clay can be used for fill. Unconsolidated deposits resulting from various geological processes, i.e., glacier activity, river deposition, wind action, and mass-wasting, contain material of varied grain sizes. However, gravel and sand are found primarily in unconsolidated deposits of glaciofluvial and glaciolacustrine origin and secondarily in morainal, eolian, alluvial, and colluvial deposits.

Rippable bedrock can also supply granular material. Competent bedrock suitable for crushing includes limestone, dolomite, sandstone and certain igneous and metamorphic rock types. Limestone and dolomite are the most abundant of these rock types in the map-areas dealt with in this study.

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124. DAM SITE INVESTIGATIONS, YUKON AND DISTRICT OF MACKENZIE

Project 710082

E. B. Owen
Terrain Sciences Division, Ottawa

The purpose of this study was to conduct a preliminary investigation of potential dam sites in the Northwest Territories and Yukon Territory, chiefly along major streams draining into Mackenzie River. This study was undertaken for the Northern Economic Development Branch, Department of Indian Affairs and Northern Development. The information obtained during the investigation will assist in management decisions and will provide a basis for further engineering planning to meet future power requirements. An important part of the investigation was to indicate those sites which appear feasible and which warrant more detailed studies in the future.

The study entailed an examination of high-level aerial photography and of topographic maps at a scale of 1:250,000, the use of barometric elevations for vertical control and an appraisal of dam site geology from surface reconnaissance. The feasibility of these projects can only be verified by more detailed, comprehensive site investigations including foundation drilling, detailed geological examinations and laboratory testing of possible foundation and construction materials. Also much more streamflow data are required for many of the streams. No data are available for some streams whereas for others the data is insufficient even to describe the mean flow of the rivers.

A total of 47 dam sites were examined in the field. They include:

River	No. of sites examined	River	No. of sites examined
Willowlake River	1	Mountain River	6
Root River	6	Peel River	6
Keele River	1	Arctic Red River	4
Redstone River	5	Anderson River	7
Dahadinni River	1	Horton River	5
Great Bear River	3	Mackenzie River	2

125. SURFICIAL DEPOSITS OF YUKON COASTAL PLAIN AND ADJACENT AREAS (Part of 107 B, 117 A, C and D)

Project 690047

V.N. Rampton
Terrain Sciences Division, Ottawa

Surficial mapping was carried out to upgrade previous work done in the area[1], and to facilitate publication at a scale of 1:125,000. The area mapped was extended south to include a substantial portion of the British Mountains and the northern Richardson Mountains. A special effort was made to characterize the ice content of surficial materials in the valleys and on the coastal plain. Shallow drilling and hammer seismograph were used to support this objective and to obtain information on the thickness and nature of unconsolidated deposits in mountain valleys and on pediment surfaces.

Coastal stratigraphy along the Beaufort Sea was studied in detail to synthesize and extrapolate earlier studies[2,3,4,5]. The general sequence along the coastal plain between Herschel Island and the Blow River is peat and fine-grained lacustrine sediments over glaciofluvial outwash, till, or glacially deformed marine, estuarine, or fluvial sediments. Till generally overlies fine-grained marine, estuarine or fluvial sediments, although east of the Blow River it may lie directly on bedrock. Material was collected from the above deposits for C^{14} dating and paleontological studies to aid correlation of stratigraphic units and to determine the paleo-environments that the different units represent. West of Herschel Island peat and lacustrine sediments are present at the surface only where the large gravelly alluvial fans do not extend to sea level.

Terraces were traced along streams from the coast into the mountains. Most streams seem to have had two or three periods of aggradation since the formation of the extensive pediments present in the region. Further

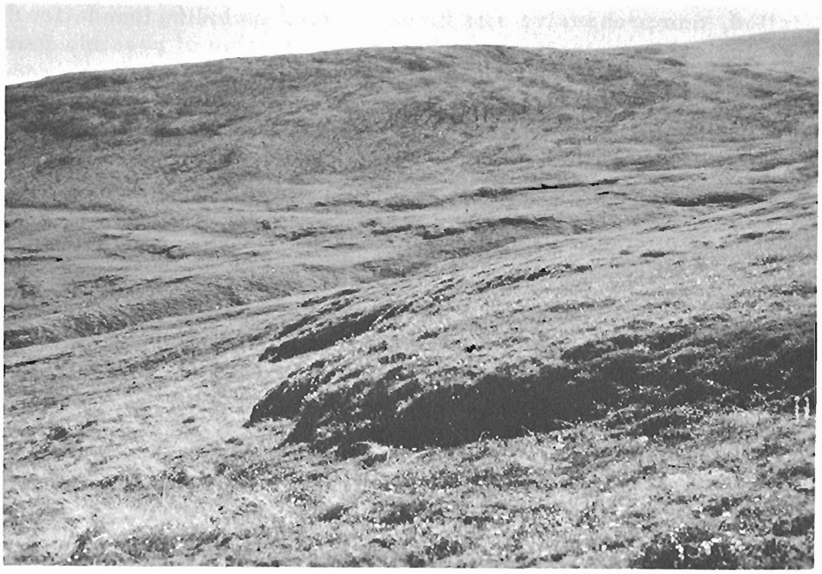

Figure 1. Turf bank (solifluction) lobes and terraces in the northern British Mountains. Small scarp in foreground is about 3 feet high. Note that these features are present only on moderate and gentle slopes. GSC Photo no. 201831-A.

study of air photographs and C^{14} dating of associated materials should indicate whether the terraces are related to sea level changes, climatic variations or tectonism.

Finally, studies were initiated under the direction of C.P. Lewis to monitor the movement of materials on slopes. Markers were placed on typical examples of most major morphologic slope types. Turf bank (solifluction) lobes and terraces (Fig. 1), which are common to poorly drained slopes and which were intuitively thought to represent the most rapid downslope movement of surface material, were trenched and the nature of the deposits studied. Organic materials overridden by the lobes and terraces were collected for C^{14} dating as an aid in checking the rate at which these features move downslope.

[1] Rampton, V.N.: Surficial geology, Herschel Island-Aklavik; Geol. Surv. Can., Open File Report 21 (1970).

[2] Fyles, J.G.: Quaternary stratigraphy, Mackenzie Delta and Arctic coastal plain; in Report of Activities, Pt. A, May to October, 1965; Geol. Surv. Can., Paper 66-1, pt. A, p. 30-31 (1966).

[3] Hughes, O.L.: Surficial geology of northern Yukon Territory and northwestern District of Mackenzie, Northwest Territories; Geol. Surv. Can., Paper 69-36 (1972).

[4] Mackay, J.R.: Glacier ice-thrust features of the Yukon coast; Geograph. Bull. (Canada) no. 3, p. 5-21 (1959).

[5] Naylor, D., McIntyre, D.J., and McMillan, N.F.: Pleistocene deposits exposed along the Yukon coast; Arctic, v. 25, p. 49-55 (1972).

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126. SURFICIAL GEOLOGY AND LAND CLASSIFICATION, MACKENZIE VALLEY TRANSPORTATION CORRIDOR (85 D, 95 B (North half), 95 G, I, K (East half), N, O)

Project 710047

N.W. Rutter and A.N. Boydell
Terrain Sciences Division, Calgary

This project is a continuation of the work carried out in 1971[1]. Field work consisted largely of mapping Quaternary deposits and geomorphology at the scale of 1:125,000 of map-areas 85 D, 95 B (north half), 95 G, I, N, O, and K (east half). Stratigraphic sections, ground-ice content of surficial deposits, permafrost distribution, nature of organic terrain, and terrain hazard areas were investigated. In addition, mineral springs were recorded and water sampled, and modern ostracods and mollusca were collected from the major lakes.

Other aspects of the environment were investigated by personnel of co-operating agencies. L.M. Lavkulich and others, University of British Columbia (A.L.U.R. Program), studied in detail the relationships among soil, vegetation and landform parameters within the surficial geology units, along an east-west strip through Wrigley (95 O) and Dahadinni River (95 N) map-areas. C. Tarnocai, Canada-Manitoba Soil Survey, classified soils within surficial geology units throughout the mapped area, and described changes in the nature and composition of organic deposits. C.D. Bird, University of Calgary, studied lichens and associated flora in the Wrigley area, to obtain correlations between their occurrence and features of particular geological interest. C. Crampton, Department of the Environment, continued mapping forest cover-landform relationships.

Permafrost is discontinuous throughout much of the mapped area, becoming more widespread at higher elevations and toward the north. Below peat plateaus, in the southern plains area, the permafrost table varies in depth between 24 and 39 inches decreasing to between 4 and 7 inches toward the north and westward into the mountainous area. Tundra polygons are present in the northern part of the Wrigley area and immediately east of the Franklin Mountains. Although numerous local thermokarst lakes reveal a history of recent degradation, palsas developing within pond areas suggest a reversal of this trend. In well-drained sediments, permafrost is deep or lacking altogether whereas in clayey-silty till or clayey-silty lacustrine deposits permafrost is near surface and is over 50 feet thick in northern latitudes and in the Mackenzie Mountains to the west.

Ground ice in the form of ice lenses, beds, or wedges is common in peat bogs, till and fine-grained sediments, but becomes less abundant with increasing depth.

Frozen groundwater (as opposed to segregated ground ice), usually in postglacial river gravels, but occasionally in silts, is common in the north and in valleys of the mountains west of the Mackenzie River. On the North Redstone River gravel deposits in excess of 100 feet thick were likewise found to be frozen to their base.

Of concern to engineering and construction, slope failures commonly occur along the Mackenzie River and its western tributaries in the north, and in the valleys to the west of the Nahanni-Liard Range in the south. These failures occur in bedrock and in unconsolidated, surficial deposits. Lower Cretaceous and Carboniferous shales are particularly susceptible whereas till and fine-grained lacustrine deposits are the most common surficial material. Retrogressive flows, detachment slides and slumping are common failure types.

Till of continental provenance constitutes the surface deposit over most of the area below 2,200 feet. Above this elevation, hill slopes and summits are largely colluviated, although scattered erratics derived from the east are present. Dead-ice moraine is predominant in the northeast part of Wrigley map-area around Blackwater Lake, where it is primarily composed of gravels and in the southern part of Kakisa River map-area (85 D) on the Cameron Hills. In the northern part of the area crevasse fillings, generally less than 6 feet high, are widespread and vary in constituent materials from till to sand and gravel.

Glaciofluvial sands and gravels, primarily as eskers, are scattered throughout the mapped area but are particularly in evidence in the northeast part of Wrigley map-area. Outwash plains of significant proportions occur in the Yohin-Little Doctor-Cli Lake areas of Sibbeston Lake map-area (95 G), and in the Mackenzie Valley in the southern part of Wrigley map-area.

Glaciolacustrine sands, silts and clays only occupy the major valleys: viz. Netla River, Rabbit Creek and Kotaneelee River areas of the Liard Valley (95 B); the mountain valleys west of the Liard-Nahanni and Camsell Ranges (95 B, 95 G, 95 K); the west part of Willowlake River in Bulmer Lake sheet (95 I); the upper Blackwater River area and the Mackenzie River Valley and its tributaries in the Wrigley sheet (95 O).

Stratigraphic and morphologic evidence indicates that three glaciations took place within the area mapped. Of these, two were discrete advances of the continental ice mass (Laurentide), and the third was the formation of cirque and valley glaciers in part in the Mackenzie Plain. The first, and most extensive, advance of Laurentide ice is recorded by a grey-black, stony till, exposed as the basal unit, mostly in tributaries of the Mackenzie River, and by glacial erratics on the summit areas of the Mackenzie Mountains at elevations up to approximately 5,000 feet.

The second Laurentide advance is recorded at the surface of the mapped area by a light grey-brown, stony till, locally variable in texture and separated from the lower till, in the section, by stratified sands and gravels up to 100 feet thick. The ice, apparently much thinner than during the earlier advance, was topographically controlled to the extent that it was deflected by mountain ranges, both to the south and to the northwest, the centre of deflection being at the Nahanni Range in the Sibbeston Lake map-area (95 G). Glacial deposits of this advance are not found above about 2,200 feet, although tongues of ice were able to penetrate into the west through the gaps in the mountain ranges.

The third glaciation is evidenced by cirque and valley formations scoured by ice in the surface of shales forming the Mackenzie Plain. Cirque formation occurred above 2,000 feet.

Late glacial activity is recorded by cirque moraines in the Liard, Nahanni and McConnell Ranges above elevations of 3,500 to 4,000 feet.

Deglaciation of the last Laurentide advance was variable in character and controlled, at least in part, by topography. In the south, it consisted of a withdrawal of the ice front to the east flanks of the Liard and Nahanni Ranges, beyond which a uniform thinning of the ice took place. On the plains, in areas of higher relief, ice masses became stranded to form the present dead-ice topography. In the centre, in the Bulmer Lake (95 I) map-area, numerous small moraine ridges record the gradual withdrawal of the ice front eastwards to the Horn Plateau. In the Wrigley and Dahadinni River areas, wholesale thinning was again predominant, following retreat of ice from the Mackenzie Valley. The area of dead-ice moraine extending northwest from Blackwater Lake is thought to represent a late position of the ice front.

Drainage of meltwater was controlled locally by ice margins and topography but, regionally, direction of flow was to the south and southeast, and ultimately to the north. Glacial lakes were formed in the major valleys, reaching maximum elevations of about 1,300 feet.

The postglacial record has been studied in minor detail. Organic layers were discovered within postglacial sands and gravels of a number of tributaries of the Mackenzie River. The layers are variable, consisting of cones, twigs, branches, and trunks, probably of white spruce, up to 8 inches in diameter. The depth of the layers is consistently about 8 to 10 feet below the surface. In the Ochre River, a similar layer was found at 22 feet (6.3 m), which has been dated at 4,470±140 B.P. (GSC-I, 747). The significance of these layers is not known although they probably reflect changes in the postglacial climatic regime.

A sample of white volcanic ash was collected from a 3 mm thick layer 11 inches below the ground surface at 60°56'N, 123°8'W. It is thought that this may be White River Ash[2].

[1] Rutter, N.W., and Minning, G.V.: Surficial geology and land classification, Mackenzie Valley Transportation Corridor (85 E, 95 A, B (South Half), H, J); in Report of Activities, Part A: April to October, 1971; Geol. Surv. Can., Paper 72-1, pt. A, p. 178 (1972).

[2] Lerbekmo, J.F., and Campbell, F.A.: Distribution, composition, and source of White River Ash, Yukon Territory; Can. J. Earth Sci., v. 6, no. 1, p. 109-116 (1969).

127. SURFICIAL GEOLOGY AND GEOMORPHOLOGY, MACKENZIE BAY - CONTINENTAL SHELF

Project 700092

J.M. Shearer
Terrain Sciences Division, Ottawa

Preliminary Determination of Nature and Distribution of Offshore Permafrost

Continuous seismic reflection work in the Eskimo Lakes, Liverpool Bay and the Continental Shelf of the Beaufort Sea has shown the existence of a discontinuous but very strong reflector. This reflector coincides with the top of a high velocity surface found by refraction techniques in Kugallit Bay (J.A. Hunter, GSC Project 680037) and is thought to be the top of permafrost. The reflector exists in both shallow (<50 ft.) and deep (≃200 ft.) water alike, showing up generally between 100 and 150 feet below the sediment-water interface.

The presence of this reflecting horizon below the bottom implies a slightly positive temperature regime with the top of the permafrost degrading or melting downwards. This permafrost is considered relict from a time when the continental shelf was emergent and exposed to low mean annual air temperatures. Nevertheless, the location of the top of this permanently frozen layer below bottom is inconsistent with sea bottom temperatures (taken in September of 1970 as part of HUDSON 70) which were less than -1°C over much of the offshore area where depths are greater than 20 metres. Pingo-like features[1] found offshore are thought to be reasonably conclusive evidence of this negative temperature regime. A core containing three feet of solidly frozen sand between two clays, obtained from the top of one of these during field work provides positive evidence of a negative temperature regime.

The seismic velocity varies considerably between a sand and a clay sediment, even when both are supposedly "frozen"; i.e., exposed to mean annual temperatures of around -1°C (lowest possible temperature for normal salt water is -1.8°C). At this temperature a fine clay may have up to 50 or 60 per cent of its porewater unfrozen with a corresponding seismic velocity very similar to its velocity in an unfrozen state[2]. On the other hand, water in the pore spaces of a sandy sediment freezes completely, the corresponding velocity being 2 to 3 times higher than when it is unfrozen. Perhaps the appearance of the top of the frozen layer below the true bottom is due to a general change in the composition of the sediment from very fine material to sand at that level.

[1] Shearer, J.M., Macnab, R.F., Pelletier, B.P., and Smith, T.B.: Submarine pingos in the Beaufort Sea; Science, v. 174, p. 816-818 (1971).

[2] Nakano, Y., Smith, M., Martin, R., Stevens, H., and Knuth, K.: Determination of the acoustic properties of frozen soils; report prepared by Cold Regions Research and Engineering Laboratory (CRREL) for Advanced Research Projects Agency (ARPA order no. 1525), 72 p. (1971).

STRATIGRAPHY and PALEONTOLOGY

A PROTEROZOIC SEDIMENTARY SUCCESSION WITH TRACES OF COPPER MINERALIZATION, CAP MOUNTAIN, SOUTHERN FRANKLIN MOUNTAINS, DISTRICT OF MACKENZIE (95 O)

Project 670068

J. D. Aitken*, R. W. Macqueen, A. E. Foscolos**
Institute of Sedimentary and Petroleum Geology, Calgary

Introduction

The Proterozoic succession at Cap Mountain in the southern Franklin Mountains near Wrigley[1] is puzzling because it bears no apparent relationship to Proterozoic successions to the north in the Operation Norman area[2,3] including those of the Mackenzie Mountains and the Coppermine Arch. In July, 1972, the presence of N. W. Rutter's helicopter-supported Geological Survey of Canada field party (Terrain Sciences Division) at Wrigley provided an opportunity to study the section. As a result of this re-examination, the authors (a) confirmed the uniqueness of the succession of Proterozoic lithologic units at Cap Mountain, (b) established that the published report of an angular unconformity at the base of the Lone Land Formation is erroneous, and (c) discovered the presence, not hitherto reported, of widespread though sporadic traces of copper mineralization throughout a 3,500-foot-thick interval of the Proterozic strata.

Proterozoic Succession at Cap Mountain

On the northeast-facing scarp of Cap Mountain (NTS 95 O; 63°26'N; 123° 14'W) is exposed a section of essentially unaltered sedimentary strata more than a mile thick, that unconformably underlies the Early Cambrian or older Mount Clark Formation[4]. Exposures of Proterozoic strata nearest to this uplifted, sixteen-square-mile block lie 80 miles to the west, in Mackenzie Mountains, and 225 miles to the northeast, on the shores of Great Bear Lake. Re-study of the Cap Mountain succession by the authors in July, 1972, confirmed the fourfold subdivision of the section earlier recognized[1] and also confirmed that the strata do not belong to any formation recognized in the Mackenzie Mountains[5,6,7].

Briefly, the Mount Cap section consists of a lowermost unit (map-unit 1 of Douglas and Norris)[1], 1,670 feet thick and consisting of purple to purple-red and minor green, extensively mudcracked mudstones and shales, interbedded with either greenish grey to pale green, dense, argillaceous and silty and yellow-weathering laminated dolomite; or very fine grained, greyish green to greyish purple, laminated, crosslaminated and ripple-marked sandstone or siltstone; or both. Contortion and various dolomite breccias suggest an evaporitic environment.

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* University of Calgary.

** Clay mineralogy laboratory, I.S.P.G. Analyst, X-ray diffraction and X-ray fluorescence determinations on selected copper-bearing Proterozoic specimens.

Map-unit 1 is overlain, apparently conformably, by map-unit 2[1], which is 1,720 feet thick and consists mainly of brick-red to purplish red mudcracked mudstone, commonly with hematite-coated fracture surfaces and subordinate amounts of greyish purple, mostly very fine grained, rarely coarse grained, generally crosslaminated or crossbedded muddy sandstone, with abundant rip-up clasts of purple shale and local ripple-marks. A zone 400-500 feet below the top contains two intervals composed of dolomite, partly stromatolitic, and minor amounts of pale grey to greenish grey quartzose sandstone.

Map-unit 2 is overlain apparently conformably by map-unit 3[1], a succession of shales, siltstones and sandstones 1,700 feet thick. The upper and lower thirds of the unit are relatively poor in sandstones and slightly recessive, and the middle third is dominated by resistant sandstones. The shales and siltstones are green or greenish grey to purple or purplish grey and lack the reddish colour of underlying units. They are mainly thin bedded to laminated. The sandstones are clean orthoquartzites, mainly very fine and fine grained, but medium to very coarse grained in isolated beds, with a few jasper-bearing grit beds. Crossbedding is generally, and in some beds spectacularly, developed.

In the basal 200 feet of map-unit 3, structures suggestive of shallow-water deposition are lacking, and contorted beds suggest deposition on a slope. Higher beds are partly mud-cracked, and the bases of sandstone beds are commonly erosional, indicating a return to prevailing shallow-water deposition which characterizes most of the Proterozoic at this locality. The basal 260 feet of the upper, relatively shaly third of the formation is characterized, however, by lenticular and interrupted bedding with a few sedimentary overfolds. These beds also are considered to be the product of slope deposition.

Map-unit 3 is overlain by the 850-foot-thick Lone Land Formation[8, 1], which commences at the base with a very resistant, 90-foot-thick member of friable orthoquartzitic sandstone. This rock is mainly white with local pink and purple patches, medium grained and well sorted, and contains layers of granules and minor beds of quartz grit. Throughout the succeeding 300 feet, the basal sands are replaced upward by progressively increasing amounts of intercalated, partly silty and sandy, pale green, olive-green, and dark grey shale. The sands become very fine grained and thin bedded upward. Shrinkage-cracks and ripple-marks are ubiquitous. The remainder of the Lone Land is uniform in character, and is composed of 80-90 per cent brownish grey to olive-grey, very fissile, mostly silty shale, and 10-20 per cent quartzose, grey to pale greenish grey, very fine grained sandstone, in thin beds with thin shaly laminae and paper-thin shale clasts. Scour-and-fill, load-casts, ripple-marks and ripple-drift crosslamination are prominent.

It has been stated that the base of the Lone Land Formation is marked by an angular unconformity[1, 9]. A.W. Norris (pers. com., 1972; field notes of 1957) has pointed out to the writers that this was a misinterpretation of field notes. Accordingly, the writers carefully re-examined the base of the Lone Land Formation. The contact is structurally concordant and nonerosional, and the only evidence suggestive of unconformity is the grit layers in the basal Lone Land sandstone. The unconformity mistakenly stated to underlie the Lone Land Formation is in fact that which separates it from the overlying, Early Cambrian or older Mount Clark Formation[4].

Correlation of the Cap Mountain Proterozoic Succession

Proterozoic rock units exposed at Cap Mountain do not correspond in lithology or sequence with any studied by Operation Norman[2, 3] personnel along the Coppermine Arch, at the east end of Great Bear Lake, in the northern Mackenzie Mountains, or with any reported[5] from the Flat River (95E), Glacier Lake (95L) and Wrigley Lake (95M) map-areas.

The assumption of angular unconformity at the base of the Lone Land Formation led to the tentative placement of the Lone Land in the Hadrynian (late Proterozoic), and map-units 1, 2, and 3 in the Helikian (middle Proterozoic). This reasoning appears to be invalid.

Several possilbe correlations merit consideration:

1. Map-unit 1 is lithologically similar to the Helikian (?) Tsezotene Formation[5]. The Tsezotene, however, is overlain by a thick, quartzite-dominated sequence (Katherine Group[10]; Tigonankweine Formation[5, 11]) that is not present at Cap Mountain.

2. The dominantly hematitic character of map-unit 2 might suggest a correlation of this unit with the lower division of the Hadrynian (?) Rapitan Group[5]. On the other hand, the base of the Rapitan is marked by an angular unconformity, and regionally the lower division is overlapped northeastward by the lithologically distinct middle and upper Rapitan. Furthermore, no strata like the coarse conglomerates and pebbly mudstones characteristic of the lower Rapitan occur in map-unit 2. In addition, our work and that of Gabrielse and others[5] shows that the entire Hadrynian(?) succession (base of Rapitan to base of Cambrian) pinches out west of the crest of the Mackenzie Arch (ref. 9, Figs. VIII - 5 and VIII - 11a). Arguments for the reappearance of Hadrynian strata northeast of the Arch appear to be based mainly on the nonexistent "sub-Lone Land unconformity".

3. The presence of traces of copper mineralization throughout a 3,500-foot interval comprising map-units 1, 2, and 3 (see below) suggests a Helikian age for the interval, because such copper occurrences are common in Helikian rocks from Montana to the northern Mackenzie Mountains[11, 12, 13]. This evidence, plus the generally mature character of the Proterozoic sequence of Cap Mountain as contrasted with the immature character of most Cordilleran Hadrynian strata, leads us to favour a Helikian assignment for the Cap Mountain Proterozoic succession. Much further work will be required to go beyond this tentative conclusion.

Copper Occurrences

The distinctive green copper mineral malachite ($CuCO_3 \cdot Cu(OH)_2$) occurs commonly or sporadically throughout an interval extending from 1,200 feet below the top of map-unit 1 to 650 feet above the base of map-unit 3.

Malachite occurs as coatings on bedding planes and fractures, and as disseminated specks and blebs in very fine grained sandstone, dolomitic siltstone, and silty dolomite of map-units 1 and 3 and as fracture coatings in deep purplish red hematitic mudstones of map-unit 2.

Semiquantitative analysis by X-ray diffraction of powdered selected specimens (malachite-coated fractures, etc., and host rock) reveals the presence of 2 to 3 per cent malachite. Qualitative X-ray fluorescence analysis of the same specimens confirms that copper is a significant elemental constituent. The specimens are not representative of the average Cu content of the rock exposed, as they were chosen for their visible malachite content.

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[2] Aitken, J.D., Cook, D.G. and Balkwill, H.R.: Operation Norman, District of Mackenzie; in Report of Activities, Part A, April to October, 1969; Geol. Surv. Can., Paper 70-1, pt. A, p. 202-206 (1970).

[3] Cook, D.G. and Aitken, J.D.: Operation Norman, District of Mackenzie; in Report of Activities, Part A, April to October, 1970; Geol. Surv. Can., Paper 71-1, pt. A, p. 197-201 (1971).

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[8] Hume, G.S.: Mackenzie River area, District of Mackenzie, Northwest Territories; Geol. Surv. Can., Sum. Rept. 1923, pt. B, p. 1-18 (1924).

[9] Douglas, R.J.W., Gabrielse, H., Wheeler, J.O., Stott, D.F. and Belyea, H.R.: Geology of Western Canada; in Geology and Economic Minerals of Canada, Econ. Geol. Rept. No. 1 (5th ed.); Geol. Surv. Can., Chapter VIII, p. 365-488 (1970).

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129. STRUCTURE AND STRATIGRAPHY, RINGNES ISLANDS AND NEARBY SMALLER ISLANDS, DISTRICT OF FRANKLIN (Parts of 59, 69 and 79)

Project 710003

H.R. Balkwill
Institute of Sedimentary and Petroleum Geology, Calgary

Ten weeks were spent in the central part of the Sverdrup Basin: completing reconnaissance bedrock mapping of Amund Ringnes Island (scale: 1/125,000); initiating comprehensive lithostratigraphic and biostratigraphic investigations of Triassic through Tertiary rocks on the Ringnes Islands and Cornwall Island (related projects by K.J. Roy, W.V. Sliter, and W.S. Hopkins, Jr.); and continuing studies of the regional structural geometry, and the kinematics and chronology of Mesozoic and Tertiary tectonism.

Stratigraphy

Lithofacies, faunas, and sedimentary structures of exposed Mesozoic rocks indicate that a marine basin persisted in the region of northern Amund Ringnes Island, in which pelite-dominated sediments comprising the Savik, Deer Bay, Christopher, and Kanguk Formations accumulated (Fig. 1). Episodic northward marine withdrawal from the basin is recorded by arenite-dominated intervals of fluvial and littoral deposition (Heiberg, Isachsen, and Hassel Formations). Intermittent Jurassic marine regression from the southern part of the basin (Cornwall Island and southern part of Amund Ringnes Island) is represented by arenaceous rocks comprising the Jaeger and Awingak Formations, and a tongue of sandstone in the middle of the Deer Bay Formation: these units are thick and conspicuous in the southern part of the basin, but they thin abruptly northward; their northward facies are thin intervals of very fine grained, glauconitic sandstone and siltstone in the Savik and Deer Bay Formations.

Prolonged regional volcanism is indicated by bentonitic shales, tuff beds, and volcanic flows in strata ranging from the upper part of the Savik Formation (probably Middle or Upper Jurassic)[1] to the lower part of the Kanguk Formation (probably Upper Cretaceous).

Structure

The northwest-plunging Cornwall anticlinorium dominates the structure of Cornwall and Amund Ringnes Islands. The anticlinorium has a relatively flat crestal region and gently to moderately dipping limbs. Normal faults and subsidiary box folds with upright axial planes are present locally along the crest of the anticlinorium. In crestal culminations, Heiberg rocks (Triassic) are exposed in central Cornwall Island, the lower part of the Savik Formation outcrops in the central part of Amund Ringnes Island, and Heiberg Formation sandstones are adjacent to diapirically intruded Paleozoic evaporites that form the core of Amund Dome in the northern part of the island. Gabbro sills and dykes[2] have intruded Lower Cretaceous and older rocks throughout the region, but they are thickest and most abundant in the regions of crestal culmination of the Cornwall anticlinorium, as for example at Amund Dome, where also there are some prominent gypsum dykes and sills in country rocks adjacent to the dome.

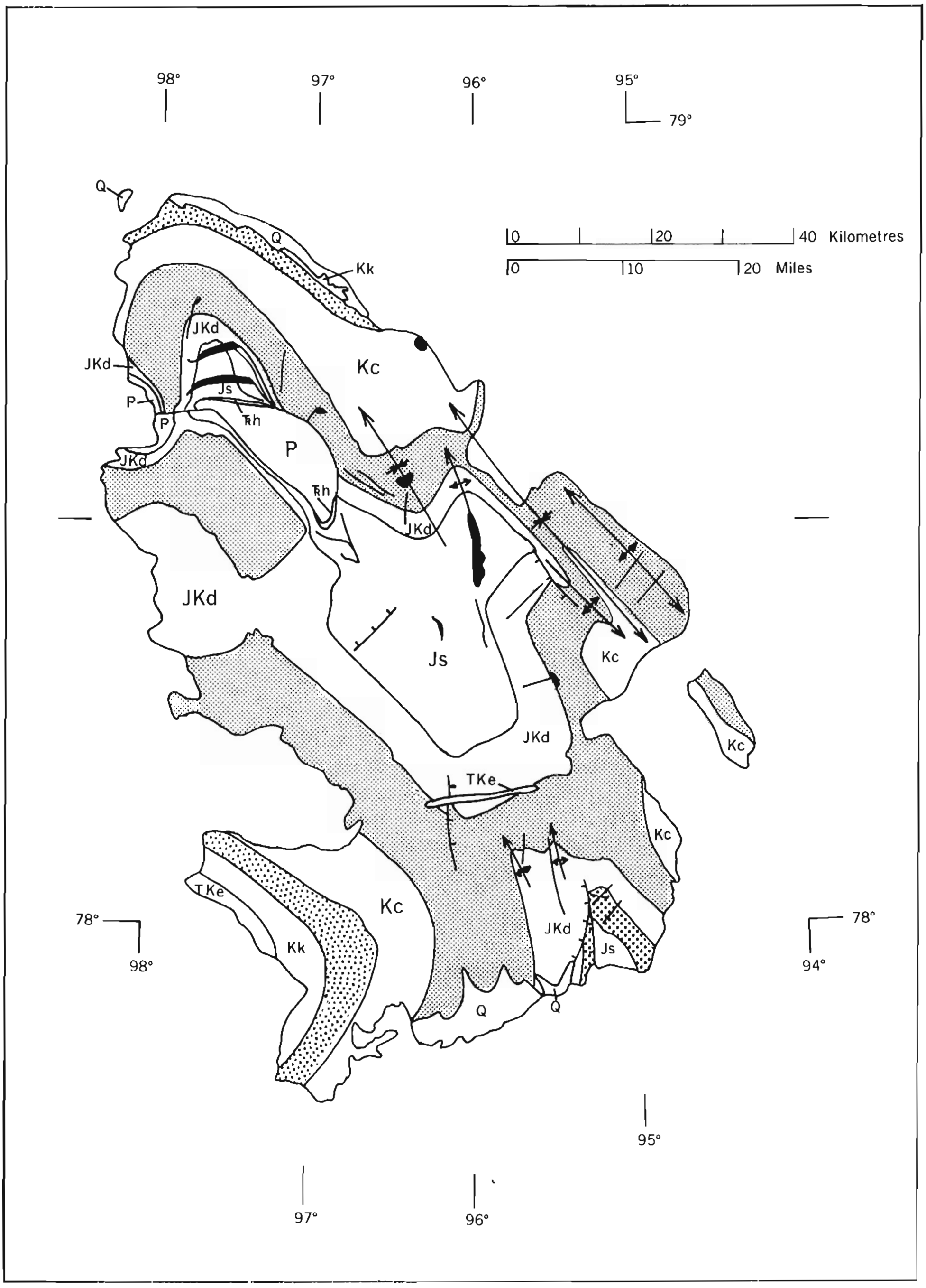

Figure 1. Sketch map, bedrock geology, Amund Ringnes Island.

LEGEND

QUATERNARY

Q — Surficial deposits

TERTIARY AND CRETACEOUS

TKe — Eureka Sound Formation

UPPER CRETACEOUS*

Kk — Kanguk Formation

LOWER AND UPPER CRETACEOUS

Gabbro sills and dikes

Hassel Formation

LOWER CRETACEOUS

Kc — Christopher Formation

Isachsen Formation

UPPER JURASSIC AND LOWER CRETACEOUS

JKd — Deer Bay Formation

JURASSIC

Awingak Formation

Js — Savik Formation

TRIASSIC AND (?)JURASSIC

Trh — Heiberg Formation

PALEOZOIC

P — Diapiric intrusions of gypsum, with included masses of anhydrite, limestone, and gabbro

Normal fault: hachures on hanging-wall block

* Age assignments of Cretaceous and older rocks based on Tozer (1970); paleontological determinations of fossils from Amund Ringnes Island incomplete at the time of this submission.

The eastern and southern limbs of a previously unreported, apparently large piercement dome are exposed around the perimeter of an unnamed bay along the northwestern coast of Amund Ringnes Island (Fig. 1). Massive and foliated gypsum composes most of the exposed mass, with subordinate random blocks of limestone, anhydrite and gabbro. The unnamed dome is near Amund Dome and is structurally aligned with it; possibly the domes are structural culminations of a large, single diapiric mass.

New evidence indicates that the style and gross structure of Cornwall anticlinorium was established during the Late Cretaceous or early Tertiary: nonmarine, carbonaceous arenites of the Eureka Sound Formation overlie the Kanguk Formation (Upper Cretaceous; marine) on the southwestern part of Amund Ringnes Island; the contact is not exposed, but it appears to be regionally conformable. Basal Eureka Sound beds at this locality are dated tentatively as Maestrichtian (latest Cretaceous) by W.S. Hopkins, Jr., from palynological studies. Eureka Sound arenites lie unconformably on the Deer Bay Formation (probably Upper Jurassic) in the south-central part of Amund Ringnes Island, and unconformably on Heiberg rocks (Upper Triassic) in the central part of Cornwall Island; basal Eureka Sound beds at these localities are dated tentatively by Hopkins as Paleocene. These relationships may mean that the Cornwall anticlinorium developed in the time interval between deposition of the Maestrichtian Eureka Sound beds and the Paleocene beds, or that the uplift was initiated during the Late Cretaceous and that it provided a local source for syntectonic Eureka Sound deposits of Maestrichtian age in adjacent lowlands.

A conspicuous Bouguer gravity anomaly (about +40 milligals) coincides with Cornwall anticlinorium[3]. It is not presently clear whether an arch in the basement or thick development of gabbroic rocks, singly or in combination, produce the anomaly.

Physiography

Evidence of widespread glaciation of Amund Ringnes Island includes: northwestward-striking grooves and striations in bedrock at three widely separated localities and at elevations of about 200, 500, and 800 feet (the latter system is developed in cemented Heiberg sandstones at the northern summit of Amund Dome); and abundant striated erratics, including granite and gneissic rocks. Isolated, sinuous deposits of boulder gravel may be eskers. An upper marine limit of about 300 feet may be indicated by the highest occurrence of Quaternary pelecypods.

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[3] Sobczak, L.W. and Weber, J.R.: Gravity measurements over the Queen Elizabeth Islands and polar continental margin; Can. Dept. Energy, Mines and Resources, Earth Physics Br., Gravity Map Series, Nos. 115 and 116 (1970).

130. PENNSYLVANIAN AND PERMIAN CONODONTS FROM ARCTIC CANADA

Project 710060

K.P. Bender
Institute of Sedimentary and Petroleum Geology, Calgary

Three sections in the Pennsylvanian and Lower Permian of northwestern Ellesmere Island were measured and sampled for conodont studies.

Girty Creek

At this locality sequential samples were obtained from the lower 2,700 feet of the type section of the Nansen Formation (Pennsylvanian and Permian). The type section was designated by R. Thorsteinsson.

Glacier at the northeastern end of Oobloyah Bay

A 3,500-foot-thick section, which probably represents most of the Nansen Formation (W.W. Nassichuk, pers. com.) was sampled.

Van Hauen Pass

The type section of the Otto Fiord Formation (Lower Pennsylvanian) and the Hare Fiord Formation (Upper Pennsylvanian and Lower Permian), both designated by R. Thorsteinsson[1], are located three miles northeast of Van Hauen Pass. At these localities samples were obtained from limestone units interbedded with anhydrites in the Otto Fiord Formation and from limestones which are predominant in the lower 1,500 feet of the Hare Fiord Formation.

Preliminary runs of samples from the Otto Fiord and Hare Fiord Formations collected by G.R. Davies and W.W. Nassichuk at Van Hauen Pass and several other localities on Ellesmere and Axel Heiberg Islands have yielded well-preserved Pennsylvanian and Permian conodonts.

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131. TAXONOMY, BIOSTRATIGRAPHY AND PALEOECOLOGY OF MESOZOIC MIOSPORE AND MICROPLANKTON ASSEMBLAGES FROM DISTRICT OF MACKENZIE

Project 710019

W.W. Brideaux
Institute of Sedimentary and Petroleum Geology, Calgary

Sequential palynologic samples were collected from Upper Jurassic and Lower Cretaceous rocks in the Aklavik Range of the Richardson Mountains, western District of Mackenzie (southwest quarter NTS 107 B), and from Lower and Upper Cretaceous rocks (northwest quarter NTS 106 M). Sections collected included parts of a Late Jurassic-Early Cretaceous sequence near Mount Gifford, Early Cretaceous rocks on a spur of Mount Goodenough and Late Cretaceous rocks on Treeless Creek. Approximately 140 samples were collected.

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132. MONOGRAPH OF MIOSPORE ASSEMBLAGES FROM THE LOWER COLORADO GROUP AND COMPARATIVE STUDIES OF ASSEMBLAGES FROM SOUTHWESTERN ALBERTA AND ADJACENT BRITISH COLUMBIA

Project 720042

W.W. Brideaux
Institute of Sedimentary and Petroleum Geology, Calgary

Field work concentrated on collections of the Fernie Group at several localities including Grassy Mountain, Carbondale River, and Daisy Creek Summit in the Blairmore-Coleman-Hillcrest region, and Canyon Creek in the Bragg Creek area, southwestern Alberta. Samples from the Toarcian Shale, the Rock Creek Member, the Grey Beds, the Green Beds, the Passage Beds and the basal Moose Mountain Member of the Kootenay Formation were collected, a total of about 80 samples.

A collection of 70 samples was made on IGC Field Trip A20 that included material ranging in age from Late Jurassic (Fernie Group-Nikinassin facies) to Early Paleocene (Paskapoo Formation).

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133. TERTIARY AND MESOZOIC MICROPALEONTOLOGY SAMPLING, WEST FLANK OF THE MACKENZIE RIVER DELTA, DISTRICT OF MACKENZIE

Project 700064

T. Potter Chamney
Institute of Sedimentary and Petroleum Geology, Calgary

Some 9,000 feet of sections were measured, described and collected for microfossil control. These represent strata of Triassic, Jurassic, Cretaceous and Tertiary age, extending from Vitrekwa River (67° 9'00"N, 135° 31'30"W) to Fish River (68° 32'30"N, 136° 28'00"W).

One of the most important results of this field work is the discovery of vertebrate bones in the questionable Upper Cretaceous sequence where Treeless Creek joins the Mackenzie River (67° 50'39"N, 135° 27'10"W). The bones were identified tentatively by the author as fish and possible bird bones (small, hollow), which might be related to the Hesperornis sp. of the "Bituminous Shale Zone" equivalent of the Anderson Plain area. The stratigraphic position of the abundant fish bones appears to correlate with the "fish bone horizon" in the subsurface of the Delta that occurs with the radiolarian assemblage of the "Bituminous Shale Zone" equivalent. The equivalent horizon is at a depth of approximately 11,000 feet in the Reindeer D-27 well and 5,670 feet in the Atkinson M-33 well.

Another of the principal contributions is the sequential microfossil sample collecting in Martin Creek and Willow (Donna) River. The section here is more or less continuous, more than 2,000 feet thick, and provides the best-exposed control for the dating and correlation of the anomalously thick Lower Sandstone Division. This rock unit appears to overlie the Husky Formation of Late Jurassic to Berriasian age and underlies the concretionary shale member of the Upper Shale-Siltstone Division of Barremian or late Hauterivian age. Additional study of the prepared microfossil slides is required before a more valid age assignment can be made.

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134. LOWER AND MIDDLE PALEOZOIC BIOSTRATIGRAPHY GASPÉ, QUÉBEC AND MARITIME REGION

Project 690006

W.T. Dean
Regional and Economic Geology Division, Ottawa

During May and June further work was carried out on the Cambrian and Ordovician rocks of Newfoundland. In particular, detailed collecting from the type section of the Elliot Cove Formation on Random Island was completed, and descriptions of the stratigraphy and trilobite faunas are now in hand.

In July systematic collecting from strata spanning and succeeding the Cambro-Ordovician boundary in the southern Canadian Rocky Mountains south of Jasper, Alberta was begun. The object of the work, which will require additional field investigations, is to establish a standard faunal sequence for the Lower Ordovician rocks of the region, and to facilitate biostratigraphic correlation with other regions. A short visit to the Klamath Mountains, in the Coast Ranges of northern California, yielded fossils which are expected to give new information regarding the paleogeography of the western margin of the North American continent during the Ordovician.

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135. CAMBRIAN BIOSTRATIGRAPHY MACKENZIE MOUNTAINS AND LABRADOR

Project 650024

W.H. Fritz
Regional and Economic Geology Division, Ottawa

Mackenzie Mountains

Four Cambrian sections were measured in the Mackenzie Mountains in conjunction with Operation Stewart (see Blusson, this publication). The location of the sections and a stratigraphic summary are shown in Figure 1. The Ekwi-Ingta headwaters section, measured in 1970, is also shown as it contains data relating to the other four. The following discussion supplements the information in Figure 1.

Within the area of study, most of the Cambrian strata are assigned to the Lower Cambrian Sekwi Formation, the lithologies of which are known to change within short lateral distances. The present study suggests that these changes can be in part explained by a southwesterly transition of the Sekwi from lithologies of the middle carbonate belt (sections I-III and part IV) to those of the outer detrital belt (section V and part IV; see refs. 1 and 2 for explanation of facies belts).

Another major change within the Sekwi Formation seems to have resulted from a regression that was responsible for dolomite and sandstone deposition at and near the level of the zone boundary between the Nevadella and Bonnia-Olenellus Zones. As might be expected, the effects of the regression are more pronounced towards the craton, resulting there in the deposition of orange-weathering dolomite and dolomitic sandstone. Seawards, dolomite and sandstone are not as prominent, and here regression ended the depositional process that was forming a thick carbonate bank. After the regression, carbonate bank deposition resumed, but the area of optimum deposition had shifted southwestwards.

Of the five sections to be discussed, the Natla River section (I) is considered to have been deposited nearest the craton (in the shallowest water). Number I has been assigned to this section, and the remaining sections given higher numbers with increasing distances seawards. In the Natla River section, the Sekwi Formation closely resembles the Sekwi at the type locality (located 22 miles east of section IV; ref. 3) in both lithology and thickness. Dolomite, mudcracks, "floating" sand grains, and crossbedded sandstone are among the lithologies that suggest shallow-water deposition. The Sekwi Formation in the Natla River section contains conspicuous bright orange-weathering intervals and is resistant to weathering (Fig. 2, a).

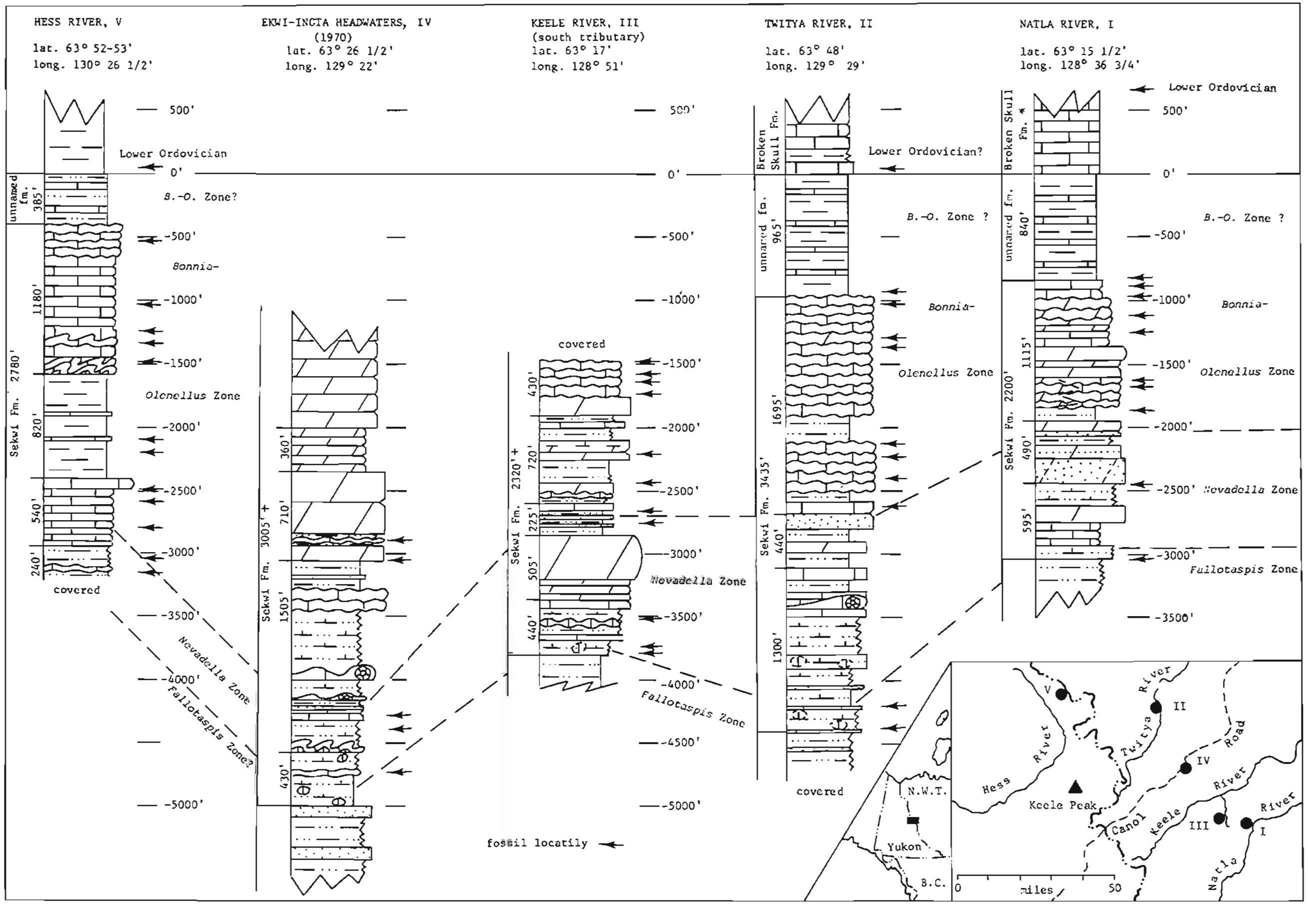
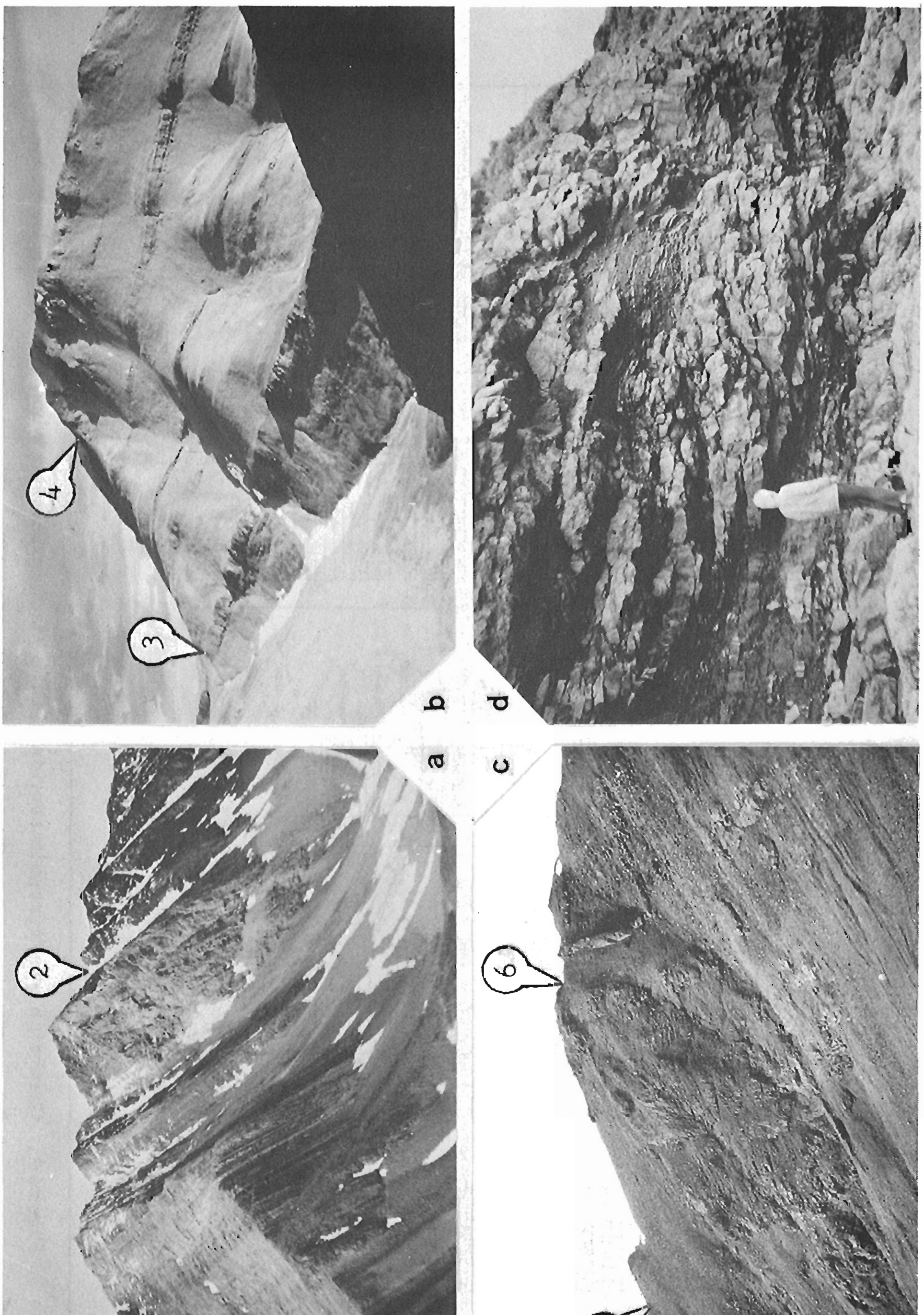


Figure 1. Cambrian stratigraphic sections in the Mackenzie Mountains, Yukon and N. W. T.
*Formation named in Geol. Surv. Can., Mem. 366 (in press).


a
b
c
d
1
2
3
4
5
6

The Twitya River section (II) is considerably thicker than the Natla River section, but is resistant and contains numerous orange-weathering intervals. Bioherms up to 25 feet thick, some containing archaeocyathids, are present in the 1,300-foot interval. Mudcracks and trails are common in the 440-foot interval.

The Keele River section (III) is of special interest as it contains a 505-foot, light grey dolomite unit (Fig. 1, c) that is interpreted as being part of the outer margin of the middle carbonate belt. Equivalent strata in the Ekwi-Ingta headwaters section are considered to represent off-bank (outer detrital) deposits laying seawards of the carbonate bank. The Ekwi-Ingta strata consist of shales and dark, thin-bedded limestones that exhibit slump structures. These strata contain numerous trilobites belonging to the Family Pagetiidae, fossils which are rarely associated with shallow-water sediments.

Higher in the Keele River section is a 225-foot unit (Fig. 1) containing quartzite and shale that records the regression mentioned earlier. Closely spaced fossil horizons locate the boundary between the Nevadella Zone and the Bonnia-Olenellus Zone as falling within this unit. Above the 225-foot unit are limestones and dolomites assigned to a younger, post-regression portion of the middle carbonate belt. These carbonates are believed to have been deposited landwards of thick-bedded carbonates that commonly characterize the outer margin of such belts; the latter are believed to be represented in the 710-foot unit of the Ekwi-Ingta headwaters section.

In the Ekwi-Ingta headwaters section (IV), strata in the 1,505-foot interval are assigned to the outer detrital belt. The regression is marked only by a 15-foot sandstone bed located 350 feet above the base of the interval. The thinness of the Nevadella Zone here and in the Hess River section relative to the same zone in the middle carbonate belt (sections I-III) might be attributed to a partial restriction of source material by the carbonate bank.

A thick carbonate succession constitutes the upper part of the Ekwi-Ingta section. It has been mentioned that the 710-foot, thick-bedded dolomite unit is believed to represent the outer margin of the middle carbonate belt. Overlying thin- and medium-bedded dolomites were probably deposited farther inside the belt. In the Ekwi-Ingta section, the position of strata belonging to the middle carbonate belt overlying strata of the outer detrital belt indicates a major oceanwards shift of the carbonate belt during Bonnia-Olenellus Zone time.

Nearly all of the strata in the Hess River section (V) are considered to belong to the outer detrital belt. Slump structures, some of major proportions, are visible in the thin-bedded limestone units. Trilobite exoskeletons

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Figure 2. (opposite)

(a) Ridge immediately south of the Natla River section showing the Sekwi Formation (overturned), upper formational contact is at 1 and lower contact is at 2 (GSC photo 201829-I).
(b) Part of the Hess River section, base of the 820-foot interval is at 3 and top is at 4 (GSC photo 201829-K).
(c) Part of the Keele River section (overturned), base of 505-foot interval is at 6 and top at 5 (GSC photo 201829-L).
(d) Forteau Formation, Labrador, above and to right of assistant are small bioherms clustered into large mass, left of assistant is interbedded limestone and shale that intertongues with bioherm cluster without appreciable change in dip (GSC photo 201829-N).

are commonly found intact. Only the uppermost beds in the Sekwi Formation contain trails and other evidence of shallow-water deposition. The high proportion of thin-bedded limestone and shale are responsible for the more subdued topography as compared to that found in the middle carbonate belt (Fig. 2, compare a and b).

In three of the five sections measured, an unnamed unit of dark siltstone and platy limestone overlies the Sekwi Formation. Fossils from the base of this unit in the Natla River and Twitya River sections belong to the Lower Cambrian Bonnia-Olenellus Zone. Elsewhere in the Mackenzie Mountains, this unit has yielded fossils of the same zone, but localities are sparse and the unit is still inadequately sampled. Immediately above the unnamed unit in the Hess River section are graptolites belonging to the Lower Ordovician. An agnostid questionably assigned to the Lower Ordovician was found in the overlying unit in the Twitya River section, and definite Lower Ordovician fossils were found high above the unnamed unit in the Natla River section. The above evidence indicates that the unnamed unit is widespread, and may be followed by an unconformity with the Middle and Upper Cambrian poorly represented or missing.

Labrador

Several days were spent in Labrador observing the Lower Cambrian Bradore and Forteau Formations at outcrops along the Strait of Belle Isle from Blanc-Sablon to L'Anse-au-Diable. Except for Skolithos, no fossils were found in the Bradore Formation.

At the contact of the Bradore and overlying Forteau Formations is a recessive interval suggesting soft shale. A 20-foot isolated section attributed to this unit is exposed in a shale pit immediately southwest of the road at a point .75 mile northeast of the present village limits of L'Anse-au-Loup. Olenellus collected from the pit indicates these strata belong to the Bonnia-Olenellus Zone.

The lowest resistant unit in the Forteau Formation contains shale and pink to light greenish grey limestone that is well exposed along the Strait of Belle Isle one mile northeast of the lighthouse located south of the village of L'Anse-Amour. Here it can be shown (Fig. 2, d) that small bioherms averaging one foot in thickness cluster into local, large masses up to thirty feet in height. Relief at the margins of these masses must have been very low, as extensive lateral beds of shale and limestone intertongue with the masses without a change in initial horizontal dip. The individual bioherms consist of finely crystalline limestone of unknown (algal?) origin. Within the bioherms are well-preserved archaeocyathids that are too sparse to suggest that they served to bind lime mud into low mounds. Marginal to many of the bioherms are small lenses and pods consisting of a coquina of brachiopods, Salterella, broken archaeocyathids, and trilobite fragments. Both the coquina and the structure of the bioherms relative to the shale and limestone beds suggest a shallow-water, high energy environment.

[1] Robinson, R.A.: Lower and Middle Cambrian stratigraphy of the eastern Great Basin; Intermountain Assoc. Petrol. Geologists, 11th Ann. Field Conf. Guidebook, p. 43-52 (1960).

[2]Palmer, A.R.: Some aspects of the early Upper Cambrian stratigraphy of White Pine County, Nevada and vicinity; Intermountain Assoc. Petrol. Geologists, 11th Ann. Field Conf. Guidebook, p. 53-62 (1960).

[3]Handfield, R.C.: Sekwi Formation, a new Lower Cambrian formation in the southern Mackenzie Mountains, District of Mackenzie; Geol. Surv. Can., Paper 68-47 (1968).

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136. CRETACEOUS AND JURASSIC STRATIGRAPHY OF NORTHERN VANCOUVER ISLAND (102 I) AND MANNING PARK AREA (92H, E/2 and W/2), BRITISH COLUMBIA

Project 670064

J.A. Jeletzky
Institute of Sedimentary and Petroleum Geology, Ottawa

In July, August, and September, 1972, about six weeks were spent in the northern part of Vancouver Island and in the Manning Park area measuring Cretaceous and Jurassic sections, collecting fossils from them, and acting as a co-leader of AO3 and CO3 excursions of the 24th International Geological Congress. The following results were obtained.

Northern Vancouver Island

Lower Cretaceous outlier at Christensen Point

The section of variegated clastic rocks, about 250 feet thick (rough estimate only), exposed on the western side of the intrusive body comprising the tip of Christensen Point (ref. 1, p. 211) was found to be of Barremian age. Well-preserved *Inoceramus colonicus* Anderson and some poorly preserved ammonites were found in the topmost beds of this unit. These variegated clastic rocks are correlative, therefore, with the lithologically similar *Inoceramus colonicus*-bearing variegated clastic rocks forming the visible base of the Cretaceous sequence on the western limb of the Christensen Point outlier (ref. 2, p. 130, 131).

No macro-invertebrates of any kind were found in the basal 500 feet (rough estimate only) of the shale-siltstone unit conformably and apparently gradationally overlying the variegated clastic unit on the eastern limb of Christensen Point syncline (ref. 1, p. 211). This part of the shale-siltstone unit is tentatively dated as Aptian to Albian in age because of its stratigraphic position between the Barremian variegated clastics and the Cenomanian to ? Turonian middle and upper parts of the shale-siltstone unit exposed closer to the mouth of Laura Creek (ref. 1, p. 211-212). The thick Aptian-Albian conglomerate unit of the Quatsino Sound area appears to be absent on the northern end of Vancouver Island, being laterally replaced by the marine argillaceous rocks of the basal part of the shale-siltstone unit.

Nanaimo Group of Suquash Basin

Several readily identifiable fragments of Metaplacenticeras occidentale (Whiteaves) were found in the upper siltstone unit at the point about 100 yards above the mouth of the second right confluent of Keogh River. This discovery confirms the suggestion made by J. E. Muller (ref. 2, p. 213) that the holotype of M. occidentale was found at this locality and not in the underlying Metaplacenticeras siltstone unit at the point on the shoreline southeast of the mouth of Keogh River (ref. 1, p. 133). The uppermost unit of the Suquash Basin Nanaimo succession forms, therefore, part of the Metaplacenticeras pacificum Zone as suggested by the writer (ref. 1, p. 133).

Manning Park Area

The following upward succession of rock units is suggested tentatively for the still insufficiently understood lower and middle parts of the eastern Group on the Lookout Road.

? Pliensbachian volcanic unit

Dull grey, speckled green or speckled lavender ? andesitic pyroclastics (mainly coarse to fine primary volcanic breccia) predominate in the unit. However, some ? andesitic lava flows may occur locally. The volcanics are believed to be mostly nonmarine because of an apparently complete absence of pillow structures, the massive unsorted appearance of pyroclastics, and the abundance of lithified to carbonized plant remains (including sizable branches and tree trunks) at several levels in the upper part of the unit. However, numerous interbeds of distinctly bedded, waterlain pyroclastics, coarse- to fine-grained tuffaceous greywacke, volcanic conglomerate and tuffaceous mudstone occur in the lowermost exposed beds of the unit in the roadcut at the southeastern side of Blackwall Peak (ref. 3, p. 34, Fig. 5). Clastic interbeds occurring in these waterlain pyroclastics yielded an abundant shallow-water marine fauna including (tentative field identifications by the writer): rare Fanninoceras-like ammonites, fragmentary belemnitids, Trigonia (? Vaughonia) sp., Trigonia (? Scaphogonia) sp., a peculiar myophoriid-like ? trigoniid, ? Weyla sp., pectenids, oysters, rhynchonellid brachiopods, Actaeonella-like gastropods, and indeterminate gastropods. An early Pliensbachian age is suggested for this fauna. The base of the ? Pliensbachian volcanic unit is cut off by a strong, southwest-dipping, high angle thrust fault (ref. 3, p. 34, Fig. 5) which brings the above described waterlain volcanics over thinly bedded to laminated, graded-bedded and sole-marked argillaceous beds ranging from pure argillite to sandy siltstone. These partly convoluted turbidites include rare interbeds of fossiliferous, pebbly mudstones rich in argillaceous pebbles apparently derived through the erosion of underlying argillaceous rocks. Numerous ammonite, belemnite, and pelecypod fragments found in these pebbly mudstones appear to be redeposited by submarine slides from a more shallow-water environment. This fauna appears to be the same as that collected by J. A. Coates from his locality (GSC loc. 64872) and tentatively dated as ? Sinemurian by the writer (ref. 3, p. 34). This tentative dating is now withdrawn because of the discovery of Chondroceras sp. (tentative field determination by the writer) in the surrounding argillites. This argillaceous unit represents, accordingly, the Middle Bajocian upper part of the Ladner

Group overthrust by the ? Pliensbachian volcanic unit. The latter represents the oldest part of the Ladner Group known on the Lookout Road.

The uppermost beds of the ? Pliensbachian volcanic unit are well exposed on the southeastern side of the seventh switchback (ref. 3, p. 31, Figs. 5, 9) where they are at least 120 feet thick. These uppermost beds were found also to outcrop on the southeastern side of the ninth switchback where their presence was previously suggested (ref. 3, p. 33, Fig. 5). In this section, a rich, shallow-water, marine fauna was collected about 50 feet stratigraphically above the top of the ? Pliensbachian volcanic unit in an argillite interbed occurring in the predominantly coarse clastic rocks, and includes Programmoceras-like ammonites, fragmentary belemnites, Weyla sp., Trigonia (? Trigonia) sp., various long-ranging pelecypods, and indeterminate gastropods (tentative field identifications by the writer). These clastics represent the basal part of the Coarse clastic unit described below and are equivalent to the basal beds of the section exposed above the seventh switchback (ref. 3, p. 31, Figs. 5, 9). The inferred late Pliensbachian or ? early Toarcian age of the marine fauna occurring closely above the top of the ? Pliensbachian volcanic unit suggests that it is entirely of Pliensbachian age.

Contrary to the ideas of Coates (ref. 4, p. 150) and the writer (ref. 3, p. 5, 33, 34, Fig. 1), all major units of the volcanics observed in the Ladner Group on the Lookout Road appear to be referable to the same ? Pliensbachian volcanic unit that outcrops continuously at least from Blackwall Peak to the Hope-Princeton highway. The geological sketch map of the Mesozoic rocks exposed on the Lookout Road (ref. 3, Fig. 5) should be emended accordingly.

The complete thickness of the ? Pliensbachian volcanic unit is not known. However, it is at least 500 feet thick and may exceed 2,000 feet if the volcanic rocks outcrop all the way from the seventh switchback to the nearest point of Hampton Creek as seems reasonable to assume (ref. 3, 1972, Fig. 5).

Coarse clastic unit

All sedimentary rocks of the lower and middle parts of the eastern facies of the Ladner Group described by Jeletzky (ref. 3, p. 3-5, 31-35, Fig. 9) on the Lookout Road appear to be younger than the ? Pliensbachian volcanic unit. The age of this predominantly coarse clastic unit, which is at least 1,000 feet thick, appears to range from late Pliensbachian or ? early Toarcian to middle Bajocian since ammonites comparable to Sonninia s. lato and Chondroceras (preliminary field identifications by the writer) were found in its uppermost conglomeratic member, which is about 120 feet thick. These ? Sonninia- and ? Chondroceras-bearing beds were found only in the interval between the ninth switchback and the point about 1 1/4 miles southwest of Blackwall Peak. They are either correlative with or younger than the uppermost conglomeratic beds of the section measured in the lower part of the eighth stretch of the Lookout Road (ref. 3, p. 31, 33, Fig. 3).

The above mentioned ? Sonninia- and ? Chondroceras-bearing uppermost member of the Coarse clastic unit either grades upward into the basal beds of the upper part of the eastern facies of the Ladner Group on the Lookout Road (ref. 3, p. 3-4, 29-31, Fig. 8) or is equivalent to its basal, predominantly coarse-grained, arenaceous to conglomeratic part.

[1]Jeletzky, J.A.: Mesozoic stratigraphy of northern and eastern parts of Vancouver Island, British Columbia; in Report of Activities, Part A, April to October 1969; Geol. Surv. Can., Paper 70-1, pt. A, p. 209-214 (1970).

[2]Jeletzky, J.A.: Mesozoic and Tertiary stratigraphy of northern Vancouver Island; in Report of Activities, Part A, April to October 1968; Geol. Surv. Can., Paper 69-1, pt. A, p. 127-134 (1969).

[3]Jeletzky, J.A.: Jurassic and Cretaceous rocks along Hope-Princeton highway and Lookout Road, Manning Park, British Columbia (supplement to Section 10 of the 24th International Geological Congress Guidebook AO3-CO3); Geol. Surv. Can., Open File 114 (1972).

[4]Coates, J.A.: Stratigraphy and structure of Manning Park area, Cascade Mountains, British Columbia in Structure of the Southern Canadian Cordillera; Geol. Assoc. Can., Spec. Paper 6, p. 149-154, Figs. 13-1 to 13-5 (1970).

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137. GRINNELL PENINSULA, DEVON ISLAND, DISTRICT OF FRANKLIN

Project 670016

J. Wm. Kerr, D. W. Morrow and K. W. Savigny
Institute of Sedimentary and Petroleum Geology, Calgary

A geological mapping and stratigraphic study was made of the western half of Grinnell Peninsula. The oldest rocks exposed in the area are in a dome south of Cape Briggs, where the oldest unit, although yielding no fossils, is tentatively assigned to the Parrish Glacier Formation. An overlying thick unit of mainly resistant limestone will probably warrant a new formational name. The Baumann Fiord Formation here consists of anhydrite, gypsum and limestone, with abundant lens-shaped stromatolites in beds. In the project area in general, the Baumann Fiord Formation is extremely variable; moreover it differs markedly from exposures on other islands in containing much less anhydrite. East of a line trending north from the head of Barrow Harbour it contains anhydrite, anhydritic limestone, stromatolitic limestone and quartz sandstone. West of this line anhydrite is nearly absent.

Three members are recognizable in the Eleanor River Formation, all being limestone. The lower and upper are resistant bluff-formers, whereas the middle member is thin bedded and recessive. A spectacular bed of stromatolites in the basal few feet of the Eleanor River Formation is an excellent marker horizon throughout the area of this study. The bed is usually about 5 feet thick and consists of low relief columnar stromatolites with internal digitate growth habit.

A hitherto unknown unconformity of Lower or Middle Silurian age occurs west of 95° 15'W only. It is overlain by a new and unnamed formation that lies conformably upon the Allen Bay Formation farther east, but westward cuts down to lie upon the Thumb Mountain Formation. The unconformity dates a gentle Silurian arching of the Cornwallis Fold Belt. A Lower Devonian unconformity overlain by the Disappointment Bay Dolomite is widespread in the area west of 93° 40'W. Lead-zinc mineralization occurs in the Thumb Mountain Formation beneath the Disappointment Bay unconformity on western Sheills Penninsula. Similar settings occur northward from Stewart Point.

Prominent north-northeast-trending normal faults that extend right across Grinnell Peninsula cut all rocks present including late Paleozoic formations on the north coast. Sporadically basic dykes occur along these faults.

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138. DEVONIAN AND OLDER PALEOZOIC ROCKS, SOUTHERN AND CENTRAL DISTRICT OF MACKENZIE

Project 700060

W. S. MacKenzie
Institute of Sedimentary and Petroleum Geology, Calgary

W. S. MacKenzie, T. T. Uyeno and A. E. H. Pedder spent 21 days near Sans Sault Rapids and Fort Good Hope in the District of Mackenzie studying outcrops of the carbonate body known variously, either in part or in whole, as the Ramparts, Beavertail or Kee Scarp Formation. Stratigraphic sections were measured and small outcrops examined at such localities as Oscar Creek and Hoosier Ridge in the south, Bell Creek, Imperial Hills and "The Ramparts" near the centre of the study area, and at Carnwath River in the north.

Physical stratigraphy of the carbonates studied in outcrop and in subsurface [1, 2] continued to support the concept of a Ramparts Formation carbonate bank with irregular surface topography and local erosional features. Isolated hills, about 75 feet high, of bedded Ramparts Formation carbonate occur near the north end of the Gibson Range. They appear, from the air and from aerial photographs, to be stratigraphically younger than similar carbonates in a section measured close by. The hills may represent primary surface topography of the carbonate bank.

A sandy unit characteristically with Leiorhynchus hippocastanea, formerly observed along Ontaratue River, at Gossage River, and in subsurface at R.O.C. Grandview Hills No. 1 well has been traced east across the Mackenzie River to north of Little Chicago. The sandy unit is to be named a member of the Ramparts Formation with a type locality north of Little Chicago.

[1] MacKenzie, W. S.: Allochthonous reef debris - Limestone Turbidites, Powell Creek, Northwest Territories; Can. Bull. Petrol. Geol., v. 18, no. 4, p. 474-492 (1970).

[2] MacKenzie, W. S.: Upper Devonian Echinoderm debris beds with graded texture, District of Mackenzie, Northwest Territories (in prep.).

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139. LOWER ORDOVICIAN EVAPORITES OF THE BAUMANN FIORD FORMATION, ELLESMERE ISLAND

Project 710007

Grant D. Mossop
Institute of Sedimentary and Petroleum Geology, Calgary

A second season of field investigation of evaporites of the Baumann Fiord Formation was completed in 1972, during which time complete sections were examined at four localities on central and eastern Ellesmere Island (Secs. 5-8, Fig. 1). In their textural and morphologic character as well as their general aspect, the sequences examined are essentially similar to those visited in 1971 and described in earlier reports[1,2] (Sec. 1-4, Fig. 1).

Basic stratigraphic information and thicknesses of sections examined in both 1971 and 1972 are given in Table I. Thicknesses were obtained by stratigraphic measurement in the field. In some sections, thickness is increased locally by small-scale overfolding and flowage due to regional structural shortening. The members referred to are those originally defined by Kerr[3,4]: thick basal anhydrite with carbonate interbeds (A Member); a middle limestone (B Member); and a thin upper anhydrite-carbonate unit (C Member). Where the C Member is missing, the B Member is indistinguishable from the overlying Eleanor River Formation and is thus considered part of that formation.

Some observations on the sections examined in 1972 are given below:

a) <u>Red beds</u> - The B Member (mainly limestones) of the Baumann Fiord Formation at locality 7 contains numerous intercalated beds of red quartz sandstone in units up to 16 feet thick. Trough crossbedding and cut-and-fill structures are present. Red, argillaceous micritic limestone also occurs at various levels, commonly just below the red bed sandstone intervals. As suggested in an earlier discussion[2], these red beds may represent the foreland clastic fan environment at the back of a sabkha-derived evaporite-carbonate platform. Section 7 lies in close proximity to the stable Precambrian paleo-landmass.

b) <u>Fossils</u> - A rich brachiopod fauna was discovered in the B Member limestones at locality 7, associated with the red beds described above. The fossils are silicified and reside in a grey, micritic limestone matrix. This locality is of special interest because the Baumann Fiord Formation is normally barren of fossils. That brachiopods were able to exist there may be attributed to local freshwater dilution of the evaporitic marine waters from which these carbonates were deposited. High salinities may have inhibited faunal development elsewhere on the evaporite platform. Preliminary examination of the fossil collection indicates that the brachiopod fauna can be precisely dated as Early Ordovician (Arenigian) in age (B.S. Norford, pers. com.).

c) <u>Stromatolites</u> - The limestone stringers in both the A and C Members as well as the thick limestones of the B Member were found everywhere to contain abundant crypt-algal structures. Single beds as much as 12 feet thick and consisting entirely of stromatolites were observed.

Three distinctive forms were recognized; the characteristics of these are summarized in Table II. The genetic and environmental significance of the various forms have yet to be determined.

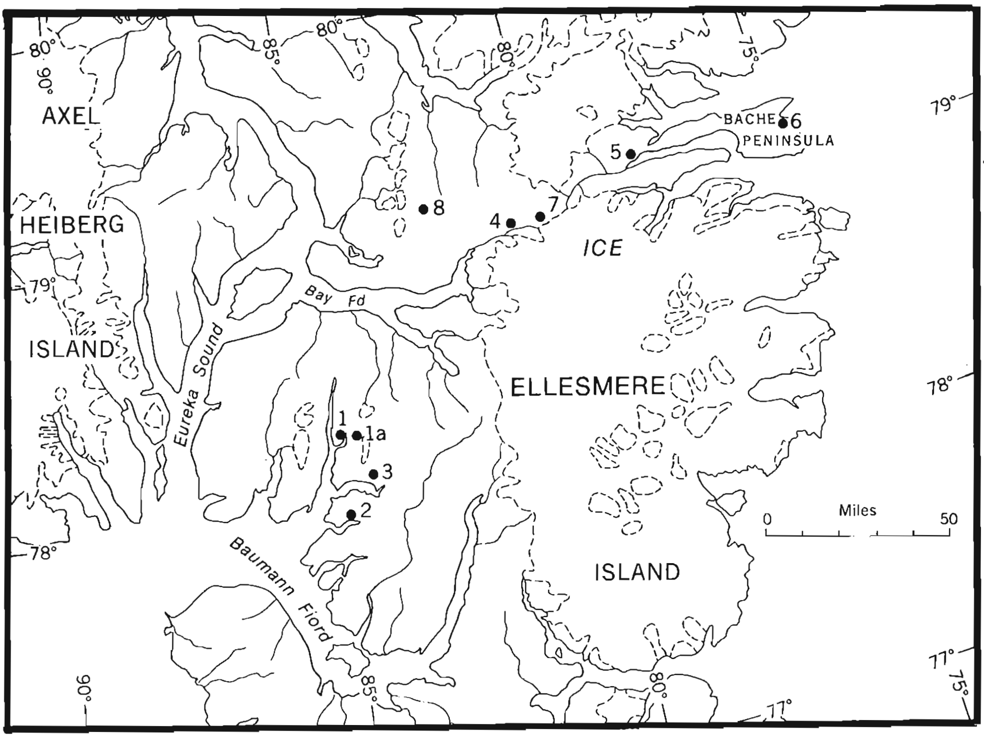


Figure 1. Index map of Baumann Fiord Formation sections examined. Localities 1, 1a, 2, 3, and 4 were studied in 1971. Localities 5, 6, 7, and 8 are the 1972 sections.

TABLE I

SECTION*	REGION	THICKNESS (FT.)	MEMBERS PRESENT
1	Trold Fiord	1375+	ABC
1a	Trold Fiord	1550	ABC
2	Flat Pebble Bay	1293	A only
3	Starfish Bay	1022	ABC
4	Sverdrup Pass	670+	ABC
5	Sanddöla Creek	868	ABC
6	Bartlett Bay	760	ABC
7	Witch Mountain	815	ABC
8	Vesle Dome	≃ 840	A only

*Sections 1 to 4 measured in 1971

TABLE II

Description and Informal Grouping of Algal Stromatolites found in the Baumann Fiord Formation.

TYPE	DESCRIPTION		OCCURRENCE
	CROSS SECTION	PLAN VIEW	
Polygonal algal mat	Essentially planar algal lamination, truncated at the edges Thickness of algal mat horizon variable; rarely more than 5 cm	Regular polygons up to 15 cm across; interlocking Micrite filled space between polygons normally 2 to 3 cm wide Very little surface relief	Rare
Finger stromatolites	Delicate algal lamination, convex upwards Single colonies uniformly 2 cm across and up to 20 cm high Small pipe between adjacent colonies (1/2 cm) commonly filled with micrite	Knobby appearance in bedding surface, the head of each colony rising 1/2 cm above matrix No apparent alignment or pattern developed amongst colonies	Common
Domal stromatolites	Fine algal lamination, convex upwards Single colonies up to 50 cm high and 30 cm across at the top Commonly narrower at base than at top (slightly conical)	Essentially circular domes with bedding plane relief up to 3 cm Adjacent domes aligned in rows	Very rare

d) Nodular anhydrite – Pervasive recrystallization has largely obliterated the primary structure and texture of the anhydrite[2] at most localities. From field data it is tentatively suggested that the recrystallization fabrics present form a series or sequence that is related to the degree and style of structural deformation. Nodular, mosaic anhydrite, perhaps representing the primary evaporite habit of the Baumann Fiord anhydrites[2], was observed at many localities.

Anhydrite fabrics were examined in a wide variety of structural settings from the virtually undeformed strata at section 5 to intensely deformed and contorted beds at locality 8, where a series of tight chevron folds (amplitude 90 feet, wavelength 65 feet) is exposed. It appears that under Arctic weathering conditions, intensely deformed anhydrite generally alters to gypsum more readily than does undeformed anhydrite.

Carbonate and anhydrite samples from all the sections examined are currently undergoing petrographical and geochemical analysis.

[1] Mossop, G. D.: Baumann Fiord Formation evaporites of central Ellesmere Island; *in* Report of Activities, Part A: April to October 1971; Geol. Surv. Can., Paper 72-1, pt. A, p. 216-217 (1972).

[2] Mossop, G. D.: Baumann Fiord Formation evaporites of central Ellesmere Island, Arctic Canada; *in* Report of Activities, Part B: November 1971 to March 1972; Geol. Surv. Can., Paper 72-1, pt. B, p. 86-90 (1972).

[3] Kerr, J. Wm.: New nomenclature for Ordovician rock units of eastern and southern Queen Elizabeth Islands, Arctic Canada; Bull. Can. Petrol. Geol., v. 15, no. 1, p. 91-113 (1967).

[4] Kerr, J. Wm.: Stratigraphy of central and eastern Ellesmere Island, Arctic Canada; Geol. Surv. Can., Paper 67-27, Pt. II, Ordovician (1967).

[5] Christie, R. L.: Bache Peninsula, Ellesmere Island, Arctic Archipelago; Geol. Surv. Can., Mem. 347 (1967).

140. JURASSIC TRIGONIIDAE OF WESTERN BRITISH COLUMBIA

Project 710015

T. P. Poulton
Institute of Sedimentary and Petroleum Geology, Calgary

The following preliminary results on the distribution of major groups of North American Jurassic trigoniid pelecypods arise from field-work by the author, from examination of Canadian and American museum collections, and from review of the pertinent literature.

Trigoniidae are not known from the Jurassic of the Canadian Arctic Islands, nor from the north slope of Alaska. In Canada, abundance and diversity of genera and species is greater in western parts of the Cordillera than in the Rocky Mountains, Foothills, or Plains. Trigoniids occur in shallow marine sedimentary rocks throughout the marine Jurassic of the Western Cordillera although they are rare in rocks younger than Early Oxfordian. Most collections, from localities yielding a diverse shelly fauna, consist of disarticulated specimens; articulated, little-transported shells are most common in localities yielding few other benthonic forms.

Sinemurian trigoniid collections are dominated by Frenguelliella ex gr. F. inexpectata Jaworski and other species of Frenguelliella sensu lato. Pleinsbachian and Toarcian rocks of southwestern British Columbia and central Oregon contain locally abundant Vaugonia. Trigonia, Psilotrigonia cf. P. beesleyana (Lycett), and Frenguelliella occur in rocks of probable Pleinsbachian or Toarcian age in western Vancouver Island.

Middle Jurassic rocks contain a greater abundance and variety of trigoniid pelecypods, mainly "Myophorella" and "Vaugonia". Trigonia, Scaphotrigonia and other genera are less common. Bajocian, Bathonian, and Callovian stages of the Middle Jurassic can be differentiated on the basis of "Myophorella" spp. and "Vaugonia" spp. Callovian Trigoniidae are closely related to early Oxfordian forms as well as to those of the earlier Middle Jurassic. "Heterotrigonia" is a common form in the Callovian of southern Alaska and occurs in central California. It is common in undated beds above Cardioceras-bearing shales in west-central British Columbia. "Heterotrigonia" and "Myophorella" show some degree of north-south differentiation along the Cordillera.

Future work will concentrate on "Myophorella" and "Vaugonia", two genera that show considerable potential for biostratigraphic and paleoecologic differentiation.

141. ISACHSEN FORMATION, AMUND RINGNES ISLAND, DISTRICT OF FRANKLIN

Project 710069

K. J. Roy
Institute of Sedimentary and Petroleum Geology, Calgary

Mesozoic rocks on Amund Ringnes and Cornwall Islands were studied in order to evaluate the stratigraphy and environments of deposition. Particular attention was given to sedimentary structures and relationships between sedimentation units. The Isachsen Formation is widely exposed on Amund Ringnes (see H.R. Balkwill, this publication, for geological map) and was examined at numerous localities. Field data and tentative interpretations concerning the Isachsen are presented in this report.

Field work was supported by H.R. Balkwill (Project 710003). About 11 weeks were spent in the field: two weeks on Cornwall, two one-day trips to Ellef Ringnes and Axel Heiberg Islands, and the remainder on Amund Ringnes Island.

Observations

The Isachsen Formation on Amund Ringnes Island is 3, 100 to 3, 800 feet thick and consists mainly of sandstone and shale with minor amounts of siltstone and coal. Black coaly bands, up to 10 feet thick and extending one mile or more along strike, are common but generally contain less than 10 per cent coal. The remaining 90 per cent comprises carbonaceous shale, siltstone and sandstone. The thickest coal band seen was one foot thick, with the average being about 1 inch. The coal seams appear to have a maximum lateral extent of one-half mile.

Four major types of lithologic units occur within the Isachsen Formation.

(1) Shale: black, hard, brittle, papery, very carbonaceous, silty. This makes up less than 5 per cent of the formation but occurs in units up to 100 feet thick which extend laterally as much as 6 miles.

(2) Shale: black to dark grey, soft, papery to shaly, carbonaceous, silty, associated with variable amounts of sandstone (unit 3).

(3) Sandstone: weathers tan to light grey; fresh colour is light grey; often iron-stained; generally very fine grained but range from medium to silt-size; flaggy to platy; parallel-wavy bedding; minor ripple-marks; minor root casts; 95 per cent or more quartz; generally noncalcareous, in part silica cemented; in part friable; generally little porosity; common carbonaceous detritus; coaly bands up to 1 inch thick; rare compressed carbonized logs, some lithified wood; thickness of sandstone bands generally two inches or less, but may be in units to 10 feet thick; over-all a recessive unit with variable amounts of interbedded shale (unit 2).

(4) Sandstone: weathers light brown to buff; fresh colour is light grey; 90 per cent or more quartz; generally medium grained but ranges from medium to fine; rare pebbly sandstone lenses, maximum pebble is 2 centimetres in diameter; less than one per cent of outcrop is conglomerate; flaggy to massive; extensively cross-stratified[1], sets generally from about 2 feet to a

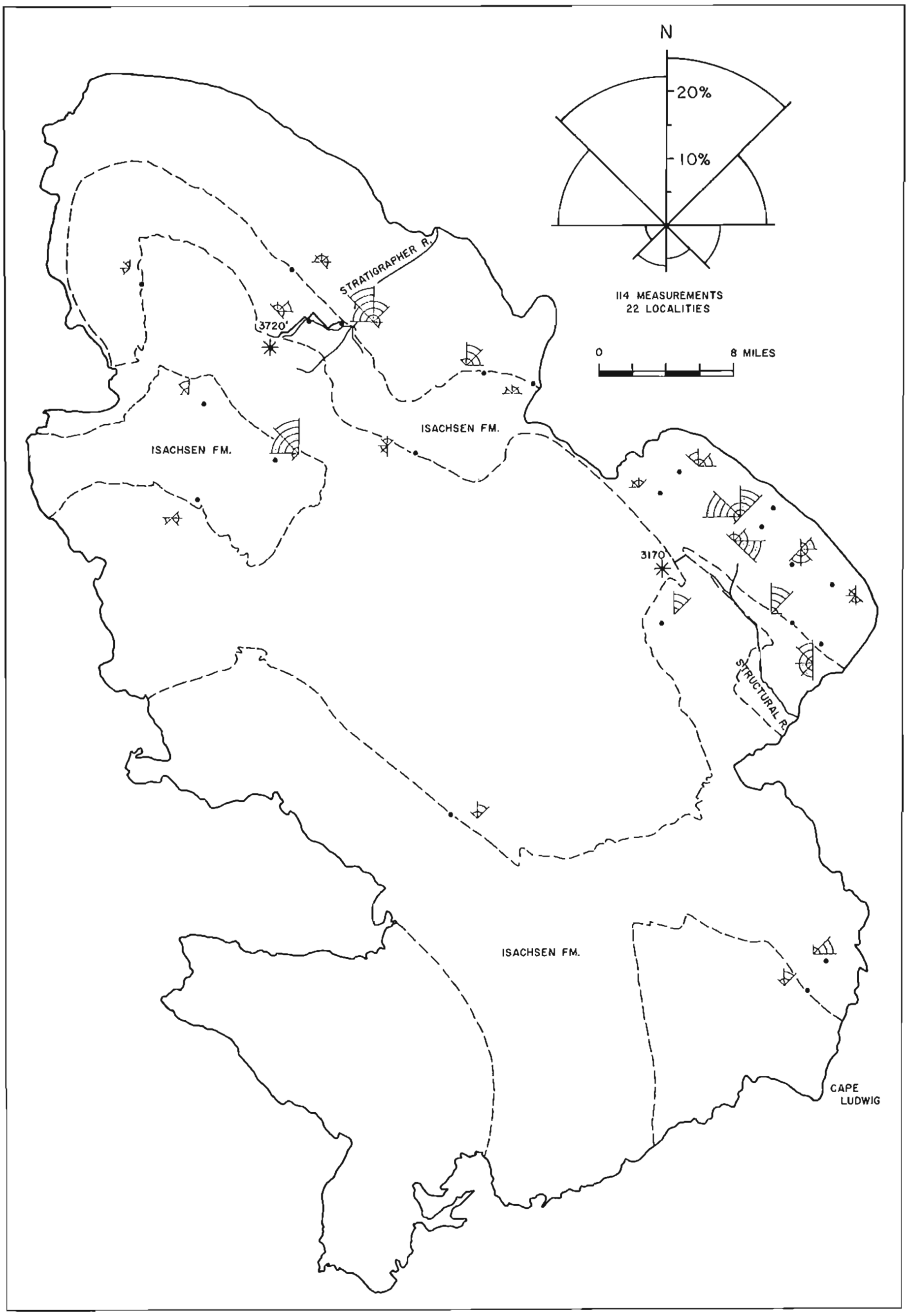
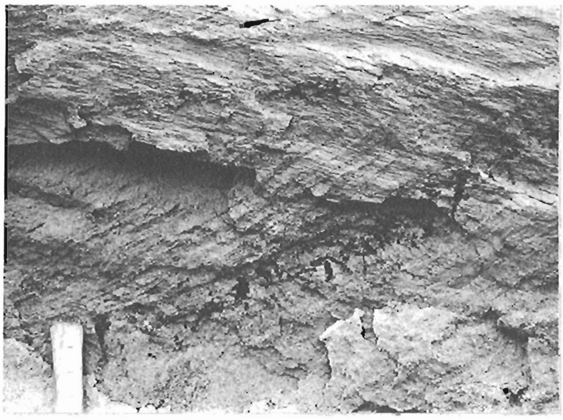
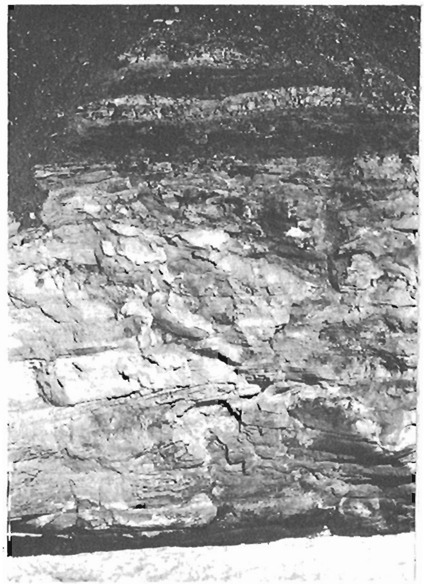


Figure 1. Distribution of direction of sediment transport in the Isachsen Formation on Amund Ringnes Island. Rose diagrams indicate number of observations and transport directions at each location. *Indicates location of measured sections and thickness of section is given.





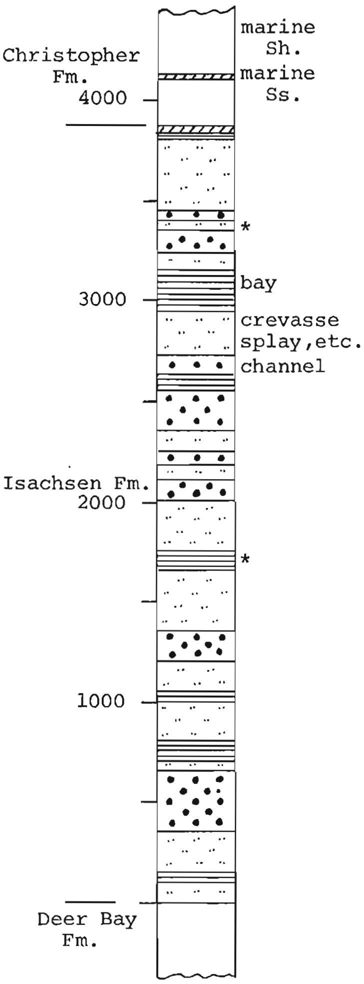


Figure 2 (top left)

Isachsen Formation (channel facies) at Stratigrapher River. Rooted zones occur along the top of cross-strata sets as well as down foreset beds. Marks on the hammer handle are 0.1 feet apart.

Figure 3 (top right)

Upward fining sequence (interpreted point bar sequence) in the lower part of Isachsen Formation east of Structural River. The stick in the lower left is 5 feet long.

Figure 4 (left)

Interpretation of the sequence of depositional environments in the Isachsen Formation at Stratigrapher River. The asterisks indicate beds of lithologic unit (1) (see text). The pattern code is indicated by the terms on the right of the column.

maximum of about 6 feet thick; sets large and high angle, both planar-wedge and trough-lenticular with broad, shallow trough-lenticular predominant; one occurrence of contorted bedding with amplitudes of 1 foot to 2 feet; rooted zones may occur at top and base of sets and rarely down foreset beds within the sets (Fig. 2); detrital carbonaceous material common along the base of the sets and up the lower part of the foreset beds (Fig. 2); carbonized logs are present although generally compressed, maximum diameter observed was about 1 foot; shale clasts on some bedding planes. This sandstone unit grades upwards in places, with a decrease in cross-strata set size and an increase in amount of horizontally bedded units to a combination of lithologic units 2 and 3 with coaly bands. The total sequence of units 4, 3 and 2 is as much as 60 feet thick (Fig. 3).

In many places at the contacts of the Isachsen Formation with underlying and overlying marine shales (Deer Bay and Christopher Formations respectively) there is a progressive change from lithologic unit 4 to a mixture of units 3 and 2 to marine shale. At Structural River and Cape Ludwig on Amund Ringnes Island and at Good Friday Bay on Axel Heiberg Island, the Deer Bay Formation becomes sandier and siltier toward the top and there is a tan-weathering, platy, rippled sandstone unit with abundant small, pelecypod fossils and burrows at the base of the Isachsen.

The upper contact of the Isachsen is similar to the lower although no fossils were observed in the uppermost beds. Abundant burrows, feeding trails and ripple-marks were seen near the top of the formation at one locality.

Attitudes of foreset beds in sets of cross-strata and, less commonly, the plunge and trend of axis of trough cross-strata were measured to determine sediment transport directions. If possible, at least three observations, at positions as far apart as possible, were made at each outcrop. Problems regarding use of the magnetic compass at this latitude were overcome by establishing reference lines between points located on maps. Stereonet rotation was done to adjust for major bedding attitude. Because of inaccuracies in the method, the directional data are grouped into 45 degree units (Fig. 1).

Interpretation

The Isachsen Formation on Amund Ringnes Island is a delta-complex formed during a major regressive-transgressive cycle. The gradational nature of the upper and lower contacts suggests no major depositional break at the formational boundaries. Figure 4 is an interpretative section through the Isachsen at Stratigrapher River (Fig. 1). To construct the section, tentative assignment of lithologic units to depositional environments was made (unit 1, marsh; unit 2, interdistributary bay; unit 3 plus unit 2, interdistributary bay–crevasse splay–levee–floodplain; unit 4, channel). This analysis indicates a number of complete and truncated cycles of channel–overbank–bay–overbank–channel deposits in the formation. The environmental units shown on Figure 4 are made up of predominantly one lithologic unit. For example, channel intervals are not all unit 4 but do have variable, but minor, amounts of the other rock types. A channel interval likely has numerous cycles of unit 4 grading up into units 3 and 2. These cycles within the channel intervals are interpreted as point bar sequences. The thicknesses of the cycles indicated bankfull river depths of up to 50 or 60 feet.

Although grain-size variation in vertical profile is small in the sandstones of unit 4, there is generally a vague trend towards fining upward. No coarsening-upward units were seen. This suggests a meandering alluvial system. However, the presence of rooted foreset beds in sets up to 2 feet thick indicates some extended periods of subaerial exposure of major bed forms, suggestive of a braided stream. Probably both braided and meandering streams existed and flowed in the general northerly direction indicated by the sedimentary structures.

[1] McKee, E.D. and Weir, G.W.: Terminology for stratification and cross-stratification in sedimentary rocks; Geol. Soc. Amer. Bull., v. 84, p. 381-390 (1953).

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142. STRATIGRAPHY AND SEDIMENTOLOGY OF UPPER ORDOVICIAN TO LOWER DEVONIAN CLASTIC FORMATIONS, CAÑON FIORD REGION, ELLESMERE ISLAND

Project 720047

H.P. Trettin
Institute of Sedimentary and Petroleum Geology, Calgary

Field work was done from six light camps east and south of Cañon Fiord, central Ellesmere Island (Fig. 1) from June 30 to August 7, 1972. The field phase of the project, as originally defined, has now essentially been completed, but additional studies in other parts of central Ellesmere Island are desirable in order to clarify some remaining problems of stratigraphic nomenclature, correlation, and provenance.

Stratigraphy and Sedimentology

Shelf-type carbonate rocks, mostly limestones, assigned to the undivided Allen Bay and Read Bay Formations[1,2] form the base of the succession studied (unit 1 of Fig. 1). These rocks are overlain by four major units that occur in vertical order at individual sections. Units 2 and 3, however, are highly diachronous and partly correlative with each other and with unit 1. Together, the five units represent a depositional cycle that resulted from two major processes: (1) the southeastward expansion of the Hazen Trough[4], i.e. the downwarping of shelf areas that had previously been sites of carbonate sedimentation; and (2) rapid and almost continuous deposition of clastic sediments derived from northerly sources that first filled the Hazen Trough and then accumulated in shelf and paralic environments.

Unit 5 is disconformably overlain by another sequence, comprising the Vendom Fiord, Blue Fiord and Okse Bay Formations[1,2] at the southeastern margin of the project area. This sequence was studied in 1970[3].

A brief description of the major types of deposits, included mainly in units 2 to 5, follows.

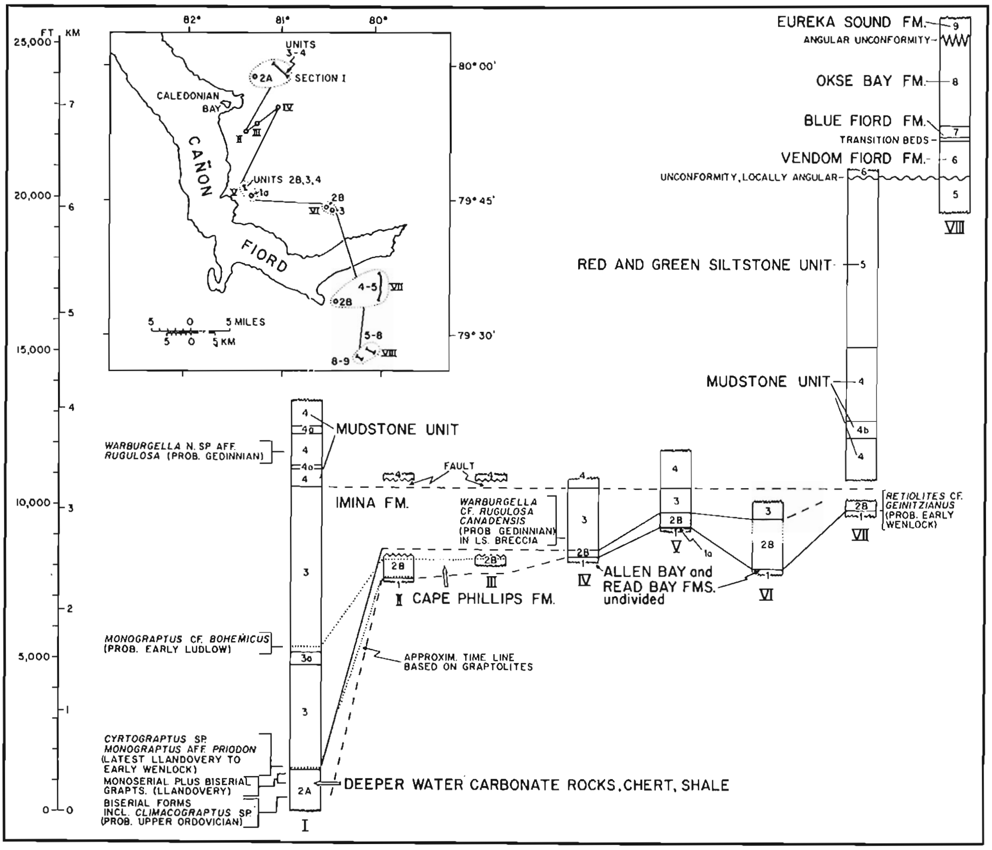

Figure 1. Columnar stratigraphic sections; for explanation of rock units see text. The 1972 field work was done at sections I, V, VI, and VII with some additional work at sections II to IV. Fossil identifications by B.S. Norford, A.R. Ormiston, and R. Thorsteinsson.

Deposits formed on the southeastern slope of the Hazen Trough are assigned to three different facies and stratigraphic units. A carbonate facies (unit 1a of Fig. 1) consists of limestone boulder breccia underlain by alternating argillaceous limestone and shale locally observed at the top of the Read Bay Formation (e.g. at section V). The breccias seem to have been formed by the disruption and down-sliding of carbonate beds, but apparently without major dislocations as these breccias are vertically and laterally continuous with the shelf carbonates. A carbonate-chert-shale facies (unit 2A), present only at section I, constitutes a new stratigraphic unit of formational rank. It has a minimum thickness of about 1,500 feet (base not exposed) and ranges in age from Late Ordovician(?) to Early Silurian (Llandoverian). It consists of deeper water carbonate rocks and interbedded dark grey, graptolitic cherts and minor shales. The carbonate rocks include: (1) medium dark grey lime-mudstones with argillaceous partings; (2) calcisiltites and calcarenites with dolomitic and terrigenous impurities, showing horizontal and crosslamination and graded bedding; (3) limestone breccia ranging from pebble to boulder grade. The most prominent breccia, occurring at the top of the unit, is about 100 feet thick and has a minimum lateral extent of seven miles. Allochthonous shelly faunas of shelf-type locally occur within the breccias. An argillaceous facies, the Cape Phillips Formation (unit 2B) consists mainly of shale and siltstone which are dark grey, dolomitic, calcareous and graptolitic with lesser amounts of bedded chert, dark grey, argillaceous limestone, and very fine grained sandstone. Local slump structures and boulders and large sheets of allochthonous shelf limestone attest to the instability of the depositional environment.

Deposits formed on the floor of the Hazen Trough and on submarine fans of its northwestern flank are included in the Imina Formation (unit 3a), a thick, flysch-like succession composed mainly of calcareous and dolomitic sandstone, siltstone, and shale showing horizontal and crosslamination, convolute and graded bedding, and sole markings [4]. A thick conglomeratic unit at section I (unit 3a) is interpreted as a submarine fan-valley deposit. Carbonate breccias ranging from pebble to boulder grade and calcarenites, in part graded, also are present.

Transitional, shallow trough to shelf environments are represented by a "mudstone unit" (unit 4) that probably corresponds to the lower part of the Eids Formation (see ref. [1]). Calcareous and slightly dolomitic, horizontally laminated mudstone is the predominant rock type. It is mainly medium dark grey, yellowish grey weathering, but is greenish grey in the middle and upper parts of section VII. Flysch-like sequences of sandstone and siltstone comparable to the Imina Formation occur in the lower part of the mudstone unit at section I (unit 4a). These sediments probably were deposited during the last stage in the development of the Hazen Trough. On the other hand, the calcareous siltstone and sandstone, and sandy and silty limestone containing abundant faunas of brachiopods, bryozoans, echinoderms, trilobites, etc. (unit 4b), which occur in the upper part of the mudstone unit at section VII, appear to have originated in shelf environments.

Subtidal shelf to supratidal paralic deposits are included in a new unit of formational rank, here referred to as the "red and green siltstone unit" (unit 5). It is about 5,500 feet thick at section VII and consists mainly of siltstone with minor mudstone and very fine grained sandstone, and a very small proportion of gypsum. The clastic sediments all contain calcite and dolomite in varying proportions. The siltstones and mudstones are both light green and pale red, and the sandstones pale red or pale yellowish brown. The red colour is due to hematite apparently derived from biotite, a common constituent of the entire clastic succession. Horizontal and crosslamination is the predominant primary structure and convolute lamination is well developed at some levels in the middle and upper part whereas trough crossbedding is rare. The stratification has been destroyed to some extent by burrowing, and trace fossils are common. The fauna includes brachiopods, bryozoans, echinoderms, fish, and ostracodes.

The following vertical changes indicate that the depth of water decreased generally, though with some fluctuations, during the deposition of the unit.

(1) Red beds are subordinate in the lower part of the section and predominant above about 2,000 feet.

(2) Sandstone is very rare in the lower 850 feet and fairly abundant from 2,850 feet to the top.

(3) Trace amounts of gypsum occur at 2,125 feet and, intermittently, from 3,155 to the top. An eight-foot bed of gypsum at 4,350 feet has a minimum lateral extent of one mile.

(4) Calcite predominates over dolomite in the lower 2,100 feet (except for the interval 600 to 1,000 feet). Calcite and dolomite are about equal in proportion, or dolomite predominates from 2,100 feet to the top (inferred from 37 X-ray diffraction analyses).

(5) Fossils gradually disappear upward in the section and those of shallower water origin persist higher than those of deeper (but still relatively shallow) origin. Thus the highest known brachiopods occur at 1,600 feet, the highest known fish at 2,160 feet, and the highest ostracodes at 3,409 feet.

Age relationships

Of the more than 50 fossil collections made, only a few diagnostic graptolites have been identified to date (by R. Thorsteinsson). These, and information from previous collections, suggest that the red and green siltstone unit and the grey mudstone unit both are Early Devonian in age. The top of the Imina Formation probably is Early Devonian in age, and the base ranges from latest Llandoverian or early Wenlockian at section I to probably Late Silurian or earliest Devonian at section IV (and probably at V and VI). The contact between the Read Bay and Cape Phillips Formations is late Llandoverian or early Wenlockian at sections II and VII.

Tectonic implications and mineralization

A major hinge separates section I from section IV. At section I, the entire succession, ranging in age from Late Ordovician to Early Devonian, is of deeper water origin and the flysch is 9,170 feet thick. At section IV, on the other hand, deeper water conditions commenced in the Late Silurian or Early Devonian, and the flysch is only 2,030 feet thick.

Llandoverian chert beds in the upper part of unit 2A (at NTS 49 H; UTM zone 17 X; 493600 E, 8880250 N) are stained by azurite and malachite. This mineralization does not seem to be of economic significance as metallic copper minerals have not been found in the area but may be significant from a metallogenic point of view because the copper carbonates occur close to the hinge and facies boundary discussed. The stratigraphic setting, therefore, is broadly comparable (but different in detail) to that of the Pb-Zn deposits on Little Cornwallis Island, and to the minor mineral occurrences at Cape Schuchert.

[1] Kerr, J.W.: Devonian of the Franklinian miogeosyncline and adjacent Stable Region, Arctic Canada; *in* International Symposium on the Devonian System, D.H. Oswald, *ed.*, v. 1, p. 483-520, Alberta Soc. Petrol. Geol., Calgary, Alberta (1967 publ. 1968).

[2] Thorsteinsson, R., comp.: Geology, Cañon Fiord, District of Franklin; Geol. Surv. Can., Map 1308A (in press).

[3] Trettin, H.P.: Stratigraphy and sedimentology of lower Paleozoic clastic units, Tanquary and Cañon Fiord regions, Ellesmere Island; *in* Report of Activities, Part A: April to October 1970; Geol. Surv. Can., Paper 71-1, pt. A, p. 236-241 (1971).

[4]Trettin, H.P.: Geology of lower Paleozoic formations, Hazen Plateau and southern Grant Land Mountains, Ellesmere Island, Arctic Archipelago; Geol. Surv. Can., Bull. 203 (1971).

[5]Norford, B.S.: Silurian stratigraphic sections at Kap Tyson, Offley Ø and Kap Schuchert, northwestern Greenland; Medd. om Grønland, v. 195, no. 2 (1972).

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143. CONODONT BIOSTRATIGRAPHY OF SILURIAN AND DEVONIAN ROCKS OF CANADA

Projects 660026, 680101

T.T. Uyeno
Institute of Sedimentary and Petroleum Geology, Calgary

Upper Silurian and Devonian strata were sampled for conodonts at three widely separated areas: (i) southwestern Ontario, (ii) eastern Prince of Wales Island, District of Franklin, and (iii) Fort Good Hope area, District of Mackenzie.

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144. JURASSIC AND CRETACEOUS STRATIGRAPHY BETWEEN BABBAGE AND BLOW RIVERS, YUKON TERRITORY

Project 700068

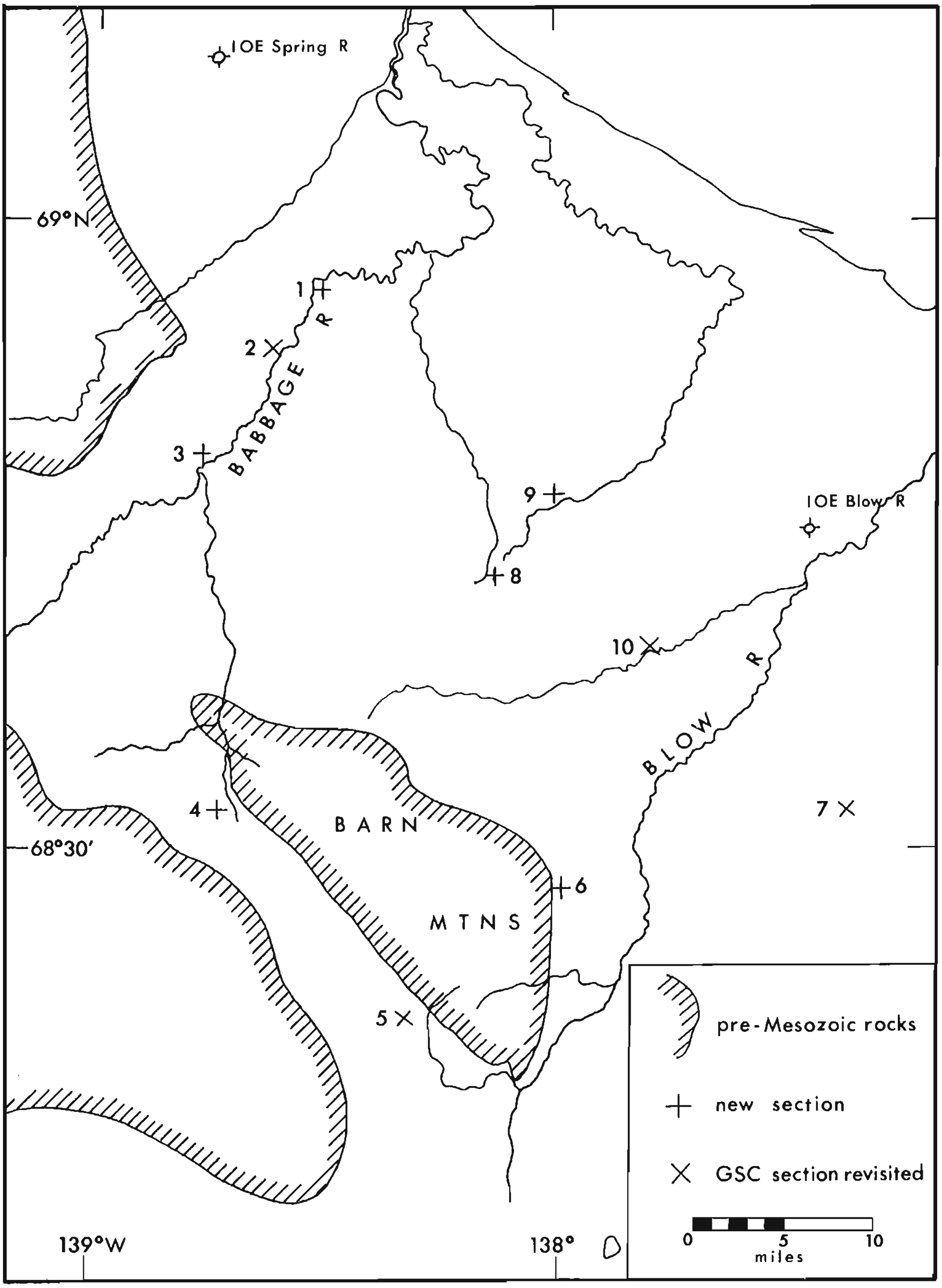
F.G. Young
Institute of Sedimentary and Petroleum Geology, Calgary

Stratigraphic studies of Mesozoic rocks were carried out in parts of Aklavik Range, Richardson Mountains, Old Crow Basin and Keele Range, but primarily in the drainage basins of Babbage and Blow Rivers of northern Yukon (Fig. 1). This area is underlain mainly by warped and faulted Mesozoic rocks, except for Barn Mountains which consist of dominantly Paleozoic rocks.

The Mesozoic succession in the study area, as in the area east of it[1], can be divided into three major depositional sequences. Triassic rocks comprise another sequence with erratic distribution in the study-area[2] but are not included in this study. The major sequences consist of a lowest Jurassic-Lower Cretaceous (Aptian) marine sequence, an Aptian-Albian flysch, and an Upper Cretaceous (Senonian-Maestrichtian) molasse.

Jurassic-Lower Cretaceous Sequence

Jeletzky[3] studied and discussed the stratigraphy of this sequence along the southern and southeastern flanks of Barn Mountains, and Mountjoy measured sections[4] on Babbage River and Sleepy Mountain. In upward order, the sequence consists of Kingak Formation, Neocomian sandstone and shale zone, Upper Shale-Siltstone Division, and Upper Sandstone Division.


IOE Spring R
69°N
1
2
3
BABBAGE R
9
8
IOE Blow R
10
BLOW R
4
BARN
MTNS
7
68°30'
6
5
pre-Mesozoic rocks
new section
GSC section revisited
0
5
10
miles
139°W
138°

The Jurassic Kingak Formation is approximately 2,000 to 2,500 feet thick southwest of Barn Mountains. No complete sections have yet been measured north of Barn Mountains, but the upper 1,500 feet have been examined. Dark grey to black, commonly concretionary shale predominates, with thin siltstone and argillaceous sandstone members appearing near the top. Many of these members contain pelecypods including species of Buchia which have not yet been identified.

The Neocomian sandstone and shale zone was examined on Babbage River, Ladas Creek, and at different localities surrounding Barn Mountains. The lowest sandstone unit is thin (generally 10 to 25 feet thick) and consists of poorly sorted, granular to fine-grained, argillaceous sandstone and siltstone. Unidentified species of Buchia are common in all occurrences, but it is as yet unknown whether or not they comprise one unit, or whether they are in any occurrence equivalent to the Lower Sandstone Division. At section 8 near the head of Ladas Creek (68°43'00"N, 138°07'30"W, Fig. 1), this unit consists of 22 feet of poorly sorted sandstone exhibiting tubular to vuggy, bitumen-lined pores and an aromatic odour when struck. This is the only occurrence on the Yukon coastal plain of bituminous, porous rock of Mesozoic age known to the writer.

Overlying the sandstone is a dark grey silty mudstone unit which grades upwards into a prominent sandstone member, referred to by Norris[5] as an equivalent of the Coaly Quartzite Division. This sandstone forms a mappable formation in the Canoe River drainage area and eastward to Ladas Creek north of Barn Mountains. Its thickness and character are relatively consistent around this semicircular outcrop belt. The sandstone is typically very fine to fine grained, well sorted, quartzose, in part glauconitic, and commonly has parallel laminations. These features suggest deposition in a relatively agitated, marine environment.

The sandstone member generally ranges in thicknesses between 250 and 500 feet, but decreases northward to only 30 feet on Babbage River (Sec. 3, Fig. 1), and 100 feet north of Sleepy Mountain (NW of Sec. 8) as the formation grades laterally into finer clastics. South of Barn Mountains (Sec. 5, Fig. 1), Jeletzky[3] noted the thickness of the White and Coaly Quartzite Divisions as being possibly 800 to 1,800 feet thick. This thick accumulation of sand is completely truncated along the immediate east flank of Barn Mountains near Mount Fitton (Sec. 6, Fig. 1), where 600 feet of chert conglomerate of probable Aptian-Albian or younger age rest upon dark grey shale with a 12-foot sandstone tongue bearing Buchia sp.

The Upper Shale-Siltstone Division is 650 feet thick on upper Canoe River (Sec. 4, Fig. 1), 1,500 feet on Babbage River near Trout Lake (Sec. 3, Fig. 1), and at least 1,000 feet on Ladas Creek, 4 miles southwest of Hidden Lake (Sec. 8, Fig. 1). It consists mainly of dark grey, silty or shaly mudstone with occasional concretion-rich horizons, and grades upward through a 200-foot interval of siltstone into the overlying Upper Sandstone Division.

The Upper Sandstone Division equivalent was examined near the confluence of Babbage River and Philip Creek (Sec. 2, Fig. 1) where it is 330 feet thick, and in the upper Canoe River area (Sec. 4, Fig. 1), where it is 165 feet thick. The sandstone closely resembles that of the underlying Coaly Quartzite equivalent in composition and facies. The Upper Sandstone grades upwards into shale, which is included in the flysch sequence.

Aptian–Albian Flysch Sequence

This sequence is predominantly a thick shale succession with minor siltstone, sandstone, and conglomerate beds in the study area. On Babbage River, it is about 10,000 feet thick and, although greatly obscured by poor exposure and structural complications, apparently thickens towards the southeast to at least 14,000 feet near Blow River.

The base of the Babbage River section (Sec. 1, Fig. 1) consists of 1,400 feet of dark grey shale with occasional concretions and silty zones. This is overlain by 70 feet of bedded ironstone and shale, the same facies encountered near Mount Davies Gilbert, 50 miles to the southeast[1]. However, each occurrence may represent lithosomes that are not time-equivalent. The ironstone is overlain by 1,500 feet of shale with minor sandstone interbeds and a covered interval, about 4,000 feet thick, presumed to be mainly shale. This in turn is overlain by 140 feet of sandstone which forms dykes in the underlying shale. The sandstone consists of fine-grained lithic arenite, in part convoluted and parallel-laminated, and without sole-marks. Sulphurous minerals and weathered bands are common in the shale interbeds. This member thickens southeastward into a turbiditic sandstone and shale facies which approaches 1,000 feet in thickness east of Ladas Creek. The top of the flysch sequence is represented by 3,000 feet of shale containing interbeds of sandstone in its basal 1,000 feet.

Associated with the flysch sequence are locally occurring chert conglomerate units. These have been reported previously from the highland between Blow River and Purkis Creek (Sec. 7, Fig. 1)[1], and from Sharp Mountain of the Keele Range[3]. The former occurrence is now believed to be the base of a 3,500-foot-thick clastic wedge in the Albian flysch sequence, instead of a coarse facies of the Upper Sandstone Division as first interpreted. This revised stratigraphic position is supported by the presence of ?Sonneratia (s. lato) n. sp. A, an early Albian ammonite (J.A. Jeletzky, internal report), recent airphoto mapping, and the relatively lithic composition of the sandstone. No microfossils were recovered from samples of the underlying shale formation.

The 1,800-foot conglomeratic unit exposed on Anker Creek near the confluence of Annett Creek (Sec. 10, Fig. 1), first described by E.W. Mountjoy (ref. 4, Sec. 117A9), probably represents the axial part of another, younger clastic wedge in the flysch basin.

A 600-foot-thick conglomerate unit also occurs on the twin peaks just northwest of Mount Fitton (Sec. 6, Fig. 1). No fossils were recovered from this unit, but its position above Buchia-bearing strata and its 95 per cent chert content associate it with either the flysch sequence or the Upper Cretaceous molasse. The conglomerate also occurs to the south one mile south of Boulder Creek, where it is 50 to 100 feet thick, and consists of very coarse sand and granules of chert. At both localities, the coarse rock has disintegrated into a well-sorted, non-clayey gravel, which may be useful as road ballast in the future.

Upper Cretaceous Sequence

This sequence outcrops sporadically on lower Babbage River and in the area near the headwaters of Deep and Conglomerate Creeks[5]. A basal member of conglomerate, sandstone and mudstone is developed locally and was studied on Deep Creek (Sec. 9, Fig. 1), 2 miles southeast of Hidden Lake (68°46'47"N, 137°59'10"W). Here it is about 350 feet thick, and consists of very lenticular conglomerate beds which grade laterally into sandstone beds. Cobbles up to 14 inches (35.6 cm) in maximum diameter occur in the conglomerates and associated mudstones. The facies may represent deposits of braided stream complexes which were preserved in local depressions on the post-Albian erosional surface. This member corresponds to and may correlate with the basal chert conglomerate and sandstone division[1] of the Fish River area.

The unnamed silty mudstone formation overlying the conglomerate beds was determined graphically to be 2,300 feet thick at two separate localities in the Deep Creek area. It characteristically displays thin limy beds with small cone-in-cone structures in common with correlative beds of the Fish River area. It is overlain by poorly exposed sandstone and shale beds, about 3,500 feet thick, in part equivalent to the Moose Channel Formation.

Upper Cretaceous sandstones of this area consist of quartz, chert, and sedimentary rock fragments, and are not visibly porous. Relatively rare lenticular units of massive conglomerate and sandstone occur. They are up to 100 feet thick and display graded beds, large-scale tabular crossbedding, and rounded quartzite cobbles up to 20 centimetres long. Because these members are enclosed within thick shale units, they may represent some type of subaqueous channel-and-fan deposition.

A report describing the stratigraphy and sedimentology of the Upper Cretaceous sequence on the coastal plain and beneath northwestern Mackenzie Delta is currently in preparation.

[1] Young, F.G.: Cretaceous stratigraphy between Blow and Fish Rivers, Yukon Territory; in Report of Activities, Part A, April to October, 1971; Geol. Surv. Can., Paper 72-1, pt. A, p. 229-235 (1972).

[2] Mountjoy, E.W.: Triassic stratigraphy of northern Yukon Territory; Geol. Surv. Can., Paper 66-19 (1967).

[3] Jeletzky, J.A.: Stratigraphy, facies and paleogeography of Mesozoic and Tertiary rocks of northern Yukon and northwest Mackenzie District, N.W.T.; Geol. Surv. Can., Open File 82 (1972).

[4] Mountjoy, E.W. and Procter, R.M.: Eleven field descriptions of some Jurassic and Cretaceous rocks in Arctic Plateau and Arctic Coastal Plain; Geol. Surv. Can., Open File 16 (1962).

[5] Norris, D.K.: Structural and stratigraphic studies in the Tectonic Complex of northern Yukon Territory, north of Porcupine River; in Report of Activities, Part B; November 1971 to March 1972; Geol. Surv. Can., Paper 72-1, pt. B, p. 91-99 (1972).

GENERAL

145. AN AURIFEROUS RADIOACTIVE HYDROCARBON FROM THE RICHARDSON MINE, ELDORADO, ONTARIO

Project 650438

R.W. Boyle and H.R. Steacy
Resource Geophysics and Geochemistry Division and
Central Laboratories and Technical Services Division

An auriferous, radioactive hydrocarbon has been identified in samples from the Richardson Mine, Eldorado, Ontario. The identification is considered significant because, to the writers' knowledge, it is the first such occurrence recognized in Canada and only the second in the world, the other being that of the Rand in South Africa[1]. The identification is also of interest in that the radioactive hydrocarbon, to which the term thucholite may be applied, occurs in an area that heretofore appears to have been overlooked in the search for uranium. One sample of skarn, altered in part to ankerite, collected in 1967 from the Richardson dumps, was also found to be slightly radioactive when tested in the laboratory. However, a scintillometer survey carried out in October, 1972, in the vicinity of the mine failed to detect any anomalous radioactivity.

The discovery sample, one of several radioactive samples apparently collected around 1870 and preserved since that time in the Geological Survey of Canada's ore reference collection, is labelled "Richardson Mine, Lot 18, Concession V of Madoc, Hastings County, Ontario". The sample consists of two small hand specimens of a dark, calc-silicate rock containing rounded masses and veinlets of a massive, black, appreciably radioactive hydrocarbon, associated with quartz. Under the binocular microscope this material is seen to contain ragged grains of gold, that analysis shows to be remarkably pure, and films and patches of white-szomolnokite ($FeSO_4.H_2O$). Gold is not restricted to the hydrocarbon, occurring also in the quartz. Fragments of the hydrocarbon, visually free of impurities, yielded a specific gravity of 1.80 and, on ignition, 27.9 per cent ash, both values being remarkably consistent with those reported by Ellsworth (ref. 2, p. 174-186) for his type thucholite from the Parry Sound area, Ontario.

In describing his material Ellsworth reports that "when examined in polished section (a very good) polished surface appeared to be entirely homogeneous, even under the highest powers, except for a few, minute, hair-like cracks near the outer edge, which stood in slightly higher relief". In contrast, polished sections of the Richardson fragments are seen to carry disseminated microscopic grains of gold and urania (pitchblende or uraninite), and in fact are literally "shot-through" with such grains (see Fig. 1). The character of these grains is suggestive of an ex-solution rather than replacement process and would appear to indicate contemporaneous deposition from a gold-uranium-organo complex. Thorium and rare earths are present as minor constituents of the hydrocarbon. Spectrochemical analysis showed a content of 0.01 to 0.05 per cent thorium, and 0.01 to 0.1 per cent yttrium, ytterbium, neodymium and lanthanum. Direct electron probe examination of the urania grains indicated a content of less than one per cent thorium, suggesting their classification as pitchblende rather than uraninite. Uraninites of the Grenville province normally carry several per cent thorium.

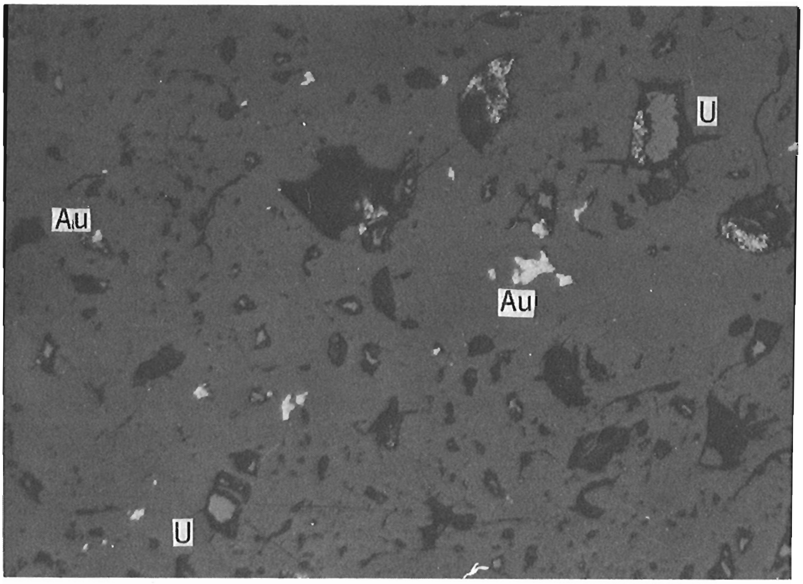


Figure 1. Photomicrograph (X160) of auriferous, radioactive hydrocarbon from the Richardson Mine, Eldorado, Ontario showing grains of gold (Au) and urania (U). The black areas are pits that developed during the polishing of the section and may represent, in part, primary voids in the hydrocarbon. GSC photo 202097.

It is of interest to know that the sample of auriferous radioactive hydrocarbon comes from the discovery site of the first gold mine in Ontario.

H. G. Vennor (ref. 3) visited the area in 1866 and wrote a short report on the gold discoveries near Eldorado, Ontario. Extracts of this report are of interest since they predate radioactivity. Vennor was aware that he was dealing with an auriferous hydrocarbon, but he had no idea that it also contained the radioactive element uranium. He says,

> "In the early part of August, 1866, while exploring in the neighborhood of Bannockburn village, in the township of Madoc, I was informed that a metal, suspected to be gold, had just been taken from an opening in the eighteenth lot of the fifth range of the township, on the property of Mr. J. Richardson. A visit was at once made to the locality, and the lot was found to be the same as that on which openings had previously been made for copper ore, described in Mr. Macfarlane's Report of 1866, (p. 106). Mr. Richardson informed me that a person named Powell, and an old Dutch miner, had lately found flakes of yellow metal resembling copper which he could beat out into thin leaves. At my request he showed me the specimens which he had collected, and I at once informed him that the metal was gold".
>
> "The opening from which it had been taken was on the east end of the lot, the copper veins being near the south-west corner; and in it an irregular layer of chloritic and epidotic gneiss was overlaid by a silicious ferruginous dolomite, and underlain by a band resembling an impure steatite, the whole dipping N. 5° E. <45°. The seat of gold

appeared to be a crevice of longitudinal ovoid form, about four feet below the surface, which was filled with reddish-brown ferruginous earth, in which were scattered fragments of a black carbonaceous matter, the latter shewing, when broken, small flakes or scales of the metal. The crevice seemed to be in the schist, at its junction with the dolomite, and presented an attitude conformable with the stratification. This I believe to have been the earliest discovery of the metal, and samples were procured and sent to the Geological Survey office long before any reports were generally circulated as to its existence in the township. Having remained in the vicinity of the opening for a few days while some fresh blasts were made, and seeing no further development of the precious metal, my general exploration was continued".

Later Vennor returned to the property after hearing of further discoveries of gold. He reported:

"Early in October, however, information was brought to me that further discoveries of gold had been made on the Richardson lot, and returning, I found that at the depth of fifteen feet another open crevice had been struck, which, beyond doubt, had proved rich in the metal. By permission of Mr. Richardson, I examined the opening, and took such samples for assay as were thought proper. The shaft, to the depth of fifteen feet, with a transverse measure of about seven feet, had been sunk the whole way on the slope of the strata, which were of the same character as those already described. The chloritic and epidotic gneiss appeared to be much intermingled with calcspar and bitter-spar, which ran in short lenticular interlocking patches, each an inch or so thick, in a total width of about eighteen inches at right angles to the stratification, and in place of them there were occasionally small openings partially filled with the ferruginous earth, in several of which gold was detected. The opening at the bottom, which was of a nearly circular shape on the plane of the bed, and about eighteen inches across the stratification, appeared to include the whole thickness of the band holding the smaller dolomitic patches and cavities above. It was partially filled with the same brown ferruginous earth as before mentioned, with which black carbonaceous matter was much intermingled. In some parts of the opening this black substance appeared to adhere to the chloritic schist, and in others to the dolomite".

"From this opening (Now known as the Phoenix Mine, 1970) I extracted about three pints (by measure) of the ferruginous carbonaceous earth, and the following were the results of some very rude experiments tried on the spot. Taking a pint of the earth, just as it came from the opening, it was reduced by washing to one-half its bulk, and when dry the residue was pulverized. Spreading the latter in a shallow tray the lighter substances were removed by continued shaking and gentle blowing, and there remained a dark colored gold dust, in which were a few angular fragments weighing from one to three-and-a-half grains each. The whole of this dust weighted fifteen pennyweights; but there can be little doubt that by the rough method used a considerable amount must have been lost. In a second experiment two-and-a-half pints gathered by me, yielded, by a rude washing and amalgamation, twenty-six pennyweights of pure gold. Rough as these experiments were, they afforded sufficient proof of the unusual richness of the deposit. At this time no trace of the metal was observed in the enclosing rock, but shortly afterwards some very beautiful and rich specimens from the same opening were shewn me, in which the gold was enclosed in the dolomite and calcspar".

In his summary of occurrences Vennor found two localities where the hydrocarbons occurred as follows:

Madoc Range IV lot 18	Gold in cavities with ferruginous earth and carbonaceous matter resulting from the decomposition of small interposed layers or irregular veins of bitter-spar, etc., between layers of chloritic and epidotic gneiss, and also of dolomite, in which latter rock also gold is sometimes seen.
Madoc Range V lot 18	Gold in the same conditions as before. This is the Richardson mine, and in this and the previous locality the stratigraphical place of the gold is in the same relation to the iron ore of the seventeenth lot of the fifth range of Madoc as it was to the Marsh iron ore in the previous instances.

Thucholite is also recorded from the Box Mine, an inactive gold producer in the Beaverlodge area, Saskatchewan (ref. 4, p. 80). A sample of this material on file in the Geological Survey's ore collection carries no visible gold but in polished section it is seen to contain numerous scattered grains of urania quite like those of the Richardson sample, with a little galena and pyrite.

[1] Liebenberg, W.R.: The occurrence and origin of gold and radioactive minerals in the Witwatersrand System, the Dominion Reef, the Ventersdorp Contact Reef, and the Black Reef; Trans. Proceed. Geol. Soc. South Africa, v. LVIII, p. 101-254 (1955).

[2] Ellsworth, H.V.: Rare-element Minerals of Canada; Geol. Surv. Can., Econ. Geol. Ser., no. 11 (1932).

[3] Vennor, H.G.: Geol. Surv. Can., Report of Progress from 1866-1869, p. 165-171 (1870).

[4] Lang, A.H.: Canadian Deposits of Uranium and Thorium; Geol. Surv. Can., Econ. Geol. Ser. no. 16 (1952).

146. A URANIUM OCCURRENCE IN PALEOZOIC ROCKS WEST OF OTTAWA

Project 720084

R.L. Grasty*, B.W. Charbonneau* and H.R. Steacy**

In October 1972, a random series of gamma-ray spectrometer profiles were flown over southern Ontario. These profiles were preliminary base level flights for an experimental airborne snow survey[1], to be carried out in the winter of 1972/73 in conjunction with the Department of the Environment and various provincial agencies and universities.

The radiation levels over the Paleozoic rocks were generally low and showed little variation compared to those over typical Shield areas. However, one profile showed an unexpected uranium anomaly on the Paleozoic rocks near South March, west of Ottawa. The northern extent of this particular flight line and the location of the anomaly (marked by an X) are indicated on the accompanying geological map of the area. A computer plotted profile over the anomalous zone is also shown. The profile shows:

(i) Integral counts per 0.5 secs (0.41 to 2.81 MeV)
(ii) Potassium counts per 2.5 secs (1.37 to 1.57 MeV); 1% K≃150 counts
(iii) Uranium counts per 2.5 secs (1.66 to 1.86 MeV); 1 ppm eU≃24 counts
(iv) Thorium counts per 2.5 secs (2.41 to 2.81 MeV); 1 ppm eTh≃9 counts
(v) Uranium/thorium counts
(vi) Uranium/potassium counts
(vii) Thorium/potassium counts

plotted against distance along the flight line, each measurement of items (ii) to (iv) being accumulated over a distance of approximately 500 feet. All count rates have been corrected for atmospheric background radiation, Compton scattering in the crystals and deviations from the nominal flying height of 500 feet. The ratio plots (v) to (vii) are the ratios of the corrected count rates and accentuate any unusual relative enrichment of the radio-elements. Thus the high uranium/thorium and uranium/potassium ratios are possible indicators of uranium mineralization. Since the uranium/thorium ratio over the anomalous zone is one of the highest that has been found by the Geological Survey airborne gamma-ray spectrometer over uncontaminated surface material, a preliminary ground investigation was carried out.

The anomalous zone lies entirely in an area mapped as March Formation[2], close to the boundary of the Nepean Formation. It is approximately 2,000 feet long by 500 wide and strikes in a direction slightly east of north, almost parallel to the aircraft flight line and approximately at right angles to the strike of the geological formations in the area. Total surface radioactivity measured with a total flux ratemeter, averages 50 to 10 times normal levels on overburden. Maximum values on frost-heaved blocks which were apparently in place indicated 90 ppm eU and 10 ppm eTh using a field gamma-ray spectrometer. Laboratory analysis of a composite sample of the outcrop material by the Earth Physics Branch using a solid-state Ge-Li detector gave values of 175 ppm eU (.02% U_3O_8) and 3.5 ppm eTh indicating a uranium:thorium ratio of 50:1.

The specimens examined in the laboratory were of a greyish carbonate rock composed of subangular fragments of a sandy dolomite and rounded grains of quartz in a calcite matrix. The rock may represent an interphase,

*Resource Geophysics and Geochemistry
**Central Laboratories and Technical Services

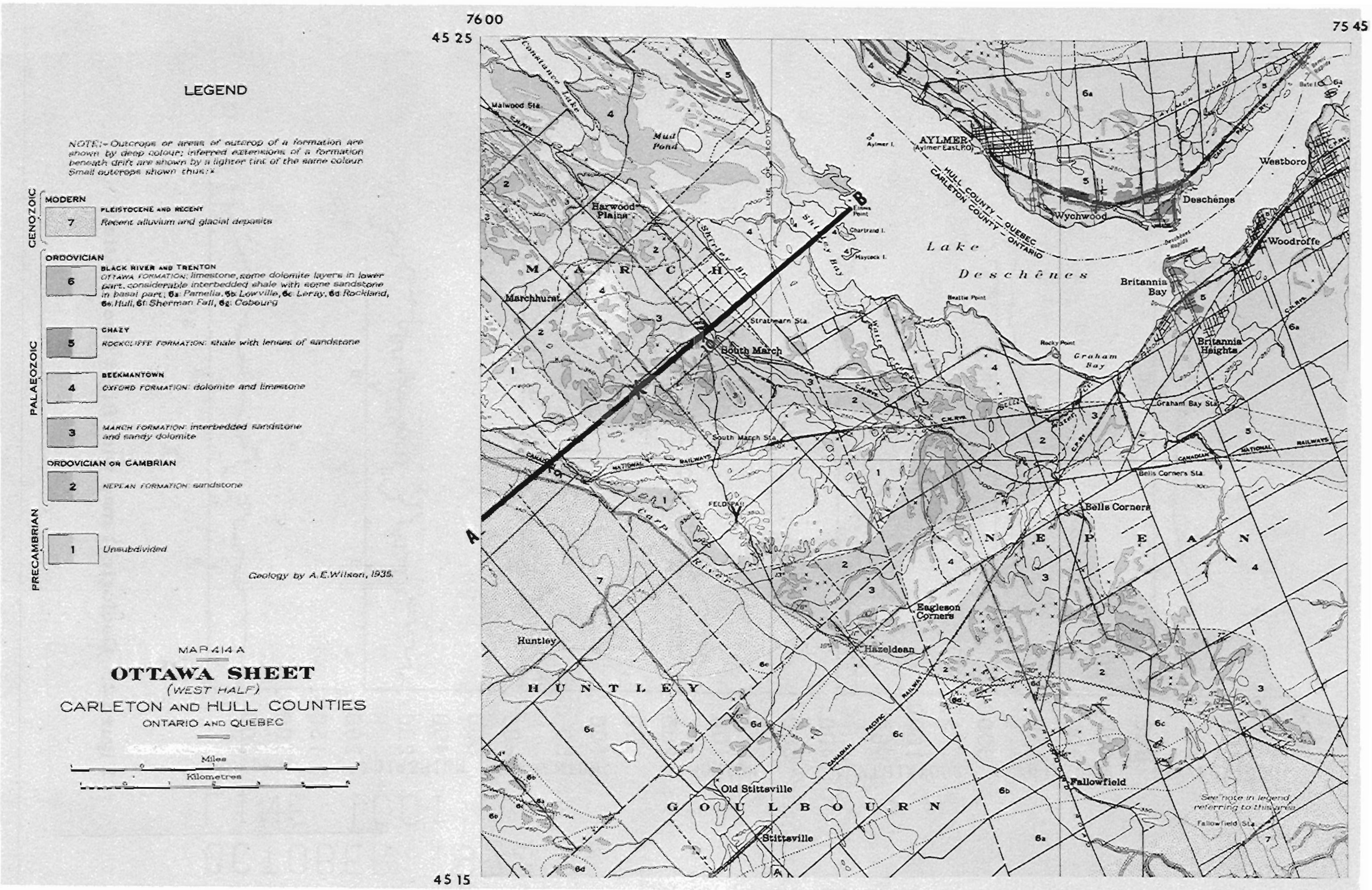


Figure 1. Computer plotted profile over anomalous zone.

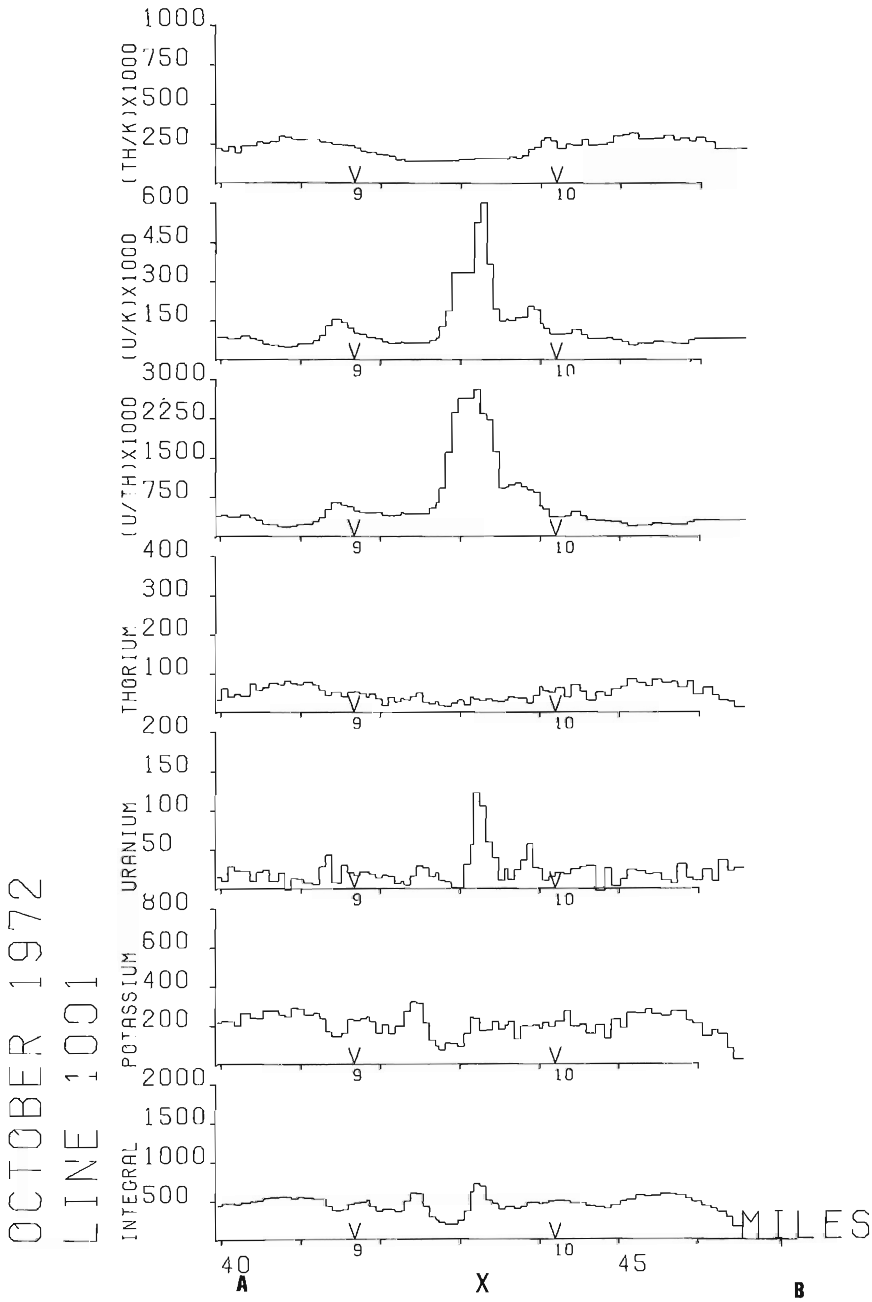


Figure 2. Geological map with flight line location.

or a locally deformed, granulated and re-cemented phase of the March Formation. The two carbonates are macrocrystalline with cleavage faces, particularly of the calcite, being readily discernible in hand specimen. Accessory minerals recognized in the rock include pyrite, chalcopyrite, apatite and zircon. A few rounded grains of feldspar were also noted. The pyrite appears to be chiefly detrital. Chalcopyrite, however, appears to be late, and here and there gives rise to microscopic stains of malachite. Attempts to define the sources of the radioactivity were not possible in the time available. Autoradiographs were made of several large polished sections but the exposure period available was too short to produce pronounced patterns to work from. Nevertheless the faint reflections obtained on the autoradiographs indicate the radioactivity to be associated in part with discrete mineral grains of microscopic size; in part with fractures which, for the most part, border rather than transect the clastic particles and which appear to be related to partings; and in part to other finely divided forms that appear as 'wisps' on the autoradiographs. Apatite and zircon, which are both normally weakly radioactive, would account for at least part of the radioactivity of the rock. However, the high uranium/thorium ratio and autoradiographic patterns suggest other forms as well. This is currently under study. Finally it may be noted that a uraninite-bearing pegmatite occurs nearby[3] at locality Y (Fig. 2). Field gamma-ray spectrometer analysis of biotite rich zones in the pegmatite yielded maximum values of 210 ppm eU and 70 ppm eTh. This pegmatite and possibly other pegmatites of Precambrian age may be a local source for the uranium. There remains the possibility that uranium occurrences in the Paleozoic rocks of the Ottawa-St. Lawrence Lowlands may be more widespread.

[1] Grasty, R.L. and Holman, P.B.: The measurement of snow-water equivalent using natural gamma-radiation. First Canadian Symposium on Remote Sensing (1972).

[2] Wilson, A.E.: Geology of the Ottawa-St. Lawrence Lowland, Ontario and Quebec; Geol. Surv. Can., Mem. 241 (1946).

[3] Lang, A.H.: Canadian Deposits of Uranium and Thorium; Geol. Surv. Can. Econ. Geol. Ser. No. 16 (1952).

147. PREPARATION OF COLLECTIONS OF CANADIAN ROCKS AND MINERALS FOR DISTRIBUTION TO THE PUBLIC

Project 400006

J.M. Larose
Central Laboratories and Technical Services Division, Ottawa

From May 18 to September 29, more than 28 tons of rocks, minerals, ores and fossils used in various collections produced by the Geological Survey of Canada have been collected from 85 localities in British Columbia, Northwest Territories, Alberta, Saskatchewan, Manitoba, Ontario and Quebec. Over 18,000 miles have been covered. During the field season, I was ably assisted by Mr. B. Machin from the Mineral Separation Unit.

148. MINERAL OCCURRENCES, BRITISH COLUMBIA AND YUKON

Project 490038

S. Leaming
Regional and Economic Geology Division, Vancouver

During the season three separate trips totalling 35 days were made to four jade properties, four producing mines, three inactive mines and several deposits of talc, fluorite, and stibnite.

The first trip of the season was made to Bridge River area which remains the most accessible and active area for jade producers. Birkenhead Jade Mines Limited spent about two months near their main deposit trying to locate further extensions of the lode which has been largely depleted. Greenbay Mining Co. Ltd., has uncovered further extensions to their deposit on Brett Creek in the Marshall Creek area. Two pods of jade-bearing alteration along the contact between chert and serpentine have a potential of 110 tons of which probably one fifth or less is saleable jade.

The second field trip was made to northern British Columbia and southern Yukon Territory and included a visit to the resident geologist's office, Indian Affairs and Northern Development in Whitehorse. Minerals were collected at New Imperial Mines near Whitehorse and included valleriite and thulite. A number of skarn minerals such as epidote, garnet, tremolite, etc. were also obtained. A side trip to Atlin provided molybdenite specimens from the Adanac property and from Interprovincial Silver Mines. The Venus Mines property was also visited and samples of ore and host rock were collected. A trip to Cassiar Asbestos Ltd. provided specimens of asbestos and specimens and photographs of the jade occurrence in the open pit. At Dease Lake, the opportunity to visit Wheaton Creek jade placer was afforded through the courtesy of Mr. G. Davis who formerly held leases there. The jade property of Mr. Ben Seyward was visited and a jade deposit in situ was mapped and photographed. Specimens were collected from the jade lode and wall rocks. The mill site of Churchill Copper south of the Alaska Highway yielded some specimens of ore but access to the mine was not possible because of closure. Rocks and fossils were collected from various localities on Alaska and Hart Highways. Specimens of cinnabar and stibnite were collected at Pinchi Lake Mercury Mine and several specimens of ore and alteration rocks were collected at Gibraltar Mines Ltd.

The last trip of the season was made to Bridge River area. International Jade which adjoins the Greenbay Property were preparing to develop jade occurrences with the view to using large quantities of non-gem quality jade as decorative stone and tiles in the construction industry. Connaplex Oil has provided funds for this purpose and the work was scheduled to start in October and continue as long as practical into the winter. The Cayoosh Creek forest access road which runs from Lillooet to the public highway at Mount Currie, 5 miles east of Pemberton affords access to the area.

149. STUDY OF MINERAL COLLECTING AREAS OF INTEREST TO COLLECTORS AND TOURISTS

Project 640048

Ann P. Sabina
Central Laboratories and Technical Services Division, Ottawa

Occurrences of minerals and rocks were investigated in the area between Val d'Or, Quebec and Timmins, Ontario in order to obtain up-to-date information on collecting localities of interest to tourists, collectors and mineralogists. A guidebook with descriptions of the localities and directions to reach them is being prepared.

Most of the collecting sites are in inactive mines and prospects. Access to the surface workings and/or dumps of most active mines is permitted and in some centres such as Timmins, Cobalt, Kirkland Lake, Noranda, and Val d'Or, tours to operating mines can be arranged through the local Chambers of Commerce. Most of the mines in the area provide a variety of metallic minerals both rare and common. Nonmetallic minerals include beryl, spodumene, pollucite, fluorite, asbestos, and talc. Associated with the deposits are rocks such as porphyries, syenites, soapstone and iron formation that are suitable for lapidary purposes.

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150. NATIONAL MINERAL COLLECTION

Project 550101

H. R. Steacy
Central Laboratories and Technical Services Division, Ottawa

H.R. Steacy, in collaboration with D.D. Hogarth, University of Ottawa, Louis Moyd, National Museum of Natural Sciences, and E.R. Rose, completed field work and planning for Excursions A-47 and C-47a of the International Geological Congress and subsequently led both excursions on their scheduled examination of 34 classic mineral collecting localities in Ontario and Quebec[1]. Site-preparation was carried out at a number of localities to facilitate the collection of specimens, primarily for the excursions but also on a retrieval basis for the National Mineral Collection.

[1] Hogarth, D. D., Moyd, L., Rose, E. R., and Steacy, H. R.: Classic Mineral Collecting Localities in Ontario and Quebec; Guidebook for Field Excursion A47-C47a, XXIV International Geological Congress, Canada.

AUTHOR INDEX

	Page		Page
Aitken, J.D.	243	Fenton, M.M.	194
Allan, R.J.	50, 58	Forbes, D.L.	182, 189
Alley, N.V.	188	Foscolos, A.E.	243
Anderson, F.D.	2	Foster, J.	136
Anderson, T.W.	178	French, H.M.	220
Balkwill, H.R.	247	Frisch, T.	145
Barnett, D.M.	182, 189	Frith, R.A.	146
Bazeley, P.	86	Fritz, W.H.	254
Becker, A.	67	Froese, E.	139
Bender, K.P.	251	Fulton, R.J.	188, 194, 212
Blusson, S.L.	17	Gadd, N.R.	183
Bostock, H.H.	2	Good, R.	86
Bower, M.E.	84	Grant, D.R.	196
Boydell, A.N.	239	Grasty, R.L.	82, 286
Boyle, R.W.	282	Grosswald, M.G.	199
Brideaux, W.W.	252	Hacquebard, P.A.	15
Bristow, Q.	53	Harris, I.M.	109
Broughton, P.	15	Harrison, J.E.	184
Brown, A.	143	Haworth, R.T.	111, 112
Buckley, D.E.	104	Heginbottom, J.A.	225, 226
Burns, R.A.	86	Henderson, E.P.	200
Cameron, B.E.B.	19	Henderson, J.B.	148
Cameron, E.M.	50	Hills, L.V.	202
Campbell, F.H.A.	141	Hobson, G.D.	83, 88
Campbell, R.B.	21	Hodgson, D.A.	185, 203
Chamney, T.P.	253	Hoffman, P.F.	151
Chandler, F.W.	162	Hood, P.J.	84, 95
Charbonneau, B.W.	67, 286	Hornbrooke, E.H.W.	56
Christie, K.W.	135	Horton, R.E.	63
Code, J.A.	224	Hughes, O.L.	229
Cranston, R.E.	107	Hunter, J.A.	86
Cumming, L.M.	5	Hutcheon, I.	139
Currie, K.L.	138	Hutchison, W.W.	42
Darnley, A.G.	79	Irvine, J.A.	15
Davis, J.B.	205	Isaacs, R.M.	230
Dean, W.T.	253	Jeletzky, J.A.	259
Dodds, C.J.	38	Jonasson, I.R.	58
Domansky, J.L.	236	Katsube, T.J.	87
Dredge, L.	192	Keeler, K.	86
Durham, C.C.	50	Keen, C.E.	112
Dyck, A.V.	81	Kerr, J.Wm.	262
Dyck, W.	54	Killeen, P.G.	88
Eckstrand, O.R.	125	King, L.H.	113
Eisbacher, G.H.	24	Kirkham, R.V.	126
Emslie, R.F.	139	Klassen, R.W.	204
Ermanovics, I.F.	143	Knight, I.	156
Fader, G.B.	113	Kornik, L.J.	90
Fahrig, W.F.	135	Kurfurst, P.J.	226

	Page
Lalonde, J-P.	57
Lambert, M.B.	148
Larochelle, A.	93
Larose, J.M.	289
Lawrence, D.E.	231
Leaming, S.	290
Lewis, C.F.M.	205
Lewis, C.P.	233
Lynch, J.J.	63
Mackay, J.R.	232
MacKenzie, W.S.	263
MacLean, B.	113
Macqueen, R.W.	243
Mathews, W.H.	210
Miller, A.R.	125
Minning, G.	236
Monger, J.W.H.	27
Morgan, W.C.	162
Morrow, D.W.	262
Mossop, G.D.	264
Mott, R.J.	180
Muller, J.E.	29
Mulligan, R.	127
McDonald, B.C.	233
McGlynn, J.C.	136
McGrath, P.H.	90
Netterville, J.A.	204
Okulitch, A.V.	21
Olson, D.W.	95
Owen, E.B.	236
Pilon, J.	229
Peeling, G.R.	148
Pelletier, B.R.	115
Poulton, T.P.	268
Rampton, V.N.	237
Reesor, J.E.	38
Reinhardt, E.W.	162
Rennie, J.A.	236
Richards, T.A.	38
Richardson, K.A.	94
Ridler, R.H.	165
Rimsaite, J.Y.H.	131
Roddick, J.A.	42

	Page
Rose, E.R.	128
Rosnuk, L.	86
Ross, D.R.	116
Roy, K.J.	269
Rutter, N.W.	239
Ryder, J.M.	212
Sabina, A.P.	291
Sangster, D.F.	129
Savigny, K.W.	262
Sawatzky, P.	95
Schafer, C.T.	117
Schau, M.	175
Schwarz, E.J.	137
Scott, J.S.	186
Scott, W.J.	97
Shearer, J.M.	242
Shilts, W.W.	213
Sinha, A.K.	67
Skinner, R.G.	218
Slaney, V.R.	98
Smyth, W.R.	8
Souther, J.G.	46
Srivastava, S.P.	118, 119
Steacy, H.R.	282, 286, 291
Stevens, R.D.	65
Stevens, R,K.	8
St-Onge, D.A.	185
Tempelman-Kluit, D.J.	48
Tiffin, D.L.	120, 121
Timperley, M.H.	58, 63
Trettin, H.P.	273
Uyeno, T.T.	277
van der Linden, W.J.	121
Veillette, J.	229
Vilks, G.	122
Walker, D.A.	123, 124
Wanless, R.K.	65
Washkurak, S.	98, 101
Whitaker, G.H.	15
Williams, H.	8
Woodworth, G.J.	44
Wootton, A.E.	205
Young, F.G.	277

LOCATION INDEX

	Report Numbers
Atlantic Ocean	46, 49, 51, 56, 60, 62
Arctic Ocean	53, 54, 58, 61
Pacific Ocean	57, 59
Alberta	5, 29, 94, 119, 132, 134
British Columbia	5, 8, 9, 10, 11, 12, 13, 14, 15, 16, 39, 65, 68, 69, 90, 94, 98, 110, 111, 132, 136, 140, 148
District of Franklin	31, 32, 81, 92, 95, 99, 104, 106, 107, 114, 129, 130, 137, 139, 141, 142, 143
District of Keewatin	25, 39, 79, 81, 87, 88, 89
District of Mackenzie	7, 18, 28, 30, 35, 39, 40, 43, 66, 69, 74, 82, 83, 84, 115, 116, 117, 120, 121, 123, 124, 126, 127, 128, 131, 133, 135, 138, 143
Manitoba	29, 40, 78, 80, 91, 101, 108
New Brunswick	34, 41, 42, 67
Newfoundland	1, 2, 3, 4, 21, 48, 49, 50, 51, 52, 70, 76, 77, 85, 86, 103, 134, 135
Nova Scotia	34, 42, 46, 63
Ontario	22, 28, 29, 37, 38, 39, 41, 44, 64, 65, 66, 73, 75, 97, 105, 108, 109, 113, 143, 145, 146
Quebec	27, 28, 37, 39, 55, 72, 77, 86, 91, 93, 96, 97, 100, 112, 134, 149
Saskatchewan	5, 6, 40
Yukon Territory	7, 17, 33, 66, 69, 118, 122, 125, 144, 148
General	19, 20, 22, 23, 24, 26, 36, 44, 45, 71, 75, 147, 150

PROJECT NUMBER INDEX

Project No.	Page	Project No.	Page
400006	289	690075	19
490038	290	690095	213
530014	127	700015	148
540028	65	700023	94
550101	291	700025	48
580175	63	700026	46
610269	15	700046	58
630016	42	700049	186
630031	98	700052	165
630037	125	700053	194
630049	87	700054	137
640004	202, 220	700059	126
640048	291	700060	263
650007	84	700064	253
650024	254	700065	139
650056	129	700067	131
650438	282	700068	277
660009	151	700087	53
660026	277	700089	98
660043	81	700090	101
670003	139	700092	242
670016	262	700093	200
670028	128	700094	230
670031	191	710003	247
670041	97	710007	264
670064	259	710012	162
670068	243	710015	268
680012	136	710019	252
680037	86	710020	229
680047	232	710025	143
680055	205	710041	189
680071	138	710042	182
680081	95	710044	185
680089	67	710045	2
680101	277	710047	239
680102	15	710049	120
680119	17	710060	251
680130	2	710069	269
690006	253	710077	226
690032	24	710080	218
690045	218	710081	183
690047	237	710082	236
690054	225	710083	192
690064	178, 180	710085	210
690066	93	710089	15
690068	93	710091	15
690072	93	710092	204
690073	93	710096	88

Project No.	Page	Project No.	Page
710097	88	720062	175
720004	188	720063	50
720005	83	720067	54
720024	162	720068	224
720028	196	720070	145
720036	56	720071	67, 79, 94
720037	21	720073	15
720038	38	720074	29
720041	27	720075	135
720042	252	720076	5
720046	136	720079	233
720047	273	720080	90
720048	156	720081	203
720052	146	720082	185
720053	38	720083	184
720054	141	720084	82, 286
720055	135	720085	231
720056	135	720086	236
720057	194	720092	57
720058	212	720093	8