Preliminary interpretations of detailed mapping in the Chilcotin Group, Chasm Provincial Park, British Columbia

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2008

Geological Survey of Canada
Current Research 2008-13

Natural Resources Canada
Ressources naturelles Canada

Canada

ISSN 1701-4387
Catalogue No. M44-2008/13E-PDF
ISBN 978-0-662-48919-1

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Toll-free (Canada and U.S.A.): 1-888-252-4301

Recommended citation

Farrell, R.-E., Simpson, K.A., Andrews, G.D.M., Russell, J.K., and Anderson, R.G., 2008. Preliminary interpretations of detailed mapping in the Chilcotin Group, Chasm Provincial Park, British Columbia; Geological Survey of Canada, Current Research 2008-13, 11 p.

Critical reviewer
M. Kelman

Authors
R.-E. Farrell (rfarrell@eos.ubc.ca)
G.D.M. Andrews (gandrews@eos.ubc.ca)
J.K. Russell (krussell@eos.ubc.ca)
Department of Earth and Ocean Sciences
The University of British Columbia
6339 Stores Road
Vancouver, BC V6T 1Z4

K.A. Simpson (ksimpson@eos.ubc.ca)
Mineral Deposits Research Unit
Department of Earth and Ocean Sciences
The University of British Columbia
6339 Stores Road
Vancouver, BC V6T 1Z40

R.G. Anderson (boanders@nrcan.gc.ca)
Geological Survey of Canada
625 Robson Street
Vancouver, BC V6B 5J3

Correction date:

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Abstract: Within Chasm Provincial Park, the Chilcotin Group basalt overlies rocks of the Permian Cache Creek Group, the Eocene Kamloops Group, and the Miocene Deadman River Formation. Detailed mapping of the Chilcotin Group has identified a variety of subaqueous and subaerial volcanic and sedimentary facies. Within the coherent rocks, three distinct facies have been described, 1) plagioclase-phyric basalt (Pp), 2) aphyric columnar-jointed basalt (Ac), and 3) aphyric massive basalt (Am). All coherent facies are interpreted as subaerial, flat-lying basalt lavas. Clastic facies include pillow-fragment breccia (Pf) and sandstone-to-breccia (Sb). The presence of intact pillows, pillow fragments, and hyaloclastite within the pillow-fragment breccia facies provides evidence for a local subaqueous environment. The sandstone-to-breccia units occur between the coherent lava units and are interpreted as paleosols that represent volcanic hiatuses during emplacement of the Chilcotin Group lavas.

Résumé : Dans le parc provincial Chasm, le basalte du Groupe de Chilcotin repose sur des roches du Groupe de Cache Creek du Permien, du Groupe de Kamloops de l'Éocène et de la Formation de Deadman River du Miocène. La cartographie détaillée du Groupe de Chilcotin a permis de reconnaître divers faciès volcaniques et sédimentaires subaquatiques et subaériens. Trois faciès distincts ont été reconnus parmi les roches cohérentes, soit du basalte à phénocristaux de plagioclase (Pp), du basalte prismé aphyrique (Ac) et du basalte massif aphyrique (Am). Tous les faciès cohérents sont considérés comme des laves basaltiques horizontales subaériennes. Les faciès clastiques comprennent une brèche à fragments de coussins (Pf) et un faciès allant du grès à de la brèche (Sb). La présence de coussins intacts, de fragments de coussins et d'hyaloclastite dans la brèche à fragments de coussins témoigne d'un milieu subaquatique localisé. Les unités allant du grès à de la brèche se trouvent entre les unités de laves cohérentes et sont considérées comme des paléosols représentant des hiatus survenus lors la mise en place des laves du Groupe de Chilcotin.

INTRODUCTION

Basaltic rocks of the Neogene Chilcotin Group cover 55 500 km² of the Intermontane Belt of the Canadian Cordillera (NTS sheets 92-O and P, 93 A, B, C, F, G, J, and K) in south-central British Columbia (Fig. 1). The Chilcotin Group unconformably overlies Paleozoic, Mesozoic, and Paleogene basement rocks that elsewhere in the region host economic Cu-Ag-Mo deposits. Exposures of the basement through the basalt cover are limited to isolated inliers (typically <50 km²), and the thickness of the Chilcotin Group cover is poorly constrained in most areas.

Previous studies of the Chilcotin Group involved mainly reconnaissance-scale fieldwork or geochemical studies (e.g. Mathews and Rouse 1963, 1986; Tipper 1978; Bevier 1983; Mathews, 1989; Dostal et al., 1996; Anderson et al., 2001). Recent work has recognized that the thickness of the Chilcotin Group (Andrews and Russell, 2007, 2008; Mihalynuk, 2007) and the styles of volcanism (Gordee et al., 2007; Farrell et al., 2007) vary significantly and that rather than being a relatively homogeneous sheet, the Chilcotin Group is spatially and compositionally complex.

This article presents new mapping that was undertaken in Chasm Provincial Park. It includes a detailed map of the Chasm area (Fig. 2), a stratigraphic section through the best exposure of Chilcotin Group basalt, and new

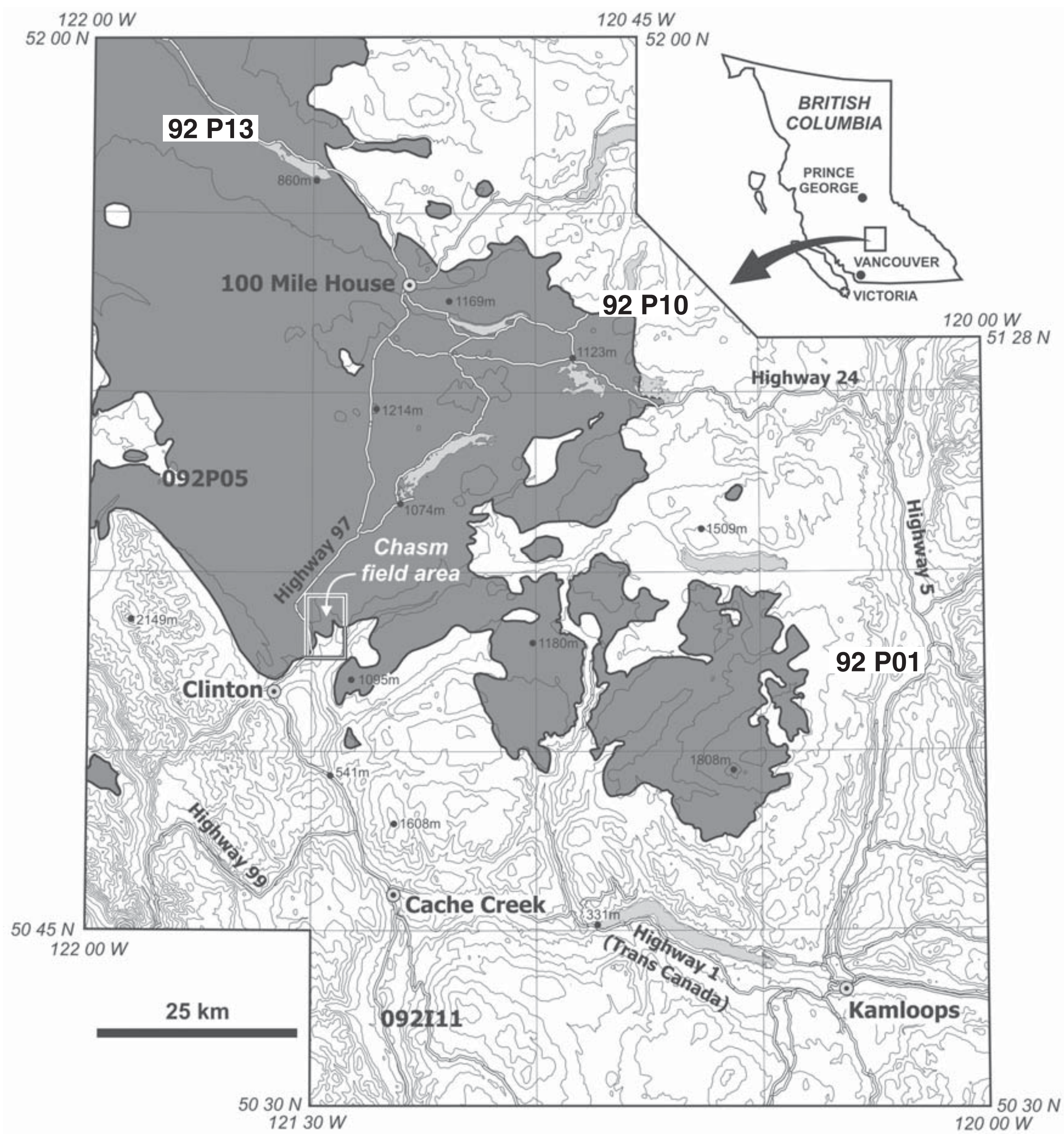

Figure 1. Simplified geological map of the southern Interior Plateau region, including the Chasm study area (outlined). The distribution of the Chilcotin Group basalt is represented in dark grey.

facies descriptions and interpretations (Table 1). The previously published study by Farrell et al. (2007) has been reinterpreted on the basis of this new mapping.

The work presented here is part of a larger research project whose object is to understand the physical volcanology of the Chilcotin Group using a variety of methods, including detailed mapping to determine the relationships between basaltic cover rocks and underlying basement rocks, identification and mapping of volcanic facies within the Chilcotin Group, compilation of existing geological maps to produce a new Chilcotin Group distribution map (J. Dohaney, G.D.M. Andrews, and J.K. Russell, work in progress, 2008), evaluation of water-well records to systematically plot the thickness of the Chilcotin Group beneath the Quaternary cover (Andrews and Russell, 2008), and physical rock property measurements of specific Chilcotin Group volcanic facies.

GEOLOGICAL SETTING

The study site is located within Chasm Provincial Park (NTS 92 P; Bonaparte Lake) in south-central British Columbia. It is situated on the southern margin of the Fraser Plateau, approximately 20 km north of the town of Clinton and 7 km east of Highway 97 (Fig. 1).

The most recent geological mapping of the Chasm area was by Campbell and Tipper (1965) as a part of a regional mapping assessment of the Bonaparte map area (NTS map

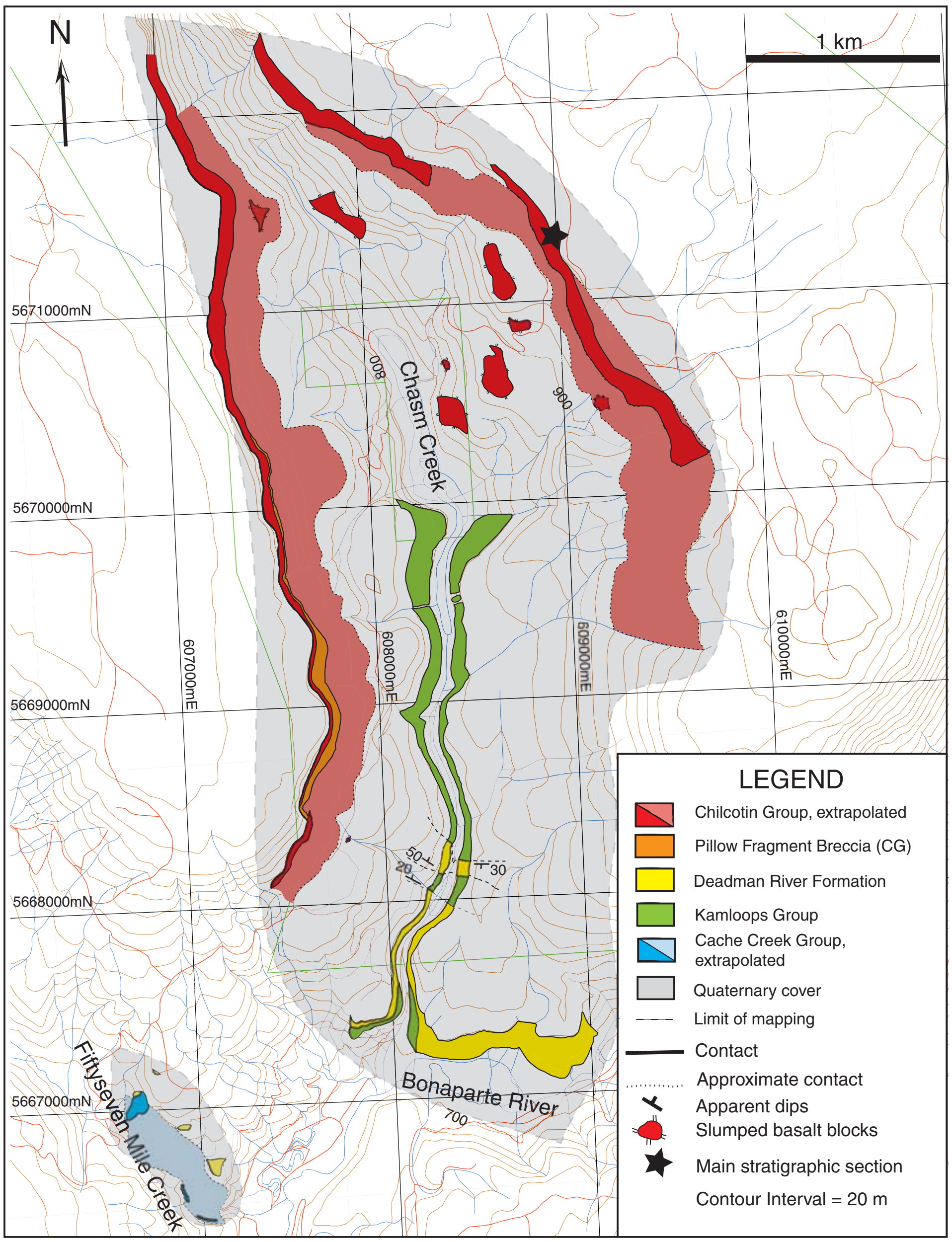

Figure 2. Preliminary geological map of the Chasm study area, near Clinton, British Columbia. The star shows the location of the graphic log illustrated in Figure 5. Units are extrapolated on the basis of topographic expression. The Chilcotin Group (red) forms the southern margin of an extensive plateau that has been incised by a number of steep-sided valleys and canyons, including the Chasm Creek canyon.

sheet 92 P, 1:250 000 scale). The bedrock geology of the Bonaparte map area is poorly exposed and the area hosts diverse lithostratigraphic units that include rocks ranging in age from the late Precambrian to the Neogene; a total of 29 different rock units have been identified in the Bonaparte map area, which are described in detail by Campbell and Tipper (1965). In the study area, the Chilcotin Group is underlain by rocks of the Upper Paleozoic Cache Creek Group, the Eocene Kamloops Group, and the Lower Miocene Deadman River Formation. A brief summary of the basement rocks to the Chilcotin Group in the Chasm area follows.

Campbell and Tipper (1965) described the Cache Creek Group in this area as a collection of greenstone, argillite, chert, and limestone units. Brachiopods and fusilinids were used to infer a Permian age for the rocks.

The Eocene Kamloops Group has been subdivided into two formations, the Chu Chua Formation and the Skull Hill Formation (Uglow, 1922; Cockfield, 1948; Mathews and Rouse, 1961, 1963). The Chu Chua Formation is a sedimentary succession consisting of conglomerate, arkose, and shale with coal seams. In contrast, the Skull Hill Formation consists of coarse, unsorted volcanic breccia, and dacite, trachyte, basalt, andesite, and rhyolite lavas have been mapped by Campbell and Tipper (1965).

The Deadman River Formation as defined by Campbell and Tipper (1965) and Read (1989) consists of cream to brown tuff, breccia, diatomite, siltstone, arenite, and conglomerate and is interpreted to have been deposited in a fluviolacustrine environment. The type locality is on the eastern shore of Skookum Lake in the Deadman River valley. Within Chasm Provincial Park, Campbell and Tipper (1965) identified three 'possible' exposures of Deadman River Formation, with the best outcrop located at the junction of Chasm Creek and the Bonaparte River. Sandstone and breccia units were mapped by Campbell and Tipper (1965) and interpreted to have been deposited as flat-lying units, with minor bedding dips attributed to postdepositional slumping or draping of paleotopography.

Table 1. Facies identified within the Chilcotin Group in the Chasm study area.

Facies	Characteristics	Thickness	Interpretation
Coherent units			
Amygdaloidal plagioclase - phyric basalt (Pp)	Dark grey, lobate structures, pipe vesicles common Phenocrysts: ~ 15% plagioclase Amygdales: spherical, 5-20%, < 1-2 mm Contacts: sharp	Individual emplacement units 10-15 m thick	Coherent component of subaerial lavas
Aphyric columnar-jointed basalt (Ac)	Dark grey or tan, commonly amygdaloidal and/or vesicular. Amygdales: spherical, 3-40%, < 1 mm Phenocrysts: olivine microphenocrysts Contacts: sharp	Individual emplacement units 5-20 m thick	Coherent component of subaerial lavas
Aphyric massive basalt (Am)	Dark grey, commonly amygdaloidal and/or vesicular, massive Amygdales: spherical, < 15% Contacts: sharp	Individual emplacement units ~ 7-10 m thick	Coherent component of subaerial lavas
Clastic units			
Pillow-fragment breccia (Pf)	Orange, massive, lensoidal, pillow fragments, intact basalt pillows Clasts: ~ 1-20 mm, angular to subangular, pillow fragments Matrix: angular, glassy basalt fragments, 1-20 mm Pillows: Average dimension 0.5 m, irregularly shaped, prismatically jointed with tiny normal joints around the periphery of pillow Contacts: irregular	~ 5-30 m for each lens	Subaqueously deposited, resedimented hyaloclastite and pillow lava
Sandstone to breccia (Sb)	Orange/red (Soil Referenced colour: 2.5 YR 5/8 "Red" (Horizon 1) to 7.5 YR 6/3 "Light Brown" (Horizon 4)) locally vesicular/ amgydaloidal, numerous cobble-sized basalt clasts set into the orange material Horizons: typically 1 to 5 separate horizons from 1 to 40 cm each, generally abrupt and irregular boundaries between horizons. Bedforms: can be thinly laminated; however bedding is not always present Contacts: gradational, irregular, forming sediment-infilled cracks	~ 0.5-3 m	Subaerial, product of weathering and erosion, soil development (paleosols)

STRATIGRAPHY OF THE CHASM CREEK CANYON AREA

Detailed field studies in 2006 and 2007 focused on Chilcotin Group rocks that overlie a varied basement sequence of Cache Creek Formation, Kamloops Group, and Deadman River Formation rocks (Fig. 2). The stratigraphic section, and in particular the Chilcotin Group units, are exposed in the walls of the Chasm Creek canyon (Fig. 3).

Cache Creek Group

Three outcrops of the Permian Cache Creek Group are located along Fiftyseven Creek (Fig. 2, 3). They consist of strongly folded calcareous phyllite (Fig. 4) and are locally unconformably overlain by rocks assigned to the Deadman River Formation. The Chasm Creek canyon area is considered to be the western extent of the Cache Creek Formation (Campbell and Tipper, 1965).

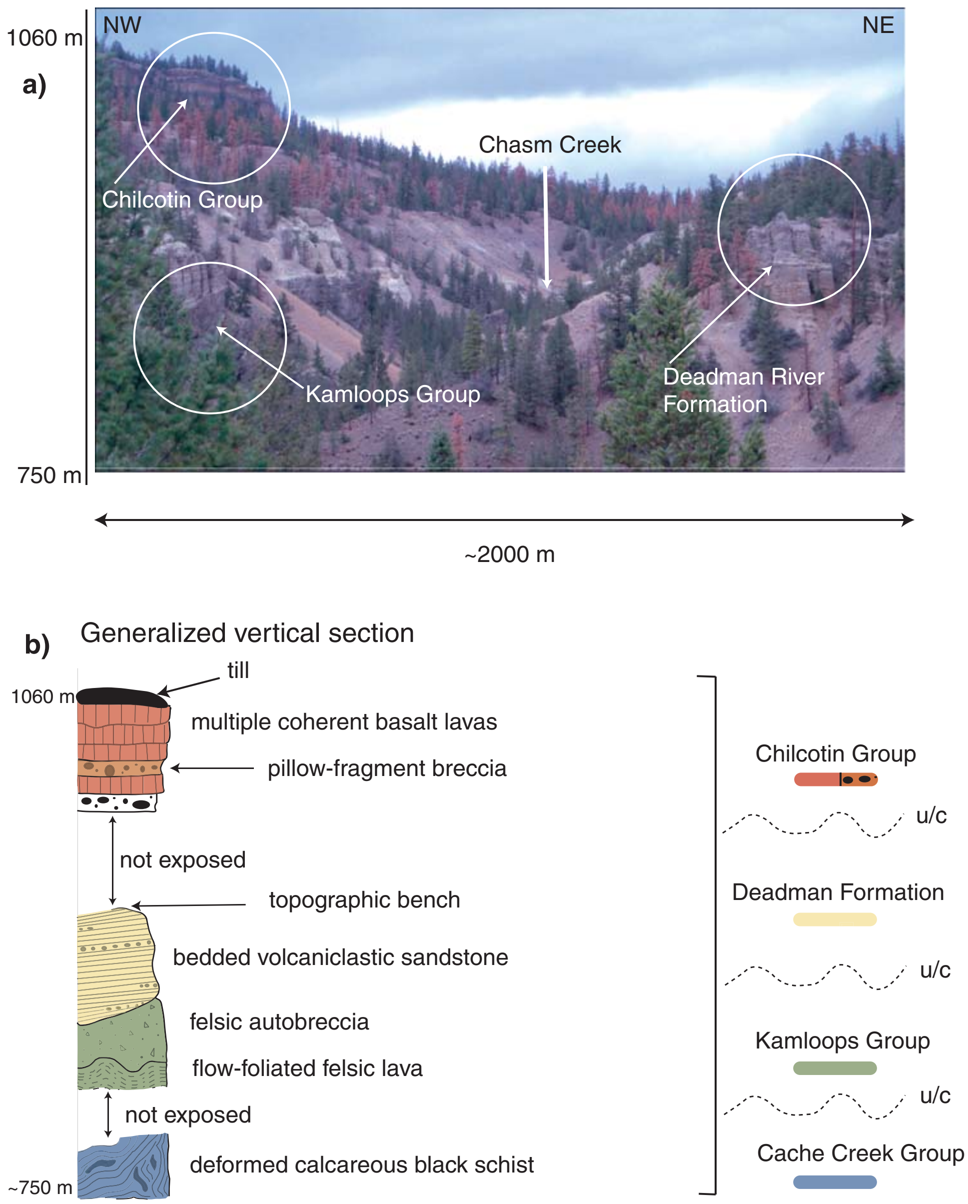

Figure 3. a) Photograph looking north along Chasm Creek showing three of the four rock formations present in the area. Photograph by R.-E. Farrell **b)** Schematic generalized vertical section summarizing the stratigraphy present in the Chasm study area. Unconformities are labeled as u/c.

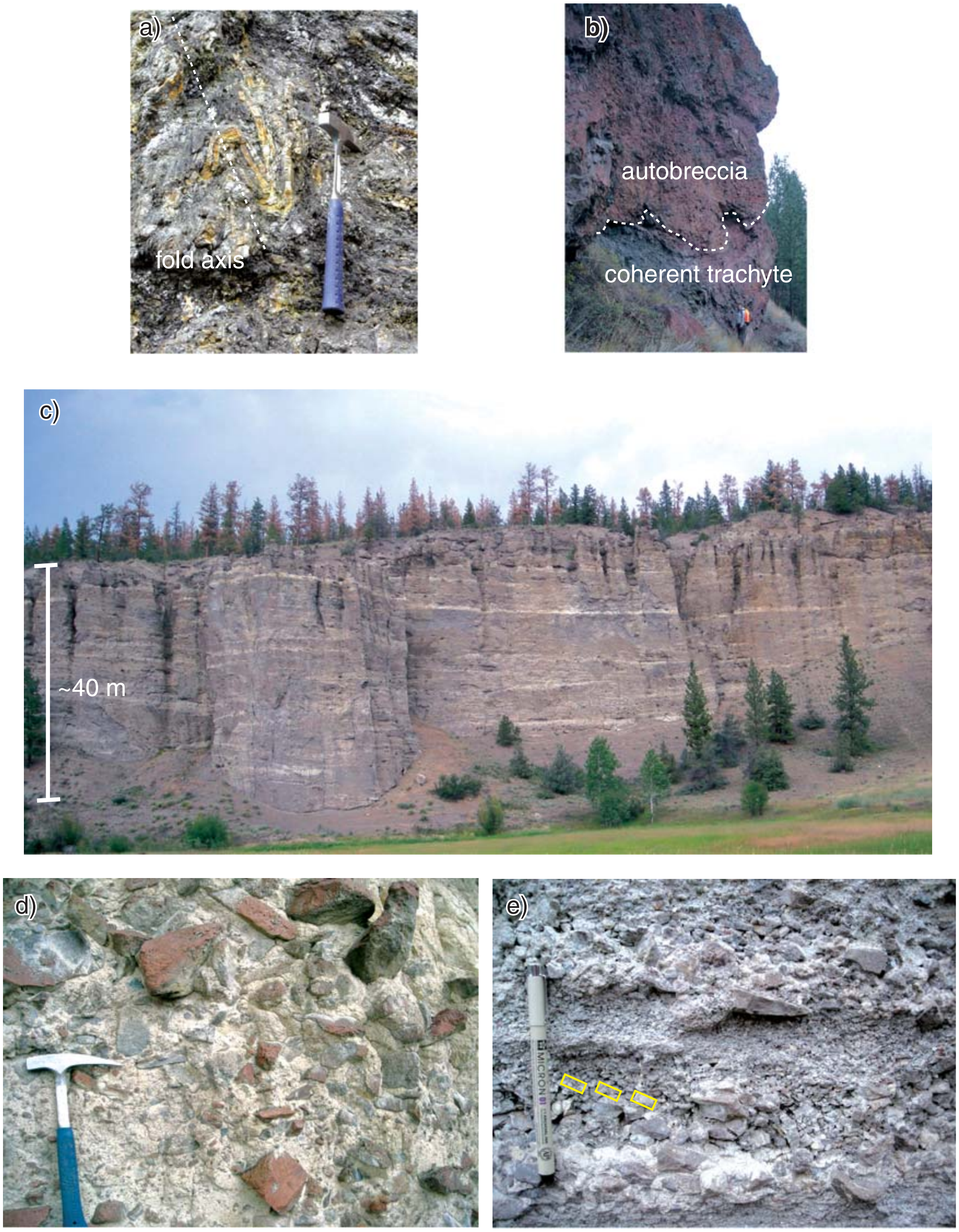

Figure 4. a) Small-scale folds in Cache Creek Group phyllite. Photograph by R.-E. Farrell **b)** Trachyte lava and autobreccia inferred to belong to the Skull Hill Formation, Kamloops Group. Photograph by R.-E. Farrell **c)** Bedded sandstone and breccia inferred to belong to the Deadman River Formation. Photograph by R.-E. Farrell **d)** Angular to subangular clasts of trachyte in a breccia bed within the Deadman River Formation. Photograph by R.-E. Farrell **e)** Imbricated angular clasts in a breccia layer within the Deadman River Formation indicating a northwesterly transport direction. View is to the southwest. Pen for scale is 9 cm long. Photograph by R.-E. Farrell

Kamloops Group

Rocks tentatively assigned to the Skull Hill Formation of the Eocene Kamloops Group are exposed discontinuously along 3 km of Sixtyone Creek and Chasm Creek (Fig. 2). The exposed thickness of the Skull Hill Formation in this area ranges from 3 to 60 m. At the junction of Chasm Creek and the Bonaparte River, the Kamloops Group is unconformably overlain by the Deadman River Formation (Fig. 2). Two associated rock units were observed (Fig. 4b); unit 1 is a red-brown, plagioclase-phyric, coherent rock with trachytic texture. From hand-sample characteristics, it has been tentatively interpreted as a trachyte (Fig. 4). Flattened vesicles are aligned parallel to the small (>1 mm) plagioclase phenocrysts. Unit 2 is a monomictic volcanic breccia that conformably overlies unit 1 and consists of clasts of trachyte. Collectively, the two units are interpreted as the coherent (unit 1) and clastic (autobreccia; unit 2) components of a single lava.

Deadman River Formation

The main exposures of the Deadman River Formation occur along Chasm Creek, at the junction of Chasm Creek and the Bonaparte River, and north of Rickett's Ranch (Fig. 2, 3). Small (<5 m thick) limited exposures are structurally above the Cache Creek Group in Fiftyseven Creek. The main exposure forms cliffs averaging 40 m in height (Fig. 4c). Outcrops consist of cream sandstone and bedded volcanic breccia. Breccia clasts are dominantly angular to subangular and imbricated (Fig. 4d, e). Three distinct clast-size populations are present (average sizes are 39.1 cm, 8.6 cm, and 1.1 cm). The clasts are set in a sand-sized matrix. Clast imbrication has been used to interpret a northwesterly transport direction (Fig. 4e), and the angularity of the clasts suggests minimal transport from their source.

Chilcotin Group

The Chasm area is host to one of the best known and thickest exposures of the Chilcotin Group and for this reason was selected for the current detailed study. Cliff-forming exposures occur continuously for 7 km along Chasm Creek, but away from the canyon walls exposures are limited (Fig. 2). In the study area, the Chilcotin Group is estimated to be approximately 140 m thick. It is divided into five distinctive facies (Table 1). The coherent rocks consist of three facies, a plagioclase-phyric basalt (Pp), an aphyric columnar-jointed basalt (Ac), and an aphyric massive basalt (Am). Two different clastic facies are identified, pillow-fragment breccia (Pf) and sandstone-to-breccia (Sb). Graphic logging of key sections provided a basis for identifying the facies (Fig. 1, 5).

Coherent units

Plagioclase-phyric basalt facies (Pp)

This facies is characterized by dark grey, amygdaloidal, plagioclase-phyric coherent basalt. The rock comprises approximately 15% plagioclase phenocrysts. Spherical vesicles and amygdales (1–2 mm diameter) are located along the margins. Vesicle chimneys (e.g. vesicle cylinder) up to 5 m in length occur in the Pp facies. The vesicle chimneys are located in the centre of the units, not at the base or top. Pipe vesicles are common, and internal boundaries within individual units are lobate. The units range from 10 to 15 m in thickness. Upper and lower contacts are sharp. The Pp facies is interpreted to be subaerially emplaced lava. There is no evidence that this facies is proximal to the vent. Lavas 7 and 8 in the logged section belong to the Pp facies (Fig. 5).

Aphyric columnar-jointed basalt facies (Ac)

This facies consists of dark grey or tan, aphyric, columnar-jointed basalt. It is commonly amygdaloidal and/or vesicular (vesicles <1 mm in size). In thin section, olivine microphenocrysts are visible, and plagioclase is observed only within the groundmass. Columnar joints vary in spacing depending on the unit, and spheroidal weathering locally masks the well defined jointing pattern. The thickness of the individual units varies from 5 to 20 m. Sediment-filled cracks occur at the top of the units (Farrell et al., 2007). Units within the Ac facies do not have lobate structures and instead have massive sheet-like morphologies (Fig. 6). The Ac facies is interpreted to be subaerially emplaced lava units, on the basis of the absence of pillows or other subaqueous textures. Lavas 1, 2, and 5 on the logged section are part of the Ac facies (Fig. 5).

Aphyric massive basalt (Am)

This facies consists of dark grey, aphyric, amygdaloidal or vesicular, massive basalt. It typically shows internal lobate structures, and the concentration of vesicles increases toward the lobe margins. Amygdales are also common. Pipe vesicles are locally present at the base of individual lobes. This facies is interpreted as subaerial lava. Lavas 3, 4, 6, and 9 on the logged section are part of the Am facies (Fig. 5).

Clastic units

Pillow-fragment breccia facies (Pf)

Multiple lenses of basaltic pillow-fragment breccia are exposed in the steep western walls of the Chasm Creek canyon. The Pf facies is not shown in the detailed graphic log section (Fig. 5). It consists dominantly of aphyric intact

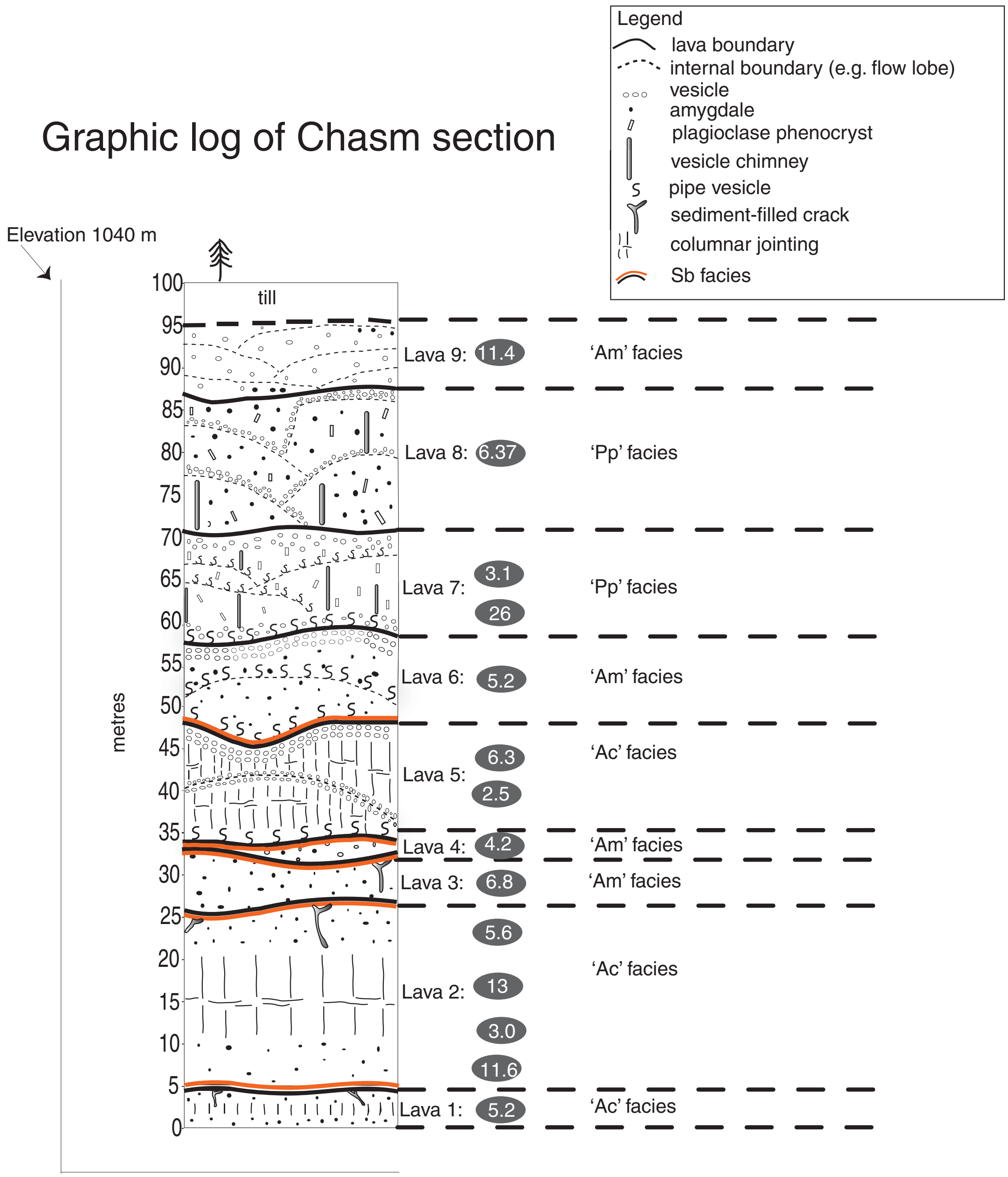

Figure 5. Detailed graphic log through the main section (Fig. 2) of Chilcotin Group lavas exposed in Chasm Creek. Grey ellipses provide magnetic susceptibility data.

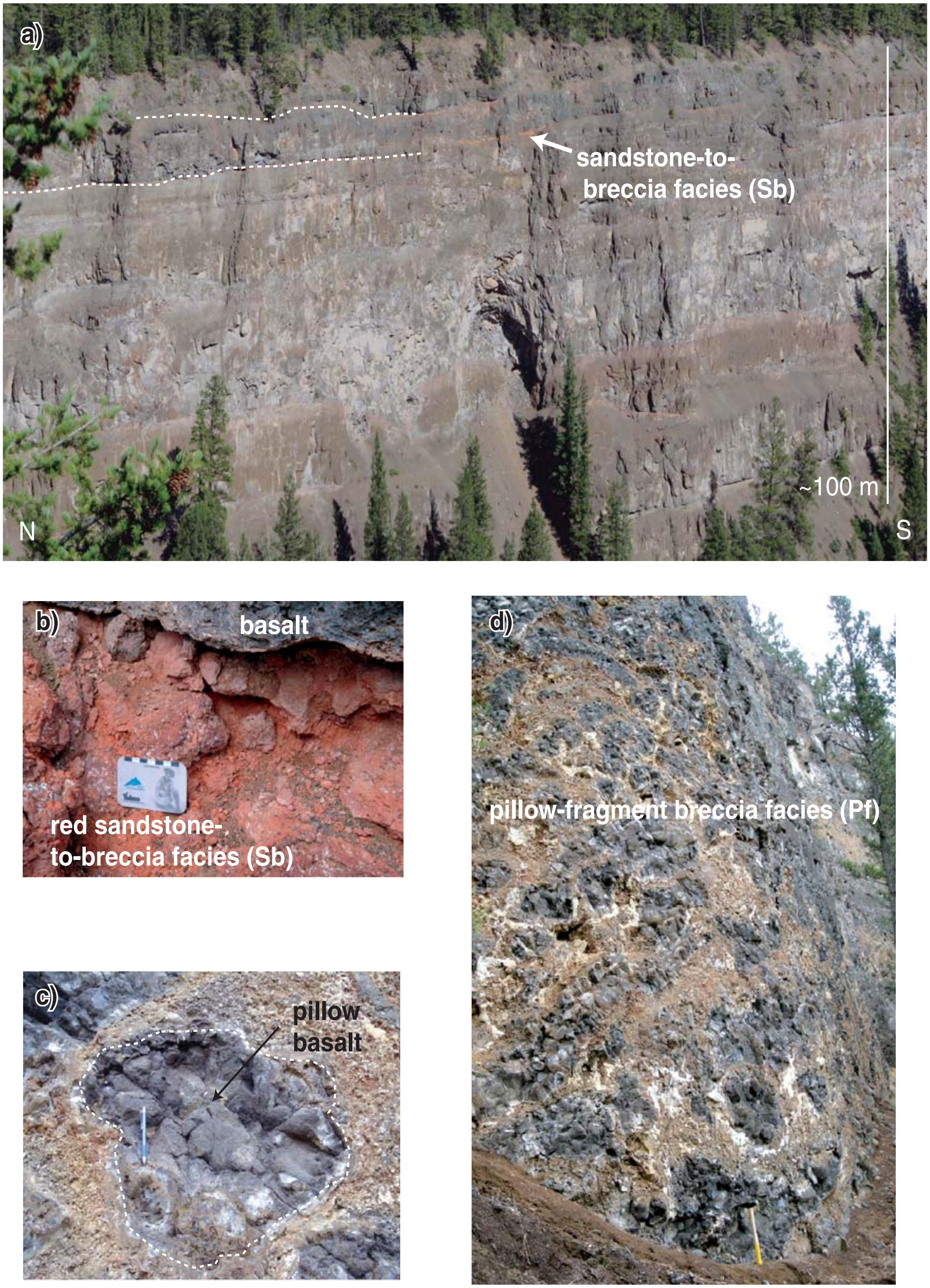

Figure 6. a) Panoramic photograph of nine lavas taken from the Chasm Provincial Park observational lookout. Note the orange sandstone-to-breccia facies delineated by the dotted lines. Photograph by G.D.M. Andrews **b)** Close-up of the sandstone-to-breccia facies seen in a). Photograph courtesy of Paul Sanborn **c)** Intact basaltic pillow set in an orange palagonitized matrix from the pillow-fragment breccia facies. Note the radial joints around the rim of the pillow. Photograph by R.-E. Farrell **d)** Pillow-fragment breccia from the western margin of the Chasm Creek canyon. Photograph by R.-E. Farrell

basaltic pillows and pillow fragments in a fine-grained matrix. The intact pillows are irregularly shaped and prismatically jointed, with tiny normal joints (centimetre scale) on the periphery of the rinds. Average pillow size is 0.5 m and pillows commonly have multiple concentric palagonitized rinds. The matrix consists largely of angular to subangular basalt pillow fragments, particularly pillow rinds, which range in size from approximately 1 to 20 mm. It is orange and composed primarily of palagonite with altered clay minerals (Fig. 6d).

The Pf facies is discontinuous in outcrop and occurs only as lenses (Fig. 2, 6). The contact between the coherent facies and the Pf facies is discontinuous over 2 km. The Pf facies occurs as a lens at the base of the cliff and is overlain by massive coherent basalt lava (aphyric columnar-jointed basalt facies). Over the 2 km, the lens of Pf facies branches into three discontinuous lenses. The basal lens is 15 m in thickness, the middle lens is 8 m, and the top lens is over 2 m. Each of these lenses is separated by coherent facies (Ac facies). The contacts with coherent facies are sharp and irregular.

The blocky, angular, glassy clasts within the matrix and the close association of pillow fragments and intact pillows suggest that the fine-grained matrix was largely derived by quench fragmentation. The lack of jigsaw-fit textures and the presence of pillow fragments suggest that the deposit has been transported. Thus, the Pf facies is interpreted to be a resedimented subaqueous volcaniclastic deposit.

Sandstone-to-breccia facies (Sb)

The rocks of the Sb facies are red to light brown sandstone and breccia consisting of weathered basalt fragments (Fig. 6). The facies commonly occurs between coherent lavas, and its thickness varies from <0.5 to 3 m. On the basis of colour and field characteristics, five discrete zones were visible in the Sb facies. Each ranges in thickness from 1 to 40 cm. The Sb facies locally contains isolated basalt clasts, which represent core stones in the surrounding finer grained sandstone. Within the facies, thin laminations are locally present, although larger scale bedding is absent. The lower contacts are typically undulating, irregular, and gradational, and material from the Sb facies commonly infills cracks within underlying coherent units (Fig. 5). The Sb facies is interpreted to be a paleosol formed by weathering of the underlying lava. The presence of paleosols suggests multiple hiatuses in volcanism in the Chasm.

DISCUSSION

Within the Chasm study area, an important transition occurs between subaqueously deposited clastic rocks and subaerially emplaced lavas. All lavas in the Chasm section are interpreted to be subaerial in origin. Intact pillows and pillow fragments occur in the volcaniclastic facies, but no pillow lava outcrops have been observed.

The Chilcotin Group lavas and volcaniclastic rocks were interpreted to have been emplaced into mature paleochannels (Farrell et al., 2007). The occurrence of paleosols between individual emplacement units of the Chilcotin Group subaerial lavas suggests that these lavas were not emplaced during a single eruptive event. All the Chilcotin Group volcanic facies in the study area were derived from or associated with effusive eruption of basaltic magma, but the location of the source vent(s) remains unknown. This preliminary work shows that the environments of deposition are both subaerial and subaqueous. On the basis of the facies associations, a preliminary hypothesis is that the source vent(s) was subaerial and that the subaqueous deposits formed when subaerial lava flowed into a standing body of water.

CONCLUSIONS

Four stratigraphic units, the Chilcotin Group, Deadman River Formation, Kamloops Group, and Cache Creek Group, were mapped within the Chasm study area. There are no exposed contacts between the Chilcotin Group and the underlying basement rocks. Five volcanic and sedimentary facies were defined within the Chilcotin Group. It is interpreted that the drainage within Chasm Provincial Park has been used multiple times, and can be considered a paleochannel. The Chasm area is an ideal natural laboratory to reconstruct the emplacement processes associated with the Chilcotin Group, understand the paleotopography, and gain information about the paleoclimate nine million years ago in south-central British Columbia. It will continue to be a focus of ongoing studies.

ACKNOWLEDGMENTS

This research was funded and supported by the Geological Survey of Canada (Natural Resources Canada) through the TGI-3 program TG6005. The authors appreciate the helpful advice and discussions from Paul Sanborn (University of Northern British Columbia), Scott Smith, Randy Enkin, Judith Baker, and Stephen Williams. Thank you Melanie Kelman (GSC) for editing expertise. Thanks to field assistants Nina Schwartzman (Smith College), Ryan Emperingham (University of Victoria), and Agatha Soful (University of British Columbia). Lastly, the authors would like to thank the residents of Clinton, Chasm, and Dog Creek, who offered a great deal of help and hospitality during our field work.

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