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Stratigraphic revision of the Franklinian stratigraphy of the northern Axel Heiberg fold belt, Nunavut

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ABSTRACT

New outcrop observations from fieldwork conducted near Rens Fiord on northern Axel Heiberg Island are described that clarify the pre-Mississippian stratigraphy. It is recommended to use the informal term Rens Fiord Sandstone for rocks previously assigned to the Grantland Formation. Dolostone of the Aurland Fiord Formation contains an inter-stratified succession of basalt flows within it, for which the older informal term of Jaeger Lake Assemblage is recommended. The Hazen Formation which could range in age from Cambrian to Early Silurian overlies the Aurland Fiord Formation. The revised stratigraphic order from oldest to youngest is Rens Fiord Sandstone, Aurland Fiord Formation containing the Jaeger Lake Assemblage, and Hazen Formation.

INTRODUCTION

The Paleozoic stratigraphy of Northern Axel Heiberg Island is correlated to the Franklinian succession of northern Ellesmere Island (Trettin, 1998). The stratigraphic nomenclature adopted by Trettin (1998) uses formations that are typical of turbidite and basinal facies from the Hazen Trough (Grantland and Hazen formations), but the lithological descriptions and stratigraphic context provided by Trettin are somewhat limited and could be refined; for example is the Grantland Formation at northern Axel Heiberg Island characterized by turbidite facies as in the Hazen Trough? There are some curiosities, such as that the Aurland Fiord Formation is interpreted to be older than the Grantland Formation yet that relationship has not been documented anywhere, instead a bedding-parallel detachment fault has been interpreted across the entire study area that places the Aurland Fiord Formation over the Grantland Formation (Trettin, 1998). The retreat of multi-year ice patches combined with visiting outcrops that were previously only interpreted from airphotos presents an opportunity to contribute new outcrop observations from fieldwork conducted in the summer of 2016 (Figure 1) to better understand the pre-Mississippian stratigraphy of northern Axel Heiberg Island.

PREVIOUS WORK

The most comprehensive Paleozoic map of northern Axel Heiberg Island is by Trettin (1996). The pre-Carboniferous stratigraphy of northern Axel Heiberg Island was first described in some detail by Fricker and Trettin (1962) who named the oldest strata as the Rens Fiord Complex. The Rens Fiord Complex was subdivided into: (a) chert and siliceous slate; (b) quartzose meta-sandstone; (c) dolomite; and (d) meta-basalt interbedded with carbonate. It was noted that schistosity and slaty cleavage are well developed in the Rens Fiord Complex but not in the Lower Silurian Svartevaeg Group (now Svartevaeg Formation).

Trettin (1969) adopted the same basic subdivision of the Rens Fiord Complex and noted that the stratigraphic order was uncertain, but listed the units in ascending order as: Sandstone Unit; Carbonate Unit; Volcanic Unit; and Argillaceous and Cherty Strata. After fieldwork in 1986 Trettin (1987) revised the informal nomenclature with the Volcanic Unit as the Jaeger Lake Assemblage and the Carbonate Unit as the Aurland Fiord beds. Based on correlation of the Aurland Fiord beds to the Ella Bay Formation of Ellesmere Island it was rationalized that the Jaeger Lake Assemblage could be the oldest unit in the succession (and correlative with the Yelverton Formation). The Sandstone Unit was assigned to the Grantland Formation and chert

and dark grey mudrock assigned to the Hazen Formation. Correlation of the Rens Fiord Complex to stratigraphy from northeastern Ellesmere Island therefore resulted in an interpreted ascending stratigraphic order of Jaeger Lake Assemblage, Aurland Fiord beds, Grantland Formation, and Hazen Formation (Figure 2). The partly informal nomenclature was formalized by Trettin (1998) as Jaeger Lake Formation, Aurland Fiord Formation, Grantland Formation, and Hazen Formation (Figure 2).

OUTCROP OBSERVATIONS

Jaeger Lake

Where multi-year ice has likely receded over the past 20 years there are outcrops near Jaeger Lake that were probably not exposed during previous GSC expeditions. In a stream cut on the southwest side of Jaeger Lake (Figure 1), is an exposure of previously unmapped sandstone that lies stratigraphically below dolostone of the Aurland Fiord Formation (Figure 3). The lower part of the sandstone is interbedded with more argillaceous thinly bedded strata and wave ripples are evident. The upper part of the sandstone is medium-grained, quartzose, and is cross-bedded in places. The partially covered contact between the sandstone and dolostone is shown in Figure 3. A few metres above the base of the dolomitic Aurland Fiord Formation are stromatolites from which a reliable bedding measurement could be taken that confirms concordant bedding attitudes between the sandstone and dolostone. The stromatolites are important because there is a prominent fracture set within the dolostone that has the appearance of bedding but is highly oblique to the actual bedding (Figure 3B). The stratigraphic implication is that the Sandstone Unit assigned to the Grantland Formation most likely has a stratigraphic position below the Aurland Fiord Formation.

The only map unit on the west side of Jaeger Lake indicated by Trettin (1996) is Aurland Fiord Formation, which was based on airphoto interpretation (Trettin, 1987). There is a significant thickness (approximately 50 m) of pillowed basalt flows inter-stratified with dolostone of the Aurland Fiord Formation exposed in a cliff section on the west side of Jaeger Lake (Figure 4A). At the base of the cliff is dolostone that is overlain by pillowed basalt flows. Between some basalt flows are dolostone interbeds (Figure 4B). Basalt flows near the top of the cliff section are in turn overlain by dolostone. The stratigraphic significance of this outcrop is that basalt flows assigned to the Jaeger Formation lie *within* the Aurland Fiord Formation.

Figure 4A is a photograph facing northwest showing the stratigraphic relationship between the east and west side of Jaeger Lake. The mapped distribution of the Jaeger Lake Formation and Aurland Fiord Formation is simply due to the presence and relative thickness of basalt flows within laterally equivalent strata. The observation that the Jaeger Lake basalts are within and interfinger with the Aurland Fiord Formation lessens the significance of the Greenstone Lake Thrust that is projected through Jaeger Lake (e.g., Trettin, 1996). There is no field evidence for a fault at Jaeger Lake and a broad anticlinal structure can explain laterally equivalent stratigraphy on the east and west side of Jaeger Lake (Figure 4A).

Greenstone Lake

The main outcrop on the east side of Greenstone Lake is a cliff section of basalt flows. At the north end of the ridge is a small outcrop of dolostone near the base of the cliff, first described here. There are dolostone beds approximately 5 m thick inter-stratified with basalt flows in the cliff section. At the top of the basalt cliff are also dolostone beds. These relations are consistent with observations at Jaeger Lake that the basalt flows are within the Aurland Fiord Formation.

Farther east of the ridge and across a valley is another outcrop exposure of Aurland Fiord Formation which is labelled "Hazen Formation breccia outcrop" in Figure 1. The map of Trettin (1996) shows the strata as west-dipping which is consistent with a prominent fracture set within the dolostone, but primary sedimentary structures are difficult to identify. Fortunately a previously unmapped outcrop of Hazen Formation, approximately 20 m thick, is exposed above the Aurland Fiord Formation (Figure 5A). Near the base of the Hazen Formation is dolostone containing rounded chert clasts consistent with a interstratified depositional contact and stratigraphic position of Hazen Formation directly above the Aurland Fiord Formation (Figure 5B). The middle and upper portion of the outcrop contains erosional surfaces that are overlain by intraformational breccia with matrix composed of both intraclast and quartzose grains (Figure 5C). The bedding attitude of the Hazen Formation is east-dipping and concordant with the overlying Svartevaeg Formation, which is inconsistent with the interpretation by Trettin (1996) that Aurland Fiord is thrust over the Svartevaeg Formation. The contact between the Hazen and Svartevaeg formations is covered but similar bedding attitudes allow for the strata to be an intact stratigraphic succession and for the structure to be simply folded instead of thrust faulted.

West Aurland Fiord

For comparison with northern Rens Fiord, an outcrop of Hazen and Svartevaeg formations was visited on the western side of Aurland Fiord (Figure 1). The bedding attitudes between the Hazen Formation and the base of the Svartevaeg Formations are concordant (Figure 6A), which is probably a depositional contact but could be a subtle bedding-parallel fault contact. Siliceous mudstone of the Hazen Formation is approximately 10-20 m thick and contains clastic beds as at Greenstone Lake (Figure 6B). The Svartevaeg Formation is closely folded.

STRATIGRAPHY

Rens Fiord Sandstone

Newly described outcrops from northern Axel Heiberg Island allow for revision of the pre-Mississippian stratigraphy. Sandstones formerly mapped as the Sandstone Unit of the Rens Fiord Complex and then assigned to the Grantland Formation (Trettin, 1987) are the oldest rocks in the area. The shallow water sedimentary structures observed at Jaeger Lake are incompatible with turbidite facies of the Grantland Formation in the Hazen Trough as summarized by Trettin (1998). The stratigraphic succession of shallow marine sandstone (Sandstone Unit), shallow marine dolostone (Aurland Fiord Formation), overlain by the cherty mudstones of the Hazen Formation is also inconsistent with correlation of the Sandstone Unit to the Grantland Formation in the Hazen Trough. At northern Axel Heiberg Island the Sandstone Unit should therefore not be assigned to the Grantland Formation. It is proposed here that until the depositional age of the Sandstone Unit can be better constrained, a return to informal nomenclature based on name Rens Fiord Complex be implemented, and that this map unit be referred to as the Rens Fiord Sandstone.

The Rens Fiord Sandstone consists mainly of medium-grained quartzose sandstone and minor: quartz pebble conglomerate, green weathering fine grained sandstone, and red more argillaceous beds. The Rens Fiord Sandstone is older than the Aurland Fiord Formation. Both formations lack age control and are older than the Hazen Formation, which has a possible age range from Cambrian to Early Silurian based on correlation to Ellesmere Island.

Aurland Fiord Formation

Established lithostratigraphy is complicated by the lateral facies equivalence of basalt flows of the Jaeger Lake Formation and dolostone of the Aurland Fiord Formation. A straightforward solution to simplify map interpretations is to consider both the flows and dolostone to be part of the Aurland Fiord Formation, which is consistent with observations from Jaeger Lake that the flows lie within, and are inter-stratified with, the dolostone. It is recommended that the older informal term Jaeger Lake Assemblage of Trettin (1987) refer to the volcanic succession within the Aurland Fiord Formation. The Aurland Fiord Formation overlies the Rens Fiord Sandstone. The Aurland Fiord Formation is older than the Hazen Formation, which ranges in age from Cambrian to Early Silurian.

Correlation to Ellesmere Island stratigraphy

As stated above, the upward succession of shallow marine sandstone (Rens Fiord Sandstone), shallow marine dolostone with stromatolites (Aurland Fiord Formation), and cherty mudstone (Hazen Formation) is incompatible with correlation to the Grantland and Hazen formations from the Hazen Trough. The shallow marine facies are probably better correlated to the Franklinian Shelf stratigraphy instead of the Hazen Trough. Part of the Franklinian Shelf stratigraphy from northern Ellesmere Island with shallow marine features that lie below the Hazen Formation are Kane Basin and Scoresby Bay formations. The Kane Basin Formation consists of quartzose sandstone, with hummocky cross-stratification and trilobites from the *Bonnia-Olenellus* Zone. In places the Kane Basin is stratigraphically overlain by the Hazen Formation, in others it is succeeded by the Scoresby Bay Formation (Dewing and DeFreitas, 2008). The Scoresby Bay Formation is dolostone with shallow marine features such as hummocky cross-stratification, oncolites, intraclast conglomerate, and stromatolites, also with trilobites from the *Bonnia-Olenellus* Zone (Dewing et al., 2008). Better age constraints are needed but the revised stratigraphy from northern Axel Heiberg Island is consistent with correlation to the Franklinian shelf stratigraphic succession on Ellesmere Island of Kane Basin Formation–Scoresby Bay Formation–Hazen Formation.

CONCLUSIONS

The revised stratigraphic succession from the northern Axel Heiberg foldbelt is from oldest to youngest: Rens Fiord Sandstone, Aurland Fiord Formation containing the Jaeger Lake Assemblage of pillowed basalt flows, Hazen Formation, Svartevaeg Formation, and Stallworthy Formation. The succession and facies of Rens Fiord Sandstone–Aurland Fiord Formation–Hazen Formation are incompatible with correlation to the Hazen Trough and compare more favourably with Franklinian shelf stratigraphy of Cambrian age.

ACKNOWLEDGEMENTS

Keith Dewing's extensive knowledge of Arctic stratigraphy has been critical to unravelling the

Paleozoic stratigraphy of the study area.

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LIST OF FIGURES

Figure 4. Outcrop photographs from Jaeger Lake. (A) View facing northwest showing the stratigraphic relationship between the basalt flows of the Jaeger Lake assemblage and dolostone of the Aurland Fiord Formation. It is unlikely that there is a significant fault below Jaeger Lake. (B) Inter-stratified dolostone and pillowed basalt flows of the Aurland Fiord Formation.

Figure 5. Outcrop photographs from the Hazen Formation breccia outcrop (location shown in Figure 1). (A) The Aurland Fiord Formation is overlain by a previously unmapped exposure of Hazen Formation which is overlain by the Svartevaeg Formation. Contacts between the three formations are not exposed but the bedding orientations are the same. (B) Cherty mudstone and dolostone are inter-stratified near the base of the Hazen Formation, and the dolostone contains clasts of chert, which is interpreted to indicate that there is a depositional contact between the dolostone of the Aurland Fiord Formation and the cherty mudstone of the Hazen Formation. (C) The Hazen Formation contains multiple horizons of intra-formational breccia.

Figure 6. Outcrop photographs from west Aurland Fiord. (A) The Hazen Formation is overlain by the Svartevaeg Formation and the concordant bedding attitudes are consistent with a depositional contact. (B) The Hazen Formation contains thin beds of chert with a clastic texture.

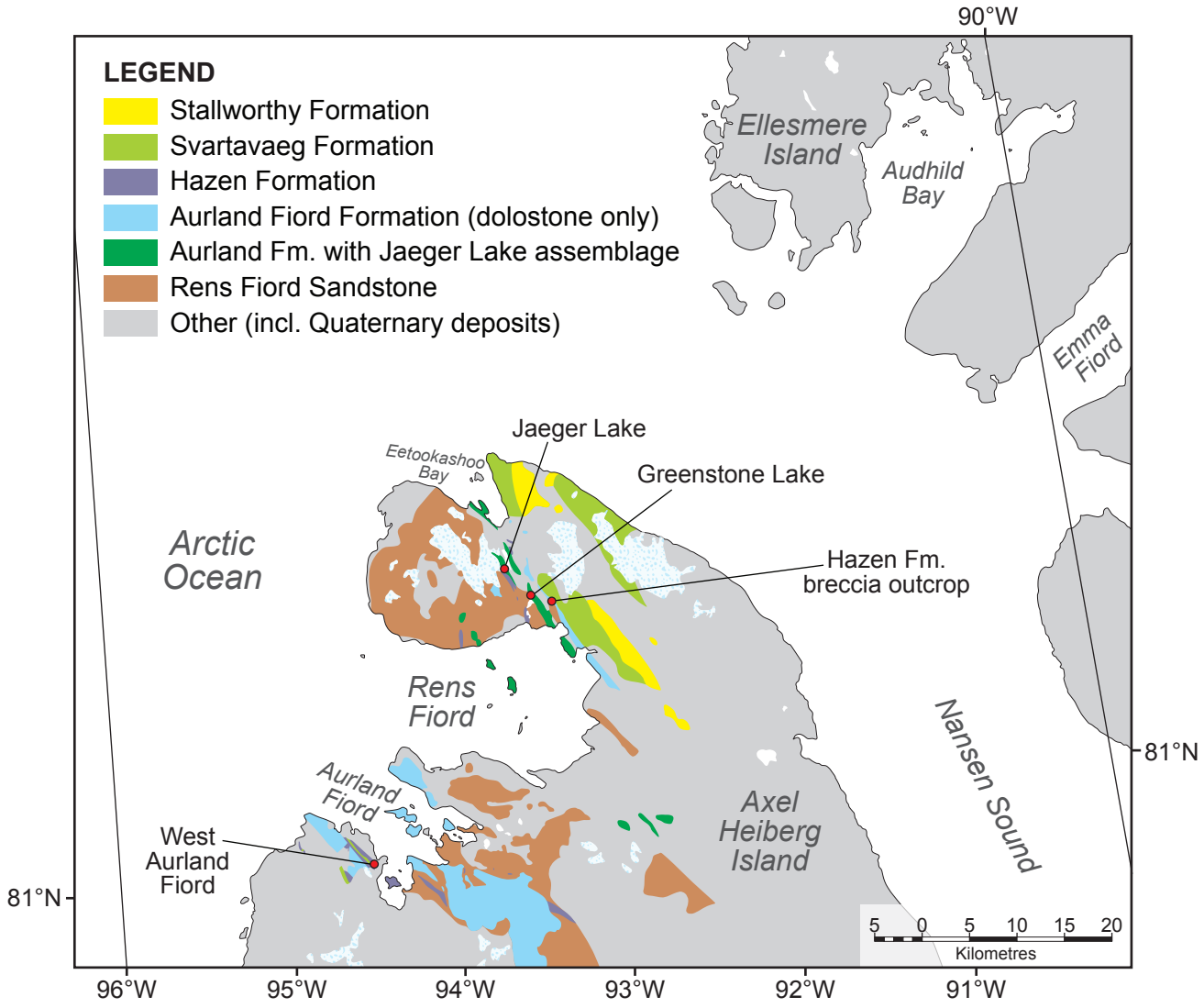
LEGEND
Stallworthy Formation
Svartavaeg Formation
Hazen Formation
Aurland Fiord Formation (dolostone only)
Aurland Fm. with Jaeger Lake assemblage
Rens Fiord Sandstone
Other (incl. Quaternary deposits)
90°W
Ellesmere Island
Audhild Bay
Emma Fiord
Jaeger Lake
Eetookashoo Bay
Greenstone Lake
Arctic Ocean
Hazen Fm. breccia outcrop
Rens Fiord
Nansen Sound
Aurland Fiord
West Aurland Fiord
Axel Heiberg Island
81°N
81°N
5 0 5 10 15 20
Kilometres
96°W
95°W
94°W
93°W
92°W
91°W

Figure 1

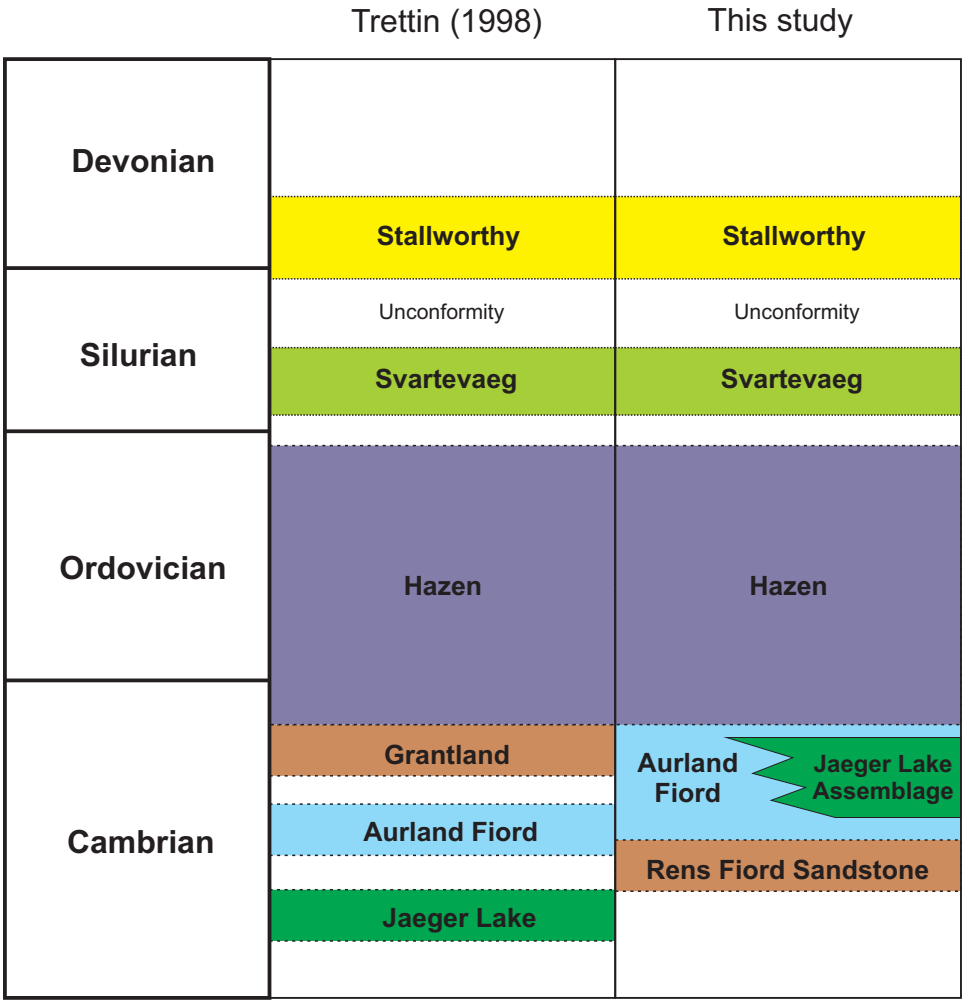
Trettin (1998)
This study
Devonian
Silurian
Ordovician
Cambrian
Stallworthy
Unconformity
Svartevaeg
Hazen
Grantland
Aurland Fiord
Jaeger Lake
Stallworthy
Unconformity
Svartevaeg
Hazen
Aurland Fiord
Jaeger Lake Assemblage
Rens Fiord Sandstone

Figure 2

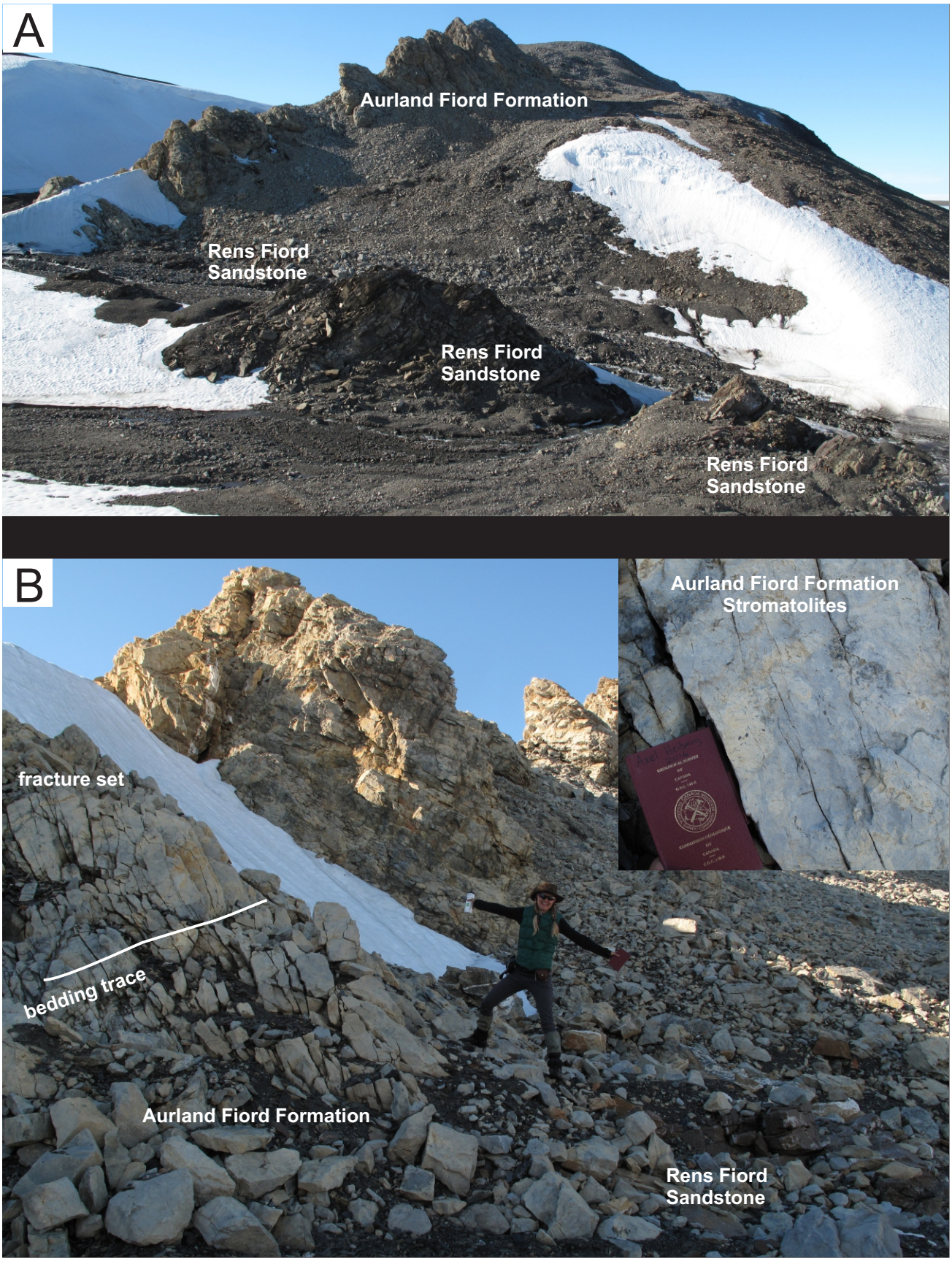
A
Aurland Fiord Formation
Rens Fiord Sandstone
Rens Fiord Sandstone
Rens Fiord Sandstone
B
Aurland Fiord Formation Stromatolites
fracture set
bedding trace
Aurland Fiord Formation
Rens Fiord Sandstone

Figure 3

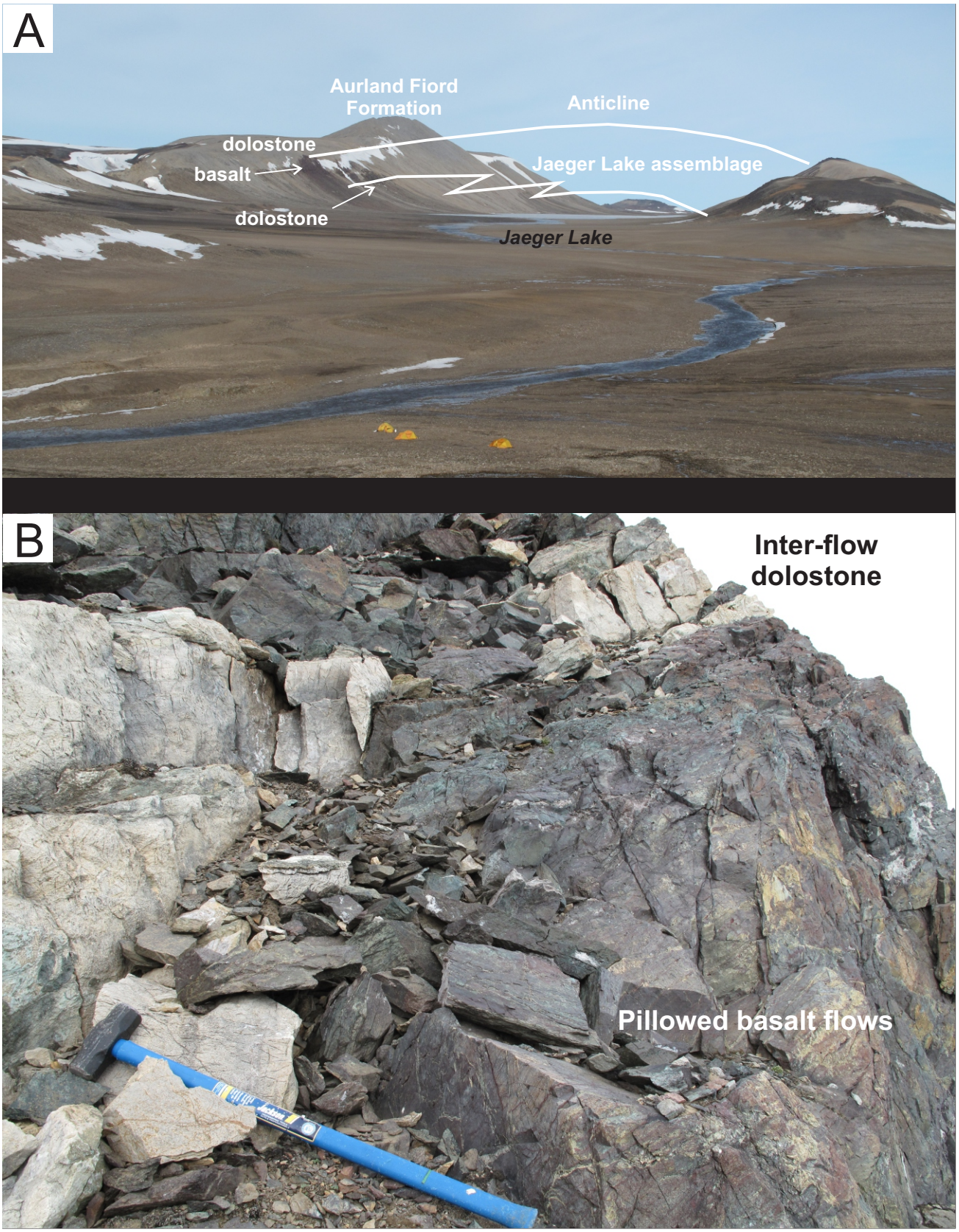
A
Aurland Fiord Formation
Anticline
dolostone
basalt
Jaeger Lake assemblage
dolostone
Jaeger Lake
B
Inter-flow dolostone
Pillowed basalt flows

Figure 4

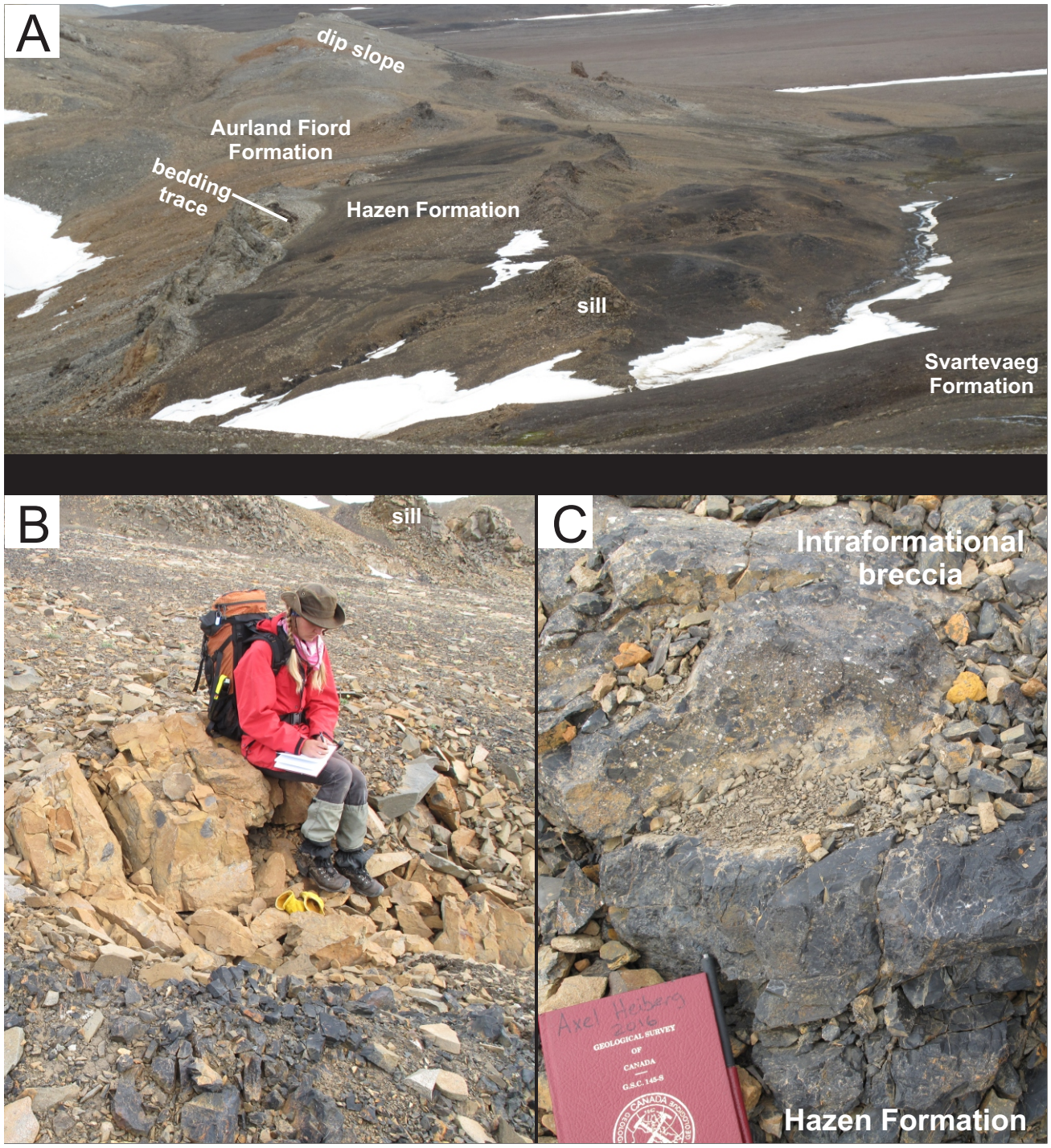
A
dip slope
Aurland Fiord Formation
bedding trace
Hazen Formation
sill
Svartevaeg Formation
B
sill
C
Intraformational breccia
Axel Heiberg 2016
GEOLOGICAL SURVEY OF CANADA
G.S.C. 145-8
Hazen Formation

Figure 5

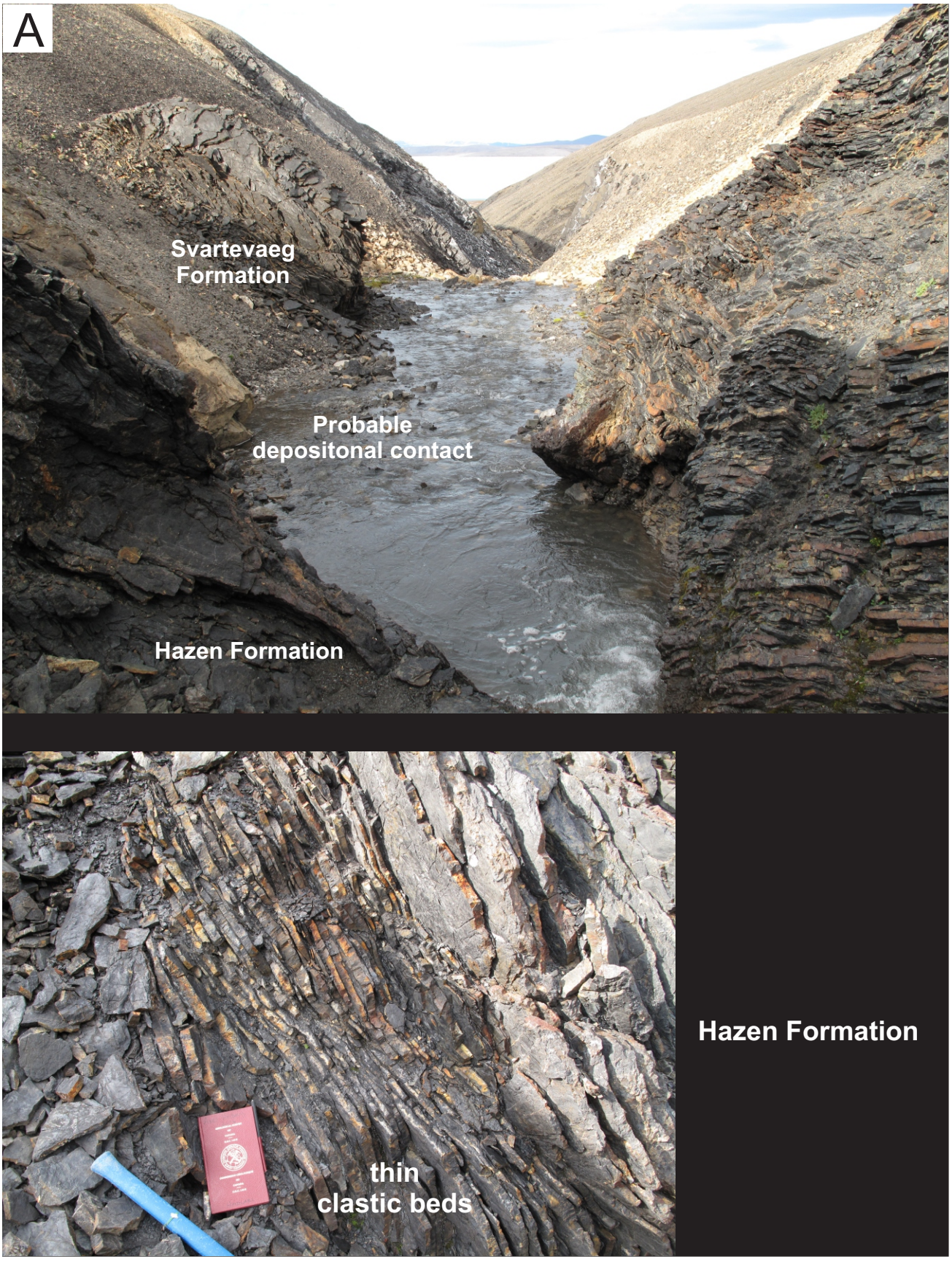
A
Svartevaeg
Formation
Probable
depositonal contact
Hazen Formation
B
thin
clastic beds
Hazen Formation

Figure 6