Geological Survey of Canada

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2003-B2

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2003

Natural Resources Canada
Ressources naturelles Canada

Canada

CURRENT RESEARCH

ISSN 1701-4387
Catalogue No. M44-2003/B2E-IN
ISBN 0-662-33584-8

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Publication approved by Canada-Nunavut Geoscience Office

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Turner, E.C., 2003: Lead-zinc showings associated with debrite layers shed from synsedimentary faults, Mesoproterozoic Society Cliffs Formation, northern Baffin Island, Nunavut; Geological Survey of Canada, Current Research 2003-B2, 7 p.

Abstract: Showings near the Adams River valley on northern Baffin Island are hosted by lowermost strata of the Mesoproterozoic Society Cliffs Formation. They are characterized by galena, sphalerite, iron sulphide, sparry dolomite, diagenetic quartz, and bitumen. Host rocks are terrigenous dolo-wacke debrite and turbidite layers shed from fault blocks that were active during sedimentation, and crackle to rubble breccia in the featureless brown dolostone that encloses the debrite and turbidite lobes. Although the late breccia units that contain sulphide mineralization are visually similar to early (synsedimentary) breccia units, they can be distinguished from the latter by examining the interstitial fill: early brecciation is associated with finely crystalline, pale dolomite, whereas late brecciation is associated with coarse sparry dolomite. The structural, stratigraphic, and sedimentological controls on mineralization at Adams River may be similar to those at other, hitherto unstudied showings in the Borden Basin, as well as the Nanisivik deposit.

Résumé : Dans la partie nord de l'île de Baffin, près de la vallée de la rivière Adams, des indices minéralisés sont contenus dans les strates basales de la Formation de Society Cliffs du Mésoprotérozoïque. Ces indices renferment de la galène, de la sphalérite, des sulfures de fer, des spaths de dolomite, du quartz diagénétique et du bitume. La minéralisation est encaissée dans des turbidites et des coulées de débris de dolo-wackes terrigènes qui se sont épanchées depuis des blocs limités par des failles actives lors de la sédimentation. On en trouve aussi dans des brèches tectoniques à fragments peu à très déplacés les uns par rapport aux autres au sein de la dolomie brune, autrement dépourvue de texture, qui enrobe les lobes de turbidite et de coulée de débris. Bien que les brèches de formation tardive renfermant la minéralisation sulfurée soient à l'oeil semblables aux brèches de formation précoce (synsédimentaires), on peut les en distinguer à l'examen des matériaux de remplissage interstitiel : à la bréchification précoce est associée de la dolomite pâle finement cristallisée, alors qu'à la bréchification tardive sont associés des spaths grossiers de dolomite. Les facteurs structuraux, stratigraphiques et sédimentologiques exerçant un rôle sur la minéralisation à la rivière Adams pourraient être semblables à ceux la déterminant à d'autres indices jusqu'à maintenant peu étudiés du bassin de Borden, ainsi qu'au gisement de Nanisivik.

INTRODUCTION

Zinc and lead showings are scattered along the length of the Milne Inlet Graben, the main structural domain of the Borden Basin, on northern Baffin Island (Sangster, 1998). Although the regional geology of the Borden Basin is well known (e.g., Jackson and Iannelli, 1981; Iannelli, 1992), the stratigraphy and sedimentology of the Society Cliffs Formation, which hosts the main sulphide showings, are not publicly known in any detail. This is particularly true for the western half of the Borden Peninsula, where zinc showings are most abundant and where the Nanisivik mine is located. Rocks are unmetamorphosed and have been affected by both synsedimentary and postdepositional normal faulting, as well as poorly understood, subtle folding (Patterson and Powis, 2002). Mineralization at Nanisivik has been tentatively interpreted as being localized in north-trending anticlines near kilometre-spaced, east-trending normal faults (Patterson and Powis, 2002), but these features have not been identified from elsewhere in the basin. The current understanding is that, in spite of various studies on the Nanisivik deposit during its 26 years of operation (Clayton and Thorpe, 1982; Olson, 1984, 1986; Ford, 1986; McNaughton and Smith, 1986; Ghazban et al., 1990, 1992; Arne et al., 1991; Patterson and Powis, 2002), little agreement has emerged regarding the timing, mechanism, controls, and even style of mineralization at Nanisivik. The overarching structural and stratigraphic controls on, the history of, and the age of mineralization throughout the district remain unknown.

MINERALIZATION

Mississippi Valley–type mineralization at Nanisivik and throughout the Milne Inlet Graben is hosted primarily by Society Cliffs Formation dolostone; sandstone and shale-hosted copper and possible sedimentary exhalative mineralization are also known from other strata in the Bylot Supergroup (Sangster, 1998). The nature of known showings in the Society Cliffs Formation appears to change eastward from Nanisivik (Fig. 1), with both zinc content and showing density diminishing east of the central Borden Peninsula (Olson, 1984; Sangster, 1998). The reasons for and implications of this trend are uncertain. Nanisivik itself contained 20 Mt of combined zinc, lead, and silver minerals, and 100 Mt of pyrite.

This paper describes a group of small showings from the central Borden Peninsula, near showing 10 of Sangster (1998). See Sangster (1998) for a summary of showings in the district.

SHOWINGS

Lead-zinc showings were examined during two days of reconnaissance work on strata of the lower Society Cliffs Formation in the Adams River valley, central Borden Peninsula (Fig. 1, 2). Individual showings are small, but have a distribution and lithological associations that may be relevant to controls on mineralization at Nanisivik and other showings throughout the basin.

In situ outcrop is very sparse; the terrain is characterized by nonvegetated felsenmeer that has not been transported significantly except on and at the base of the steepest talus slopes. Rare outcrop shows a gentle northeast structural dip (<10°). Galena and minor sphalerite are present in scattered locations along the lower flanks of hills forming the north slope of the Adams River valley. The showings form a linear trend that is roughly parallel to the strike of the Arctic Bay–Society Cliffs contact, in rocks of the lower Society Cliffs Formation (described in Turner, 2003). With the exception of one site, sulphide minerals were found in float (felsenmeer); the mineralized float, however, has the same distribution and host lithofacies as those of the one showing in in situ strata. The showings are within 1 km of a southeast-trending diabase dyke (to the northeast) and 1 to 4 km north of a major east-southeast-trending normal fault (to the south) that belongs to a set of faults that was active during basin formation and sedimentation, as well as episodically since then (Jackson and Iannelli, 1981; Iannelli, 1992).

The outcrop showing (Fig. 3) is about 10 m stratigraphically above the inferred contact with the Arctic Bay Formation. It is about 7.5 m thick and 40 m long, and consists of featureless, brown, fine- to medium-crystalline dolostone interlayered with 1 to 70 cm thick units of sand- to granule-sized quartz and lithic fragments (up to 5 cm long) in a pale grey dolomitic matrix ('dolo-wacke'; Fig. 4A; *see also* Turner, 2003). Some of these units pinch out along the length of the outcrop, indicating that they are laterally limited and lenticular in cross-section. Identical terrigenous units are evident in felsenmeer to the northeast of (stratigraphically above) the outcrop showing, standing out clearly as strike-parallel, laterally delimited, pale bands of rubble, on the order of 100 m long, against the dark background dolostone rubble. They are also present to the northwest, in a similar outcrop about 2 km away (*see* Turner, 2003)

Clasts in the wacke are angular, and are either ungraded, unsorted, and floating in the dolomitic matrix, or clast supported and faintly cross laminated. In wacke not associated with mineralization, clasts are unaltered and porosity is comparatively low (Fig. 4A). In wacke that contains or is spatially associated with sulphide minerals, certain clast types (chiefly dolostone intraclasts) have been leached out, porosity is significant, millimetre- to centimetre-scale vugs are present in the dolomitic matrix, and euhedral smoky quartz crystals partly fill some of the resultant voids (Fig. 4B). Brown dolostone immediately overlying terrigenous layers has areas of crackle to rubble breccia (Fig. 4C) that are parallel to and in contact with the underlying terrigenous unit, or form decimetre-scale breccia chimneys and domes. Locally, thin layers of dolostone immediately below wacke layers are also affected (Fig. 4B).

Euhedral to subhedral galena crystals up to 5 mm in diameter are present in both the wacke (Fig. 4D) and the dolostone, and are variably associated with sparry, flat-faced dolomite,

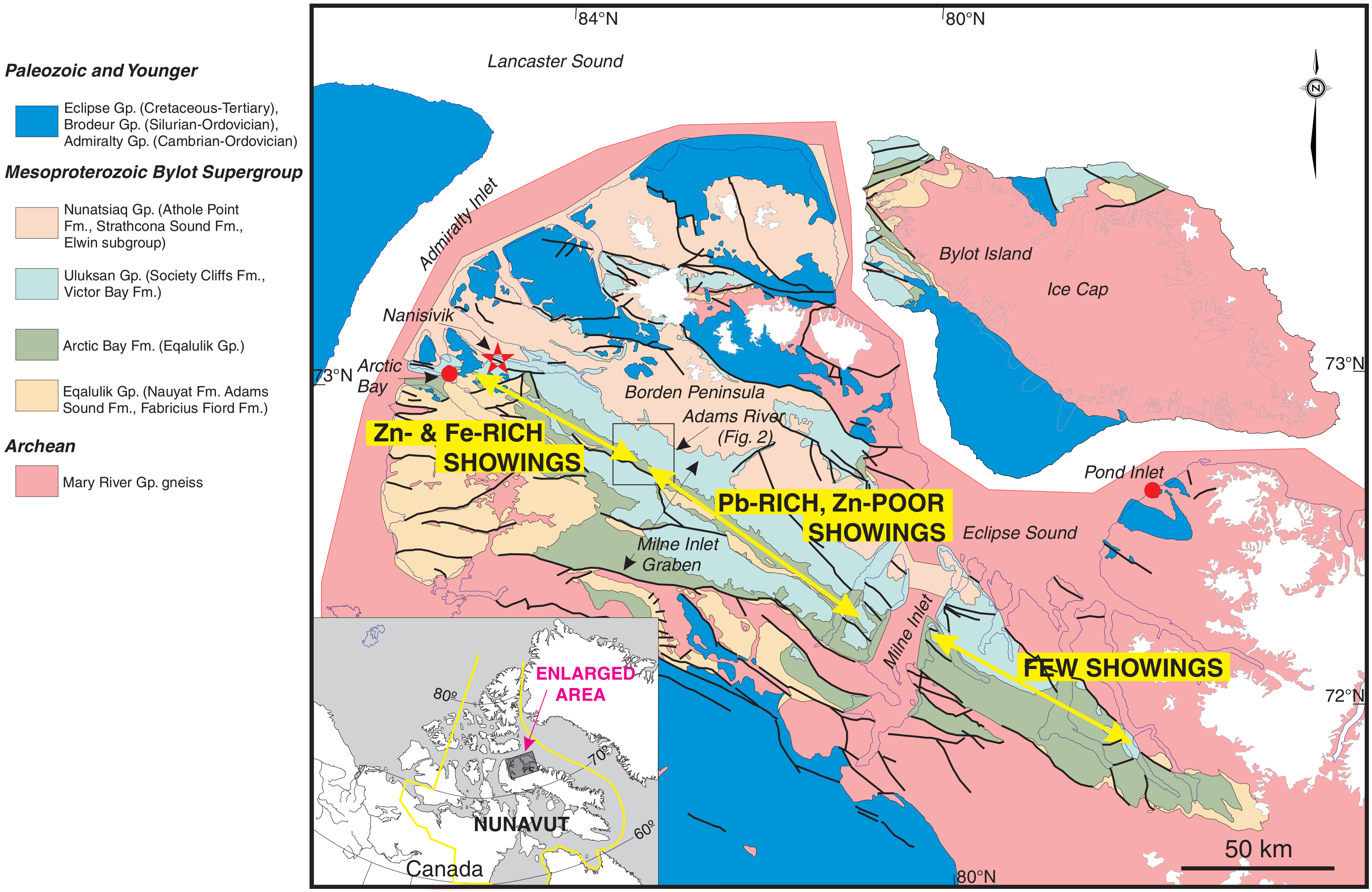

Figure 1. *Geology of northern Baffin Island, showing trends in mineralization in Society Cliffs Formation and location of Adams River study area (Fig. 2).*

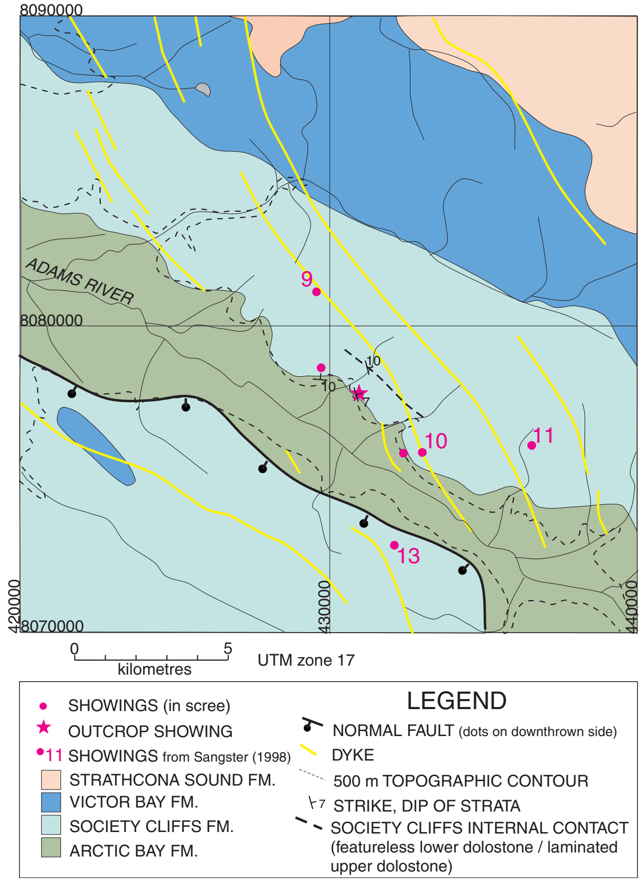

Figure 2. *Geology and showings near Adams River. Geology and numbered showings after Sangster (1998); details of numbered showings available in Sangster (1998) and references therein. Heavy dotted line near showings indicates transition between featureless dolostone (southwest) and laminated dolostone (northeast) of Society Cliffs Formation. Sparse mineralization is also present between the marked showings.*

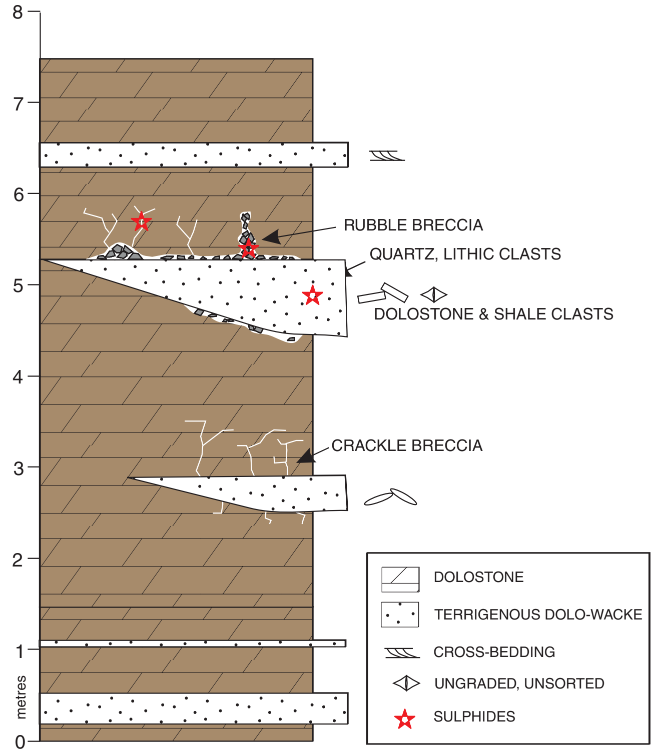

Figure 3. *Diagrammatic stratigraphy at outcrop showing (UTM 17, 430951E, 8077873N). Terrigenous dolo-wacke beds form layers and lenses up to 0.7 m thick in background brown, finely crystalline dolostone. Terrigenous dolo-wacke layers that have undergone subsequent leaching of dolostone clasts are associated with dissolution and incipient brecciation of immediately enclosing dolostone, and with sulphide mineralization.*

euhedral quartz, bitumen, and iron sulphide. Dark reddish brown sphalerite euhedra form sparse, sub-millimetre clusters within the wacke and are apparently not associated with the larger pores.

During this brief survey of the area, sulphide minerals were found only sparsely in Society Cliffs rocks stratigraphically above the level of the outcrop showing.

INTERPRETATION

Sulphide minerals at all showings examined are in both dolostone and terrigenous dolo-wacke; mineralization is always spatially associated with the terrigenous layers. Lateral restriction of terrigenous dolo-wacke layers, together with textural characteristics, identify some layers as locally derived debrite (angularity and compositional immaturity of clasts, lack of sorting, grading, or preferred clast orientation) and others as related turbidite (graded beds with approximately horizontal clast long axes or crossbedding; Turner, 2003). These are most parsimoniously interpreted as being derived from a local, normal fault that was active during sedimentation, such as the one several kilometres south of the outcrop showing. Leaching of certain clastic constituents, and emplacement of sulphide minerals within terrigenous dolo-wacke layers and solution-brecciated enclosing dolostone, clearly indicate that some of the debrite lenses acted as paleoaquifers for mineralizing fluids.

There are several potential explanations for fluid flow (Fig. 5). If flow predated tilting of the rocks into their present-day northeast-dipping disposition, it might have been northward from a possible permeable zone in the normal fault to the south, following northward-thinning, permeable debrite wedges. Alternatively, if it postdated tilting, it might have moved through the structure in which the dyke to the north was emplaced, spreading outwards to flow up-dip along those terrigenous dolo-wacke wedges that extend far enough north to be crosscut by the dyke. In either case, fluids moving through debrite and turbidite layers dissolved certain types of dolostone in the paleoaquifer (clasts but not matrix of the debrite and turbidite), caused dissolution and incipient

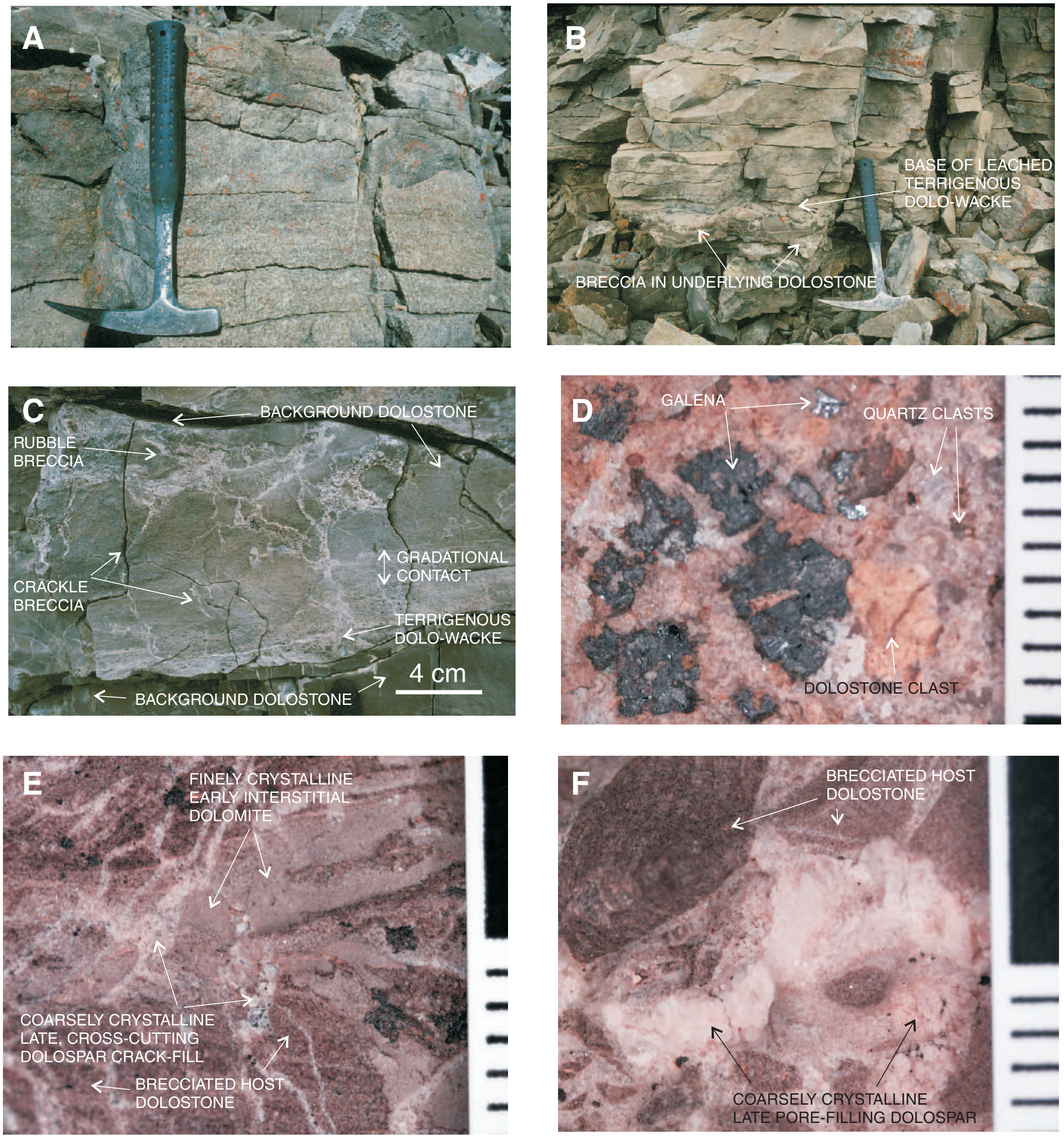

Figure 4. A) *Unaltered, graded terrigenous dolo-wacke, UTM 17, 430951E, 8077873N; hammer is 33 cm long.* ***B)*** *Terrigenous dolo-wacke that has undergone leaching, same location as A; dark speckles are empty voids left after clast dissolution; hammer is 33 cm long.* ***C)*** *Crackle to rubble breccia in dolostone gradationally overlying a graded and leached terrigenous dolo-wacke layer, same location as A.* ***D)*** *Galena crystals in terrigenous dolo-wacke, same location as A; scale in millimetres.* ***E)*** *Early breccia with finely crystalline, pale brown-grey interstitial dolomite, crosscut by fractures filled with coarse sparry dolomite, UTM 17, 431327E, 8078766N; scale in millimetres;* ***F)*** *Late breccia, with coarsely crystalline sparry dolomite filling interstices, UTM 17, 431681E, 8078117N; scale in millimetres.*

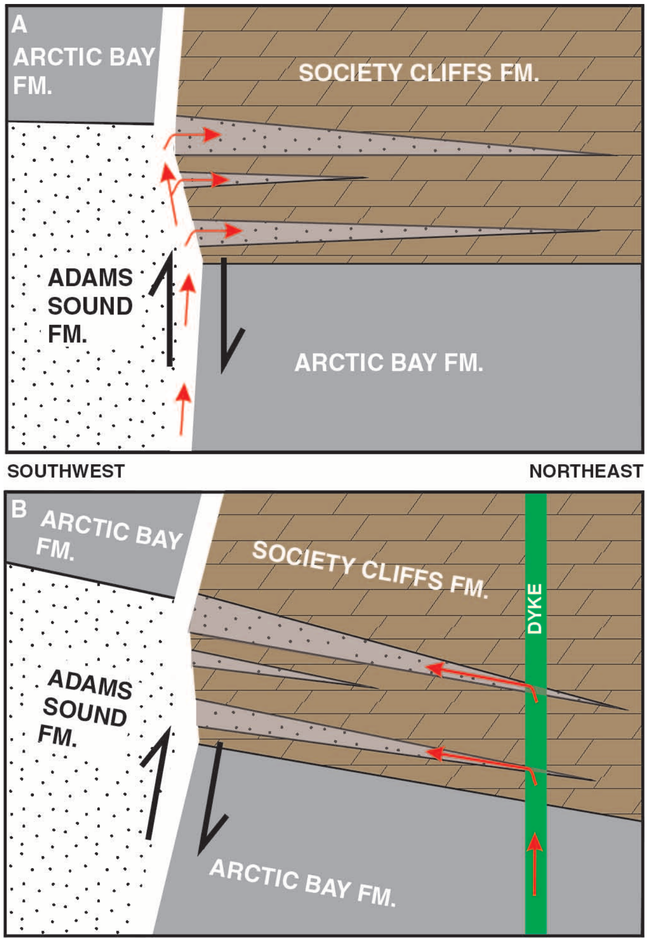

Figure 5. *Possible flow of dissolving-mineralizing fluid to form Adams River showings:* ***A)*** *fluid flow that might have occurred prior to significant tilting of host strata;* ***B)*** *fluid flow that might have occurred after such tilting.*

collapse of small areas of enclosing dolostone, and emplaced sulphide minerals, minor sparry dolomite, and quartz in the resultant pores. This dissolution-collapse event would have been unrelated to the early dissolution-collapse postulated to have taken place in the shallow subsurface to form the synsedimentary, in situ 'breccia' that is so typical of the upper Society Cliffs Formation in the western Borden Peninsula. The simplest way to distinguish the two similar-looking phenomena is by examining the grain size and crystallinity of the material that fills the pore space within cracks and between collapsed clasts: synsedimentary brecciation is characterized by pale grey to brown, microcrystalline dolomite, whereas late brecciation is healed by coarser dolomite crystals (Fig. 4E, F). Coarsely crystalline dolomite of the late phase might, in some cases, replace the early, crack-filling fine dolomite, but also commonly crosscuts the earlier phase in a separate generation of fractures (Fig. 4E).

DISCUSSION

Flow of metalliferous fluids at this locality is interpreted to be controlled by the distribution of wedges of terrigenous material shed from syndepositional faults, that acted as paleoaquifers; the impetus for precipitation of sulphide minerals, however, is less clear. Given that many known showings in the Borden Basin (Sangster, 1998), including the Nanisivik deposit, are close to either faults or dykes (some of which were undoubtedly fault structures of the same generation as the main, unintruded normal faults), this leads to the question of whether a combined sedimentary and structural control of a very specific type is a general requirement for this system: proximity to a fault that actively shed material that was susceptible to later fluid flow. It is intriguing that a number of the showings reported in Sangster (1998) have mineralization in the lower Society Cliffs Formation near a fault.

The sedimentology and stratigraphy of host rocks at Nanisivik have never been properly documented and interpreted. Although coarse-grained terrigenous material appears to be absent from the formation at Nanisivik, the enigmatic, altered 'white rock' (Sutherland and Dumka, 1995) associated with the orebody might have had an originally siliciclastic component. It is not known whether some of the other, enigmatic lithofacies in the Society Cliffs Formation (*see* Patterson and Powis, 2002), or indeed other formations, might have had a similar origin and role in fluid flow at Nanisivik as do the terrigenous debrite wedges at Adams River. It also remains unknown whether a similar set of pre-existing sedimentary and structural conditions might have been prevalent at showing localities throughout the basin.

The concentration of known sulphide showings in the Society Cliffs Formation, and the proportion of showings that contain significant zinc, appear to diminish east of the central Borden Peninsula (Sangster, 1998). The drop-off in showing density coincides roughly with the proposed location of basin subdivision (Turner, 2003). There is also an eastward decrease in the areal density of both dykes and major normal faults that transect areas underlain by Society Cliffs rocks (Scott and deKemp, 1998). It is as yet unknown which, if any, of these factors are critical to mineralization, and which are merely fortuitous. Mineralization is controlled by 1) some aspect of primary lithofacies, and is largely limited to certain dolomitic facies of the western sub-basin; 2) tectonic features, and is delimited largely by fault structures (and/or deposits that accumulated in the basin as a result of their synsedimentary movement), some of which could also control the division of the basin into western and eastern domains during Society Cliffs time; 3) some other east-trending phenomenon such as fluid flow, changes in fault density, or decrease in dyke density; or 4) all three of these phenomena. These complex and compelling questions may be resolved with the application of a variety of stratigraphic, sedimentological, mapping, and geochemical analyses to carefully selected localities.

ACKNOWLEDGMENTS

Many thanks are extended to De Beers Exploration Canada Inc., who provided helicopter transport in the field. Julie Beaulieu's stoic endurance of cliff-teetering, muck-glopping, and snow-postholing is much appreciated. The manuscript benefited greatly from a critical reading by Ross Sherlock. This project was funded by the Canada-Nunavut Geoscience Office (Project 000004).

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Geological Survey of Canada Project 000004