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Correlation of the Hazen Formation (Lower Cambrian through Silurian) on northeastern Ellesmere Island, northern Nunavut

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Abstract: The Carbonate Member of the slope-and-basin facies Hazen Formation has five subdivisions on northeastern Ellesmere Island. Four of these can be mapped individually and correlated over at least 100 km. The same units are lithologically indistinguishable from strata of North Greenland. Correlated units include the lower and upper parts of the Aftenstjernesø Formation (subdivisions A and B, respectively) and the Henson Gletscher (subdivision C) and Kap Stanton (subdivision D) formations of adjacent Nyboe Land. Biostratigraphic data from the North Greenland sections indicate that the four lower subdivisions of the Hazen Formation are equivalent in age to the Scoresby Bay, Parrish Glacier, and Cass Fjord formations of the adjacent Franklinian shelf succession. An additional constraint on the local upper age limit of the Hazen Formation is provided by a gradational contact with the Cape Clay Formation along the shelf margin.

Résumé : Le Membre carbonaté du faciès de talus et bassin de la Formation de Hazen comprend cinq subdivisions dans le nord-est de l'île d'Ellesmere. On peut en cartographier quatre et les corréler individuellement sur une distance d'au moins 100 km. La lithologie de ces unités est identique à celle de strates du Groenland septentrional. Les unités mises en corrélation sont les parties supérieure et inférieure de la Formation d'Aftenstjernesø (respectivement les subdivisions A et B) ainsi que les formations de Henson Gletscher (subdivision C) et de Kap Stanton (subdivision D) de la région voisine de Nyboe Land. Les données biostratigraphiques de coupes au Groenland septentrional indiquent que les quatre subdivisions inférieures de la Formation de Hazen ont un âge équivalent à celui des formations de Scoresby Bay, de Parrish Glacier et de Cass Fjord de la succession adjacente de la plate-forme franklinienne. La présence d'un contact transitionnel avec la Formation de Cape Clay le long de marge de la plate-forme continentale fournit une contrainte additionnelle pour la limite d'âge supérieure locale de la Formation de Hazen.

INTRODUCTION AND PRESENT WORK

The Geological Survey of Canada, in co-operation with the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) of Hannover, Germany, has recently completed the second of three field seasons intended to update and complete (to 1:125 000 scale) the bedrock geological mapping and supportive geological activities throughout coastal and inland northeastern Ellesmere Island between latitudes 79°00NN and approximately 81°33NN (Fig. 1, 2). An especially significant unit exposed within the project area is the slope-and-basin facies Hazen Formation. Although this is a relatively thin succession, its depositional history spans almost 100 Ma including much of the Cambrian, all of the Ordovician, and over half of the Silurian (Trettin, 1971, 1994). It underlies and is exposed throughout a substantial portion of the Arctic Islands and correlates with at least 10 formations on the adjacent Paleozoic shelf. The Hazen Formation may once have acted as a source for metallogenic brines and hydrocarbons and may contain undiscovered base-metal resources of economic significance. The aim of this contribution is to provide preliminary observations concerning the nature and correlation of the Hazen Formation with age-equivalent portions of the basinal succession in North Greenland and the adjacent shelf succession of northeastern Ellesmere Island. Descriptions of new base-metal sulphide occurrences are provided in a separate report (Harrison et al., 1999).

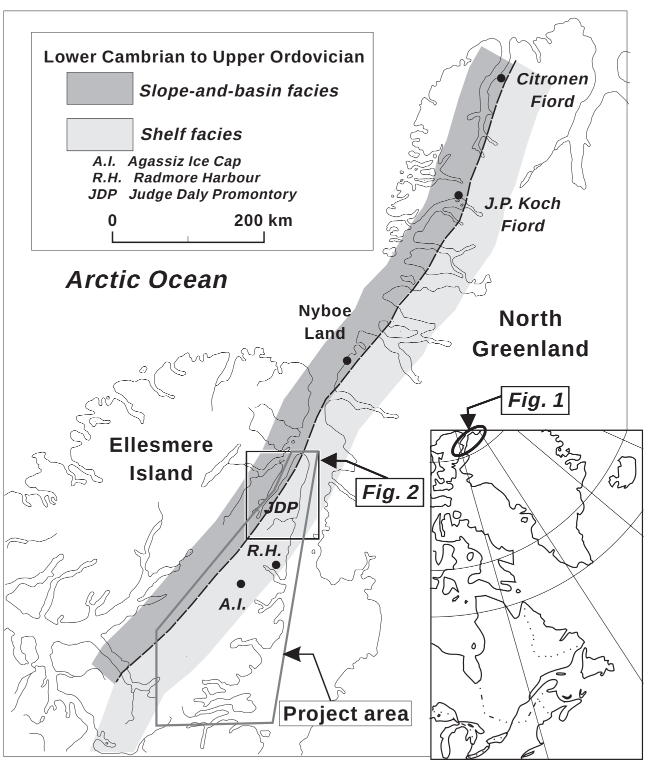

Figure 1. *Project and report area locations relative to the Lower Cambrian through Upper Ordovician shelf edge and other key localities in northern Ellesmere Island and North Greenland.*

GEOLOGICAL SETTING

The exposed succession on Judge Daly Promontory features Lower Cambrian through Silurian shelf, slope, and deep-water-basin strata and three large outliers of Paleocene strata (Fig. 1, 2). The lower Paleozoic is divisible into two distinct geological provinces, 1) a southeastern belt of long-wavelength, open, upright, and southeast-vergent, shallow, southwest-plunging folds developed in a thick succession of light-coloured, weathering-resistant, outer-shelf strata (Central Ellesmere Fold Belt) and 2) a northwestern belt of shorter wavelength, shallow-plunging, tight, asymmetric folds, often overturned to the southeast, composed of a dark-weathering and more recessive succession of slope-and-basin facies strata with a well developed, slaty cleavage (Hazen Fold Belt).

Although the boundary between the two fold belts is locally faulted, opportunities for examining relationships along the associated facies front occur over 65 km from south of Ella Bay to northeast of Twin Glacier. New observations, summarized in this report, were obtained during three weeks of ground traverses northeast of Twin Glacier.

STRATIGRAPHY OF JUDGE DALY PROMONTORY

Outer-shelf succession

The oldest exposed rocks are siliciclastic formations of the Lower Cambrian Ellesmere Group. The upper two units of this succession, assigned to the Rawlings Bay and Kane Basin formations, underlie both the Hazen Formation on the basinal side of the facies front and the Scoresby Bay Formation of the shelf. Older strata, exposed within nunataks of the Agassiz Ice Cap (Fig. 3; de Freitas, 1998), include older units of the Ellesmere Group (Archer Fiord and Ritter Bay formations) and the underlying Ella Bay and Kennedy Channel formations.

After deposition of the Kane Basin Formation, distinct shelf and basin realms persisted throughout the remainder of the Cambrian and all of the Ordovician. The shelf province is dominated by warm-water, open-marine and restricted, shallow-water carbonate rocks and some anhydrite, collectively represented by 10 formations to 3700 m thick. The termination of carbonate deposition on the shelf is marked by Llandovery to Ludlow graptolitic mudstone of the Cape Phillips Formation, which is succeeded by mid-Silurian and younger turbidites of the Danish River Formation. The base of the Danish River Formation is a low-angle unconformity. Beneath this surface, the thickness of the Cape Phillips Formation ranges from 8 m near station HBB-99-157 to 380 m

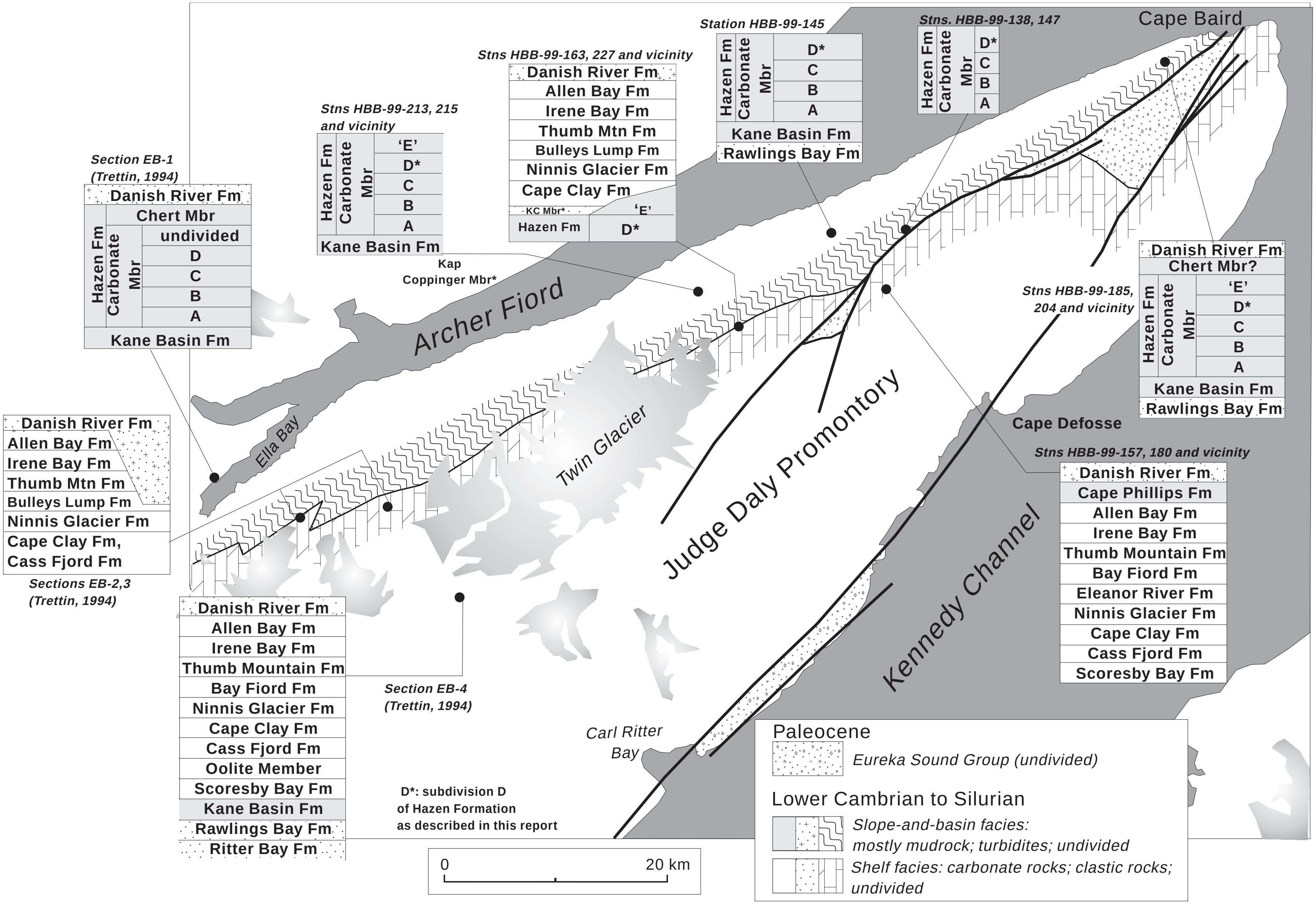

Figure 2. *Mapped stratigraphic units at selected localities on Judge Daly Promontory, northeastern Ellesmere Island (see map area in Fig. 1).*

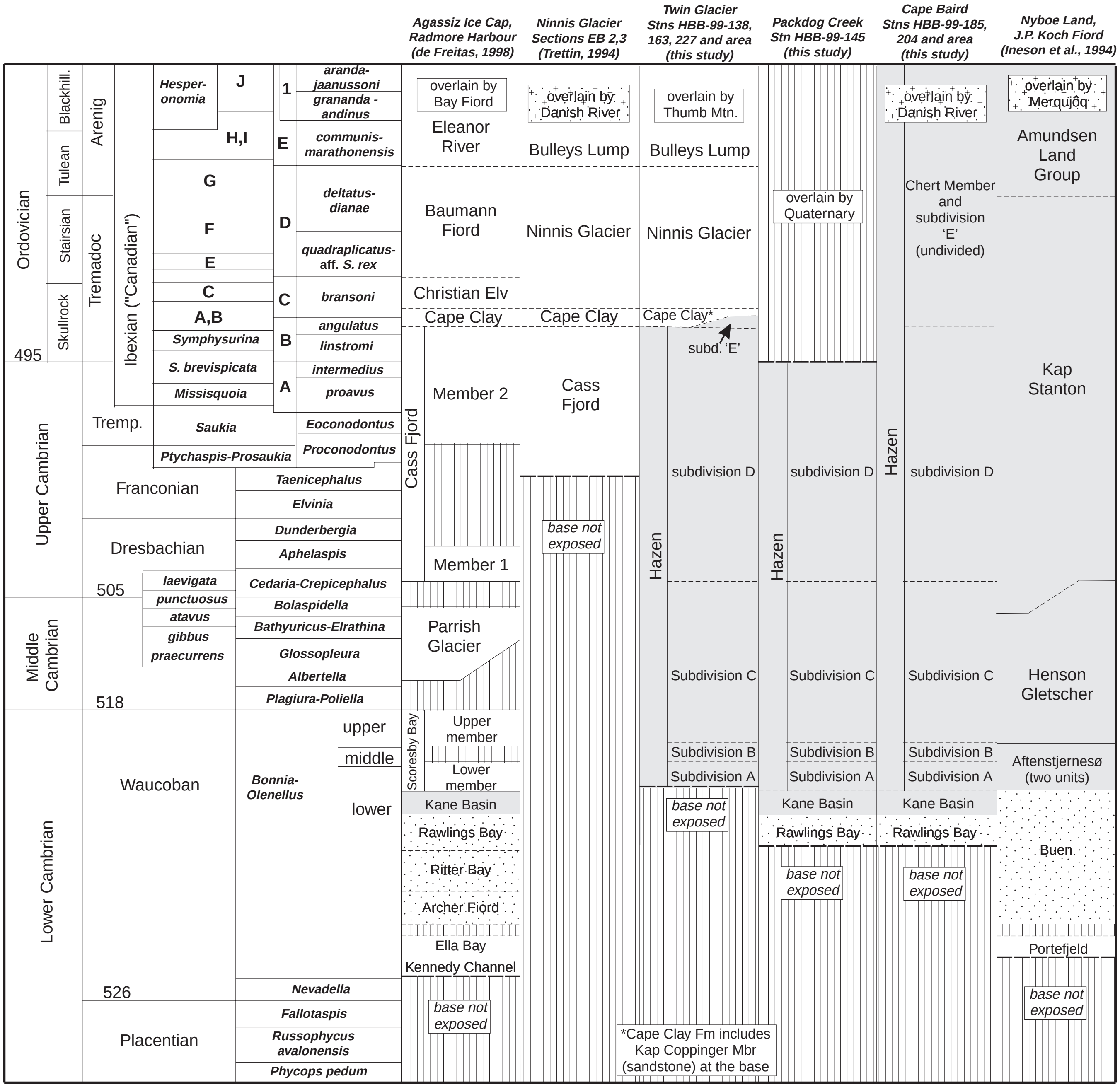

Figure 3. *Correlation of Lower Cambrian through Lower Ordovician strata of northeastern Ellesmere Island and North Greenland. Biozones are from de Freitas et al. (1997).* See *Figure 2 for legend of fill patterns.*

near Cape Defosse (Fig. 2). Elsewhere, the Danish River Formation unconformably overlies the shelf-edge Allen Bay Formation.

The Ordovician portion of the shelf-edge succession has prograded out over Cambrian basin-slope deposits and, in outcrops southeast of Ella Bay, features a submarine escarpment the upper surface of which is mostly concealed beneath Danish River Formation turbidites (section EB-2 of Trettin, 1994; Fig. 2).

Basin-fill succession

Basin-fill strata above the Kane Basin Formation on Judge Daly Promontory are primarily represented by the Hazen Formation, which includes a lower Carbonate Member and, at the head of Ella Bay, the Chert Member (Trettin, 1994). This is a highly condensed succession of pyrite-rich mudstone, bedded chert, slope carbonate rocks, breccia, and minor deep-water sandstone. The Carbonate Member of the Hazen Formation is the youngest preserved portion of the basinal succession throughout much of northeastern Judge Daly Promontory. Exceptions include the Cape Baird region, examined by us in 1999, and other areas mapped by Trettin (1994) southeast of Ella Bay, where one or another member of the Hazen Formation is overlain by the Danish River Formation. Trettin (1994) also recognized that the Carbonate Member southeast of Ella Bay was overlain by the Bulleys Lump Formation of the outer-shelf succession or by the undivided Cass Fjord and Cape Clay formations. Our own field work northeast of Twin Glacier recognizes similar relationships of the Hazen Formation to the shelf edge. At station HBB-99-227, the Hazen Formation is gradationally overlain by the Cape Clay Formation and dark-coloured, outer-shelf mudstone interfingers with tongues of shallow-water limestone along strike. Elsewhere (at station HBB-99-171), the Hazen Formation is overlain by 20 m of trough-cross-stratified, coarse-grained, mature quartz sandstone tentatively assigned to the Kap Coppinger Member of the uppermost Cass Fjord Formation (de Freitas et al., 1997). Here the contact is abrupt and may be disconformable. However, there is no biostratigraphic proof of this relationship.

The Carbonate Member of the Hazen Formation on northeastern Judge Daly Promontory is subdivided into five regionally mapped units (Fig. 2 to 6). These include the Cambrian subdivisions A, B, C, and D of Trettin (1994) and a fifth subdivision, here informally labelled as subdivision 'E', which is mostly Ordovician.

DESCRIPTION OF MAPPED UNITS OF THE HAZEN FORMATION

Subdivision A

Trettin (1994) measured subdivision A in five sections around the head of Ella Bay. This dark grey, recessive succession is composed of interbedded mudstone, lime mudstone, calcarenite, and sandstone and ranges in thickness from 163.5 m in the southwest to 70.0 m in the northeast. Similar strata were examined during the 1999 field season at 18 new localities and mapped over 48 km between Twin Glacier and Cape Baird (Fig. 2, 4, 5a–c, 6a). As field work was primarily directed towards regional-scale bedrock mapping and an evaluation of resource potential, there was no opportunity to measure a complete section. However, the range in thickness seems to be similar to that encountered to the southwest. The base of subdivision A is drawn above the Kane Basin Formation where interbedded, dark grey to black, slaty mudstone and lime mudstone replace dark greenish-grey, siliceous mudstone, siltstone, and fine-grained, micaceous, argillaceous sandstone as the dominant components in the section.

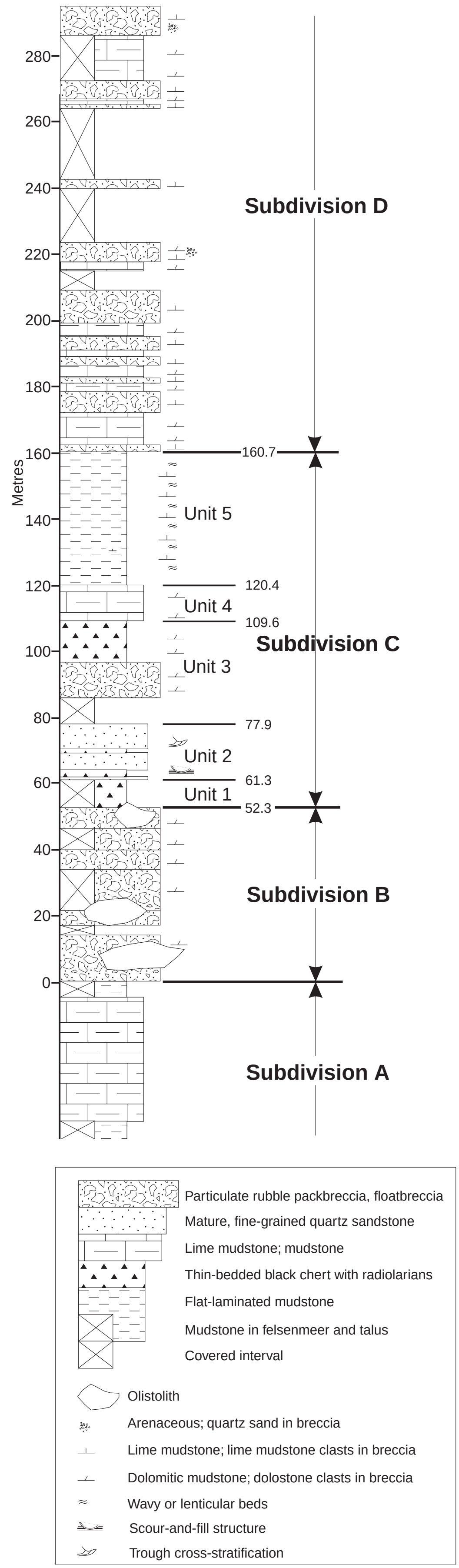

Figure 4. *Measured section of the Hazen Formation at station HBB-99-138 (position shown* in *Fig. 2 and Table 1). Subdivision A is based on observations near station HBB-99-147.*

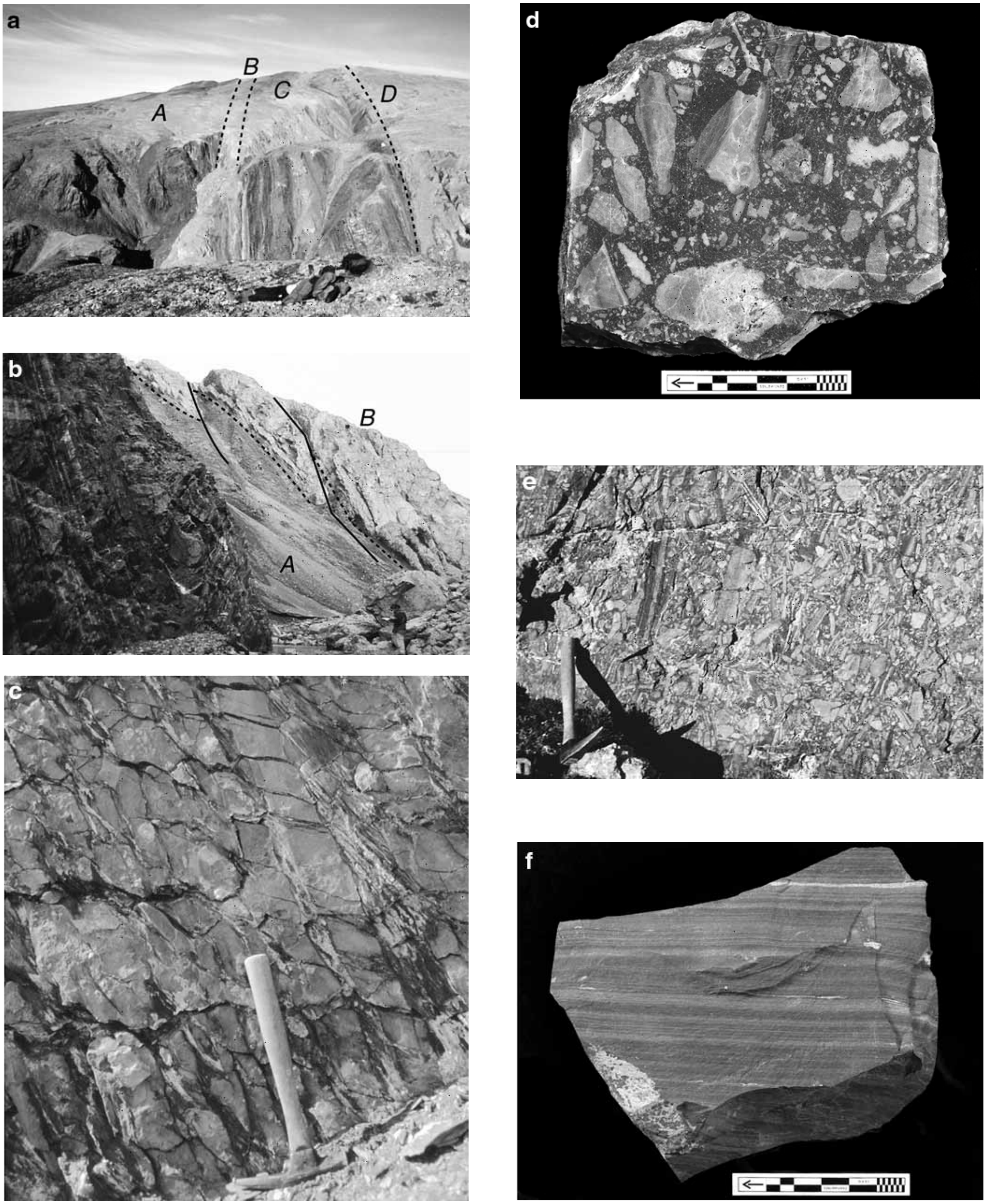

***Figure 5. a)** Subdivisions A through D of the Hazen Formation at station HBB-99-145 on Packdog Creek; **b)** subdivisions A and B of the Hazen Formation at station HBB-99-138; **c)** slaty mudstone and lime mudstone of subdivision A; **d, e)** outcrop and hand specimen of dolomitized, particulate rubble packbreccia of subdivision B; **f)** flat-laminated, pyritic mudstone of upper subdivision C (station HBB-99-185).*

Table 1. Location of stations mentioned in the text.

Station	Latitude (N)	Longitiude (W)
HBB-99-121	81°25.02′	66°07.55′
HBB-99-138	81°22.01′	66°28.90′
HBB-99-142	81°20.74′	66°41.22′
HBB-99-145	81°21.32′	66°50.83′
HBB-99-147	81°21.35′	66°9.60′
HBB-99-150	81°21.22′	66°29.38′
HBB-99-157	81°19.47′	66°34.31′
HBB-99-163	81°17.04′	66°54.16′
HBB-99-171	81°18.16′	66°56.66′
HBB-99-180	81°17.36′	66°43.15′
HBB-99-185	81°29.13′	65°25.56′
HBB-99-204	81°30.52′	66°08.12′
HBB-99-213	81°17.53′	67°27.87′
HBB-99-215	81°17.75′	67°26.09′
HBB-99-227	81°16.32′	66°20.82′

The contact, interpreted to be either a downlap surface or the base of a condensed interval, is relatively sharp, but apparently conformable.

A closely spaced slaty cleavage is the dominant fabric in outcrop and talus. However, compositional flat lamination without bioturbation is well preserved and obvious on transecting cleavage surfaces. This is especially true in the lower part of subdivision A where dark grey slaty mudstone is dominant. Interbeds of dark-yellowish-brown-weathering lime mudstone (each 5 to 10 cm thick) gradationally replace slaty mudstone in the upper half of subdivision A and account for 40% to 60% of the section from 5 to 40 m below the upper contact. In this interval, lime-mudstone beds are slightly wavy with a tendency to form lenses. Transecting cleavage surfaces are only well developed in thin (1 to 5 cm) mudstone interbeds, but a refracted spaced cleavage also exists in the lime-mudstone beds (Fig. 5c). The upper 5 m of subdivision A is dominated by dark grey, graphitic, slaty mudstone and, for this reason, often forms a recessive or covered interval between the underlying lime mudstones and the talus or cliffs of overlying subdivision B (Fig. 5a, b).

Subdivision B

Subdivision B of Trettin (1994) features 9.0 to 26.0 m of light-grey-weathering granule and cobble conglomerate. Thickness decreases towards the north and northeast in the five Ella Bay area sections.

Correlative strata, also assigned to subdivision B, are now identified throughout northeastern Judge Daly Promontory with exposure distribution and examined sections similar to those of subdivision A. Thickness ranges from 52.5 m at station HBB-99-138 (Fig. 4) to approximately 4 m in the Cape Baird area (station HBB-99-185; Fig. 2). Sections northeast of Twin Glacier (estimated thickness 8–10 m at station HBB-99-213) and on lower Packdog Creek (estimated thickness 10–15 m at station HBB-99-145) are also significantly thinner than those close to the Cambrian shelf edge. The dominant rock type is medium-yellowish-grey-weathering, cliff-forming rubble packbreccia and lesser floatbreccia (Morrow, 1982) invariably featuring a dark grey, dolomitized, particulate matrix (Fig. 5d, e) and up to 5% vuggy to cavernous voids (to 1 cm in size). The basal contact is a sharp, probably channelized, submarine erosion surface. These deposits are internally unstratified with only a general alignment of some clast long axes parallel to bedding surfaces. The entire subdivision is often represented by only a single thick bed. However, the section at station HBB-99-138 features six separate beds, with thicknesses ranging from 3.4 to 14.0 m (Fig. 4). Eighty to ninety per cent of the clasts are angular to subangular, compositionally flat-laminated, medium- to dark-grey- and yellowish-brown-weathering dolostones. Clast elongation is parallel to the internal compositional lamination. The remaining clasts are pale-brown-weathering dolostones that lack compositional lamination and are more equidimensional. Clasts of all types are mostly less than 20 cm long, but occasionally more than 1 m long, and an exposure at station HBB-99-147 contains a probable slide block of shelf-derived, pale-yellow-weathering, moderately crystalline dolostone with a strike length of 165 m.

Subdivision C

Trettin's (1994) subdivision C ranges in thickness from 19.5 m to 66.5 m as determined in four sections around the head of Ella Bay. Directions of thinning are similar to those of the underlying subdivisions. Two units of similar thickness were recognized in that area: a lower unit (C_1) of mostly radiolarian chert, minor mudstone, lime mudstone, and calcarenite, and an upper unit (C_2) of mudstone with minor lime mudstone and calcarenite. A similar distribution of chert and mudstone is recognized in sections of subdivision C throughout northeastern Judge Daly Promontory where the full thickness ranges from about 30 m to 145 m. The measured thickness at station HBB-99-138 is 108.4 m (Fig. 4). Sections contain at least two progradational cycles with the lower part of a third cycle located below the gradational upper contact. Units of regional significance include the following:

Unit 5

Unit 5 is a recessive, dark grey, laminated, slaty mudstone with common wavy beds, lenses, and flattened lenticular nodules of crossfibre, calcite-encased, lime mudstone (15 m to an estimated 120 m thick). Lime-mudstone interbeds are thicker and more abundant in the upper part of the unit. The thickness of sections closest to the shelf edge ranges from 100 to 120 m (station HBB-99-150, HBB-99-142). The unit is thinner and has abundant, flat-laminated, pyritic mudstone (Fig. 5f) in sections farther northwest. The basal contact is sharp, but likely conformable.

Unit 4

Unit 4 is a thick-bedded, dark-yellowish-brown- and dark-grey-weathering, resistant, dolomitic mudstone with minor intercalated radiolarian chert (total thickness 5 to

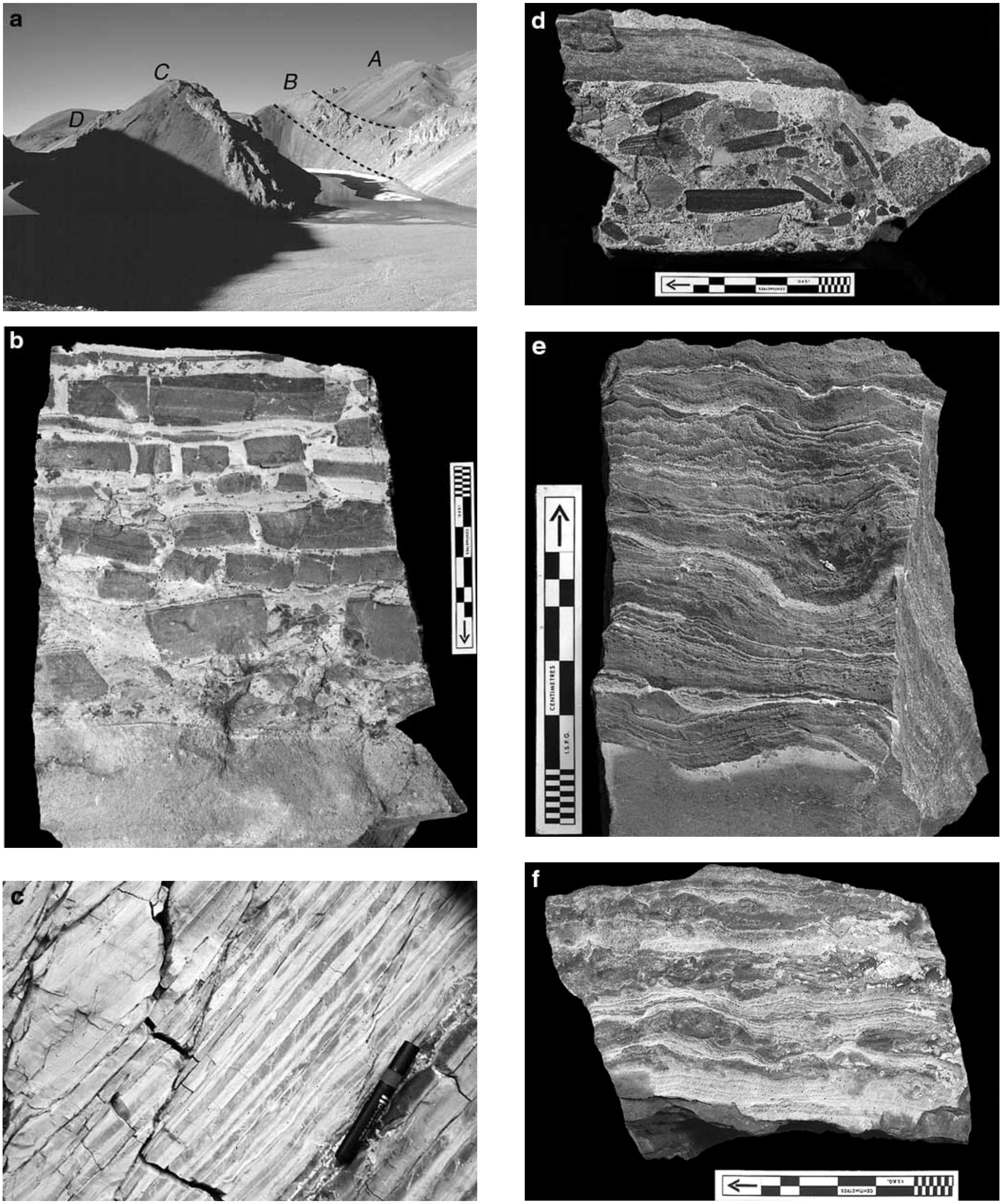

Figure 6. a) *Subdivisions A through D of the Hazen Formation near station HBB-99-150;* ***b)*** *hand specimen of subdivision D mudstone showing incipient brecciation and pull-apart of thin lime-mudstone beds;* ***c)*** *thin-bedded lime mudstone and dolomitic lime mudstone of subdivision D;* ***d)*** *particulate rubble float breccia with a coarse, arenaceous, sand matrix (subdivision 'E'; station HBB-99-204);* ***e, f)*** *hand specimens of flat-laminated, slaty, lime mudstone of subdivision 'E' (station HBB-99-215).*

20 m). The thickest sections lie in outcrops closest to the Cambrian shelf edge (Fig. 6a). The basal contact is gradational.

Unit 3

Unit 3 (about 10 to 32 m thick) is a radiolarian chert with lesser slaty mudstone, partly chertified dolomitic mudstone, and minor argillaceous quartz sandstone. Several sections contain one or more, mostly thin, packbreccia (debris-flow) beds including one 10 m thick at station HBB-99-138 (Fig. 4). Laminated, pyritic mudstone is especially significant in sections farther to the northwest. Dark grey, dolomitic mudstone smells of sulphur on fresh surfaces. The basal contact is sharp.

Unit 2

Unit 2 is a fine-grained quartz sandstone 4 to 14 m thick, with a sparse, dark grey, presumably argillaceous matrix. The arenaceous grains are exceptionally well rounded and apparently compositionally mature, although this must be confirmed microscopically. Individual beds range in thickness from several centimetres to several tens of centimetres and are often interbedded with minor chert or slaty mudstone. The unit pinches and swells significantly along strike. The basal contact is locally gradational and, where this is the case, comprises thin sandstone beds with interbedded chert.

Unit 1

Unit 1 comprises black radiolarian chert, black pyritic and sulphurous dolostone, lime mudstone, and flat-laminated, pyritic, slaty mudstone up to 8 m thick. Limonite staining and gossans are common. The basal contact above subdivision B is sharp, but likely conformable.

Subdivision D

Trettin (1994) restricted the definition of subdivision D to the first carbonate conglomerate unit above mudstones of subdivision C, but also measured additional beds of lime mudstone and limestone-clast conglomerate through the overlying succession. Although the first occurrence of breccia and/or conglomerate serves as a useful definition for the base of subdivision D, the lowest such beds at station HBB-99-138 (Fig. 4) and elsewhere are often thin and lie anywhere up to 15 m below the first resistant breccia marker. As all such breccia beds are generally indistinguishable from one another, apart from differences in thickness, there is no practical reason for attempting to name and correlate just one of these. For this reason and others, we recommend modifying subdivision D to include the entire mappable unit of lime mudstones and breccia beds that lie above subdivision C throughout northeastern Judge Daly Promontory. Graphic estimates of thickness for the redefinable subdivision D succession range from 290 m near Cape Baird to at least 350 to 400 m in sections north of Twin Glacier.

There are two dominant facies: 1) a medium-grey-weathering lime mudstone cyclically interbedded with medium-yellowish-grey- to yellowish-orange-weathering, flat-laminated, dolomitic and lime-dolomitic mudstone and 2) a particulate rubble packbreccia with lesser floatbreccia (Fig. 6b). The section at station HBB-99-138 represents the lower 134.0 m of our subdivision D. Breccia, mudstone, and covered intervals represent 36%, 24%, and 40%, respectively, of this section. The breccias are represented by 13 exposed beds 20 cm to 10.2 m thick. Sections farther northeast and higher in the package are more uniformly dominated by laminated and thin-bedded lime mudstone and dolomitic mudstone.

The relative proportion of lime mudstone and dolomitic mudstone in the breccia beds about matches the alternating facies that are uniformly arranged in sharply bound couplets 1 to 5 cm thick (Fig. 6c). These rocks are not bioturbated, but selective soft-sediment deformation is common. Neither type of mudstone shows a preferred tendency to differential weathering and the derived platy to flaggy talus is dominated by a spaced cleavage that transects bedding.

The formation of breccia beds in our subdivision D is clearly related to basin-slope movements, since it is possible to identify, in outcrop and talus, all transitional states from coherent lime-mudstone beds through beds that have been fractured yet remain intact, pulled apart or boudinaged under soft-sediment conditions, moderately to intensely rotated, or intensely churned. The lime-mudstone beds tend to have been cemented earlier and for this reason represent the dominant clast composition in the resulting breccia bodies. Breccia clasts are up to 50 cm or more in length and their long axes are parallel to contained compositional lamination. Dolomitic silt and sand apparently remained uncemented during the brecciation process and dominate the breccia matrix. Breccia beds are generally unstructured, but individual clasts may show a crude alignment parallel to the surfaces of the bounding beds. Some breccia bodies contain significant quantities of fine to coarse quartz sand. These beds are associated with intervals of unstructured, compositionally mature quartz sandstones with a more or less calcareous cement. The lateral continuity of individual breccia bodies and the usual sharp contacts between these beds and intervening mudstones indicate that many breccia bodies have likely moved downslope as chaotic slope-failure sheet deposits.

Subdivision 'E'

Trettin (1994) has indicated that carbonate conglomerate and chert, respectively typical of the lower and upper members of the Hazen Formation, terminate to the southeast in the sections close to the shelf edge southeast of Ella Bay and are replaced by a laminated facies of the Carbonate Member consisting of fine-grained carbonate and siliciclastic rocks (map unit $CO_{H1\text{-}lam}$). Our current work northeast of Twin Glacier has shown that the presence of subdivisions A through C cannot be confirmed in some areas close to the shelf margin because of a conformable cover of younger strata and that breccia beds are less common in the upper part of our subdivision D. Field work in 1999 established the existence of a fifth unit of the Carbonate Member of the Hazen Formation, which we refer to here as subdivision 'E'. These rocks are the youngest preserved in a syncline northeast of Twin Glacier and are present immediately below progradational Lower Ordovician shelf carbonate rocks along the facies front to the southeast. Subdivision 'E' conformably overlies strata of our subdivision D in all these areas.

Subdivision 'E' is dominated by dark grey, flat-laminated, slaty mudstone and slaty lime mudstone (Fig. 6e, f). It is distinguished from subdivision D because it is darker and less resistant and contains no yellowish-grey-weathering, dolomitic mudstone. Lamination is mostly flat and parallel. However, a slightly wavy or crinkly lamination is common and laminae have been modified by centimetre-scale masses and irregular knots of laminae-parallel, diagenetic carbonate. Bioturbation and horizontal surface traces are observed throughout this unit where it is succeeded by the Cape Clay Formation at station HBB-99-227. Several as yet unidentified trilobite specimens have been collected where the rocks are free of cleavage. The contact with the Cape Clay Formation is gradational and represented by an upsection increase in the proportion and thickness of lime-mudstone and skeletal lime-wackestone beds. The upper part of subdivision 'E' also becomes lighter coloured closer to the upper contact.

Dark-coloured lime mudstone and mudstone are also present above our subdivision D near Cape Baird. Although they are tentatively included with subdivision 'E', an associated outcrop of bedded chert and several prominent carbonate-breccia beds (Fig. 6d) may be more appropriately assigned to the Chert Member of the Hazen Formation. Although stratigraphic relationships in this area remain unresolved in part because of inadequate outcrop and insufficient field work, it is clear that the Hazen Formation is overlain by turbiditic sandstones of the Danish River Formation.

AGE AND CORRELATION OF THE HAZEN FORMATION

Correlation with North Greenland

Including localities near Ella Bay, subdivisions A through D and possibly subdivision 'E' have now been mapped and are continuous over a strike length of at least 100 km with no indication that they should not continue beyond this area to the southwest beneath the Agassiz Ice Cap or to the northeast towards North Greenland. From the occurrence of *Olenellus* sp. in section EB1 near Ella Bay and trilobites of olenellid aspect at 10 m above the base at station HBB-99-121, subdivision A seems to be late Early Cambrian (probable *Bonnia-Olenellus* Zone). Subdivisions B, C, D, and 'E' are not younger than the overlying Cape Clay Formation, which contains early to middle Tremadoc conodonts in Trettin's (1994) section EB4 southeast of Ella Bay.

Additional age constraints are provided by correlative sections described from northern Nyboe Land and J.P. Koch Fiord in North Greenland (Fig. 3; Ineson et al., 1994). Subdivisions A and B are lithologically similar to the Aftenstjernesø Formation (about 62 m thick), which includes a lower succession of dark-coloured, nodular lime mudstones or dolostones and a persistent capping marker of carbonate breccia. The Aftenstjernesø Formation overlies greenish-grey, siliciclastic mudstones of the Buen Formation, beds that closely resemble those of the Kane Basin Formation on Judge Daly Promontory. The basal strata of the Aftenstjernesø Formation contain a diverse *Bonnia-Olenellus* Zone fauna.

The Aftenstjernesø Formation is succeeded by the Henson Gletscher Formation (20 to 90 m thick) in northern Nyboe Land and on J.P. Koch Fiord, which, like subdivision C, features a starved succession of black chert, black lime mudstone, shaly mudstone, and dolostone with intervals of white, pale grey, and yellow sandstone in the lower and middle parts of the formation and parallel-laminated and nodular limestone and mudstone in the upper part. The Henson Gletscher Formation includes fauna of the *Bonnia-Olennellus*, *Glossopleura*, *gibbus*, and *atavus* zones and therefore ranges from late Early Cambrian through Middle Cambrian. The upper contact is diachronous and, on J.P. Koch Fiord, climbs from the *gibbus* Zone nearest the platform (middle Middle Cambrian) to the *laevigata* Zone in the north (latest Middle Cambrian).

The Kap Stanton Formation (100 to 350 m thick) gradationally overlies the Henson Gletscher Formation and, like our subdivision D, has an identical range of parallel-laminated, argillaceous carbonate rocks with pull-apart features and intraformational breccia beds. Its age ranges from not older than middle Middle Cambrian at the base on J.P. Koch Fiord to not older than late Tremadoc at the top in northeastern Nyboe Land.

The Kap Stanton Formation is succeeded by the Amundsen Land Group, which is lithologically similar to subdivision 'E' and the highest part of the Hazen Formation below the Danish River Formation near Cape Baird.

Correlation with the shelf succession

The age of the Cambrian and Lower Ordovician outer-shelf succession is provided by Trettin (1994) and de Freitas (1998) and is summarized on the correlation charts of de Freitas et al. (1997). The age of the various subdivisions of the Hazen Formation is based on presumed equivalence with similar fossiliferous strata of North Greenland as indicated in the preceding section (Fig. 3).

Subdivision A and the lower part of the Aftenstjernesø Formation are correlated with the lower member of the Scoresby Bay Formation. he upward increase in the quantity of nodular lime mudstone in subdivision A suggests that the lower member of the Scoresby Bay Formation prograded basinward. On this evidence, the Scoresby Bay is likely to be found gradationally overlying a tongue of transgressive and slope-facies Hazen Formation.

Subdivision B and the breccia marker in the upper Aftenstjernesø Formation correlate with an erosional hiatus above the lower member of the Scoresby Bay Formation; these deposits may have been produced by a drop in the relative sea level below the shelf–slope break and a resulting widespread excavation and transport of shelf-edge and upper-slope materials into deep water.

The Henson Gletscher Formation and subdivision C (which features at least two depositional sequences and the lower part of a third) correlate with the upper member of the Scoresby Bay Formation, the Parrish Glacier Formation, a hiatus above the Parrish Glacier Formation, and potentially some part of Member 1 of the Cass Fiord Formation. Deep-water sandstones, noted in both the Henson Gletscher Formation and in subdivision C, may have been transported basinward during sea-level lowstands that coincided with the development of shelf disconformities that formed above each of the correlative shelf units.

Our subdivision D and the lower part of the Kap Stanton Formation correlate with the Cass Fjord Formation. Although a disconformity is suspected to exist between the two members of the Cass Fjord, no separate or corresponding depositional interval has been recognized within subdivision D. Periodic shelf exposure is suggested by the occurrence of quartz sand as a common matrix constituent of some breccia beds in the lower and middle parts of subdivision D.

Subdivision ‘E’ is overlain by the progradational Cape Clay Formation northeast of Twin Glacier and is therefore likely to be laterally correlated with these strata. The Amundsen Land Group and subdivision ‘E’ near Cape Baird may also be equivalent in age to the Cape Clay Formation and to all the succeeding shelf units below the Danish River Formation, including the Ninnis Glacier, Bulleys Lump, Eleanor River, Bay Fiord, Thumb Mountain, Irene Bay, Allen Bay, and Cape Phillips formations. Subdivision ‘E’ may prove to be locally equivalent to map unit $CO_{H1\text{-}lam}$ of Trettin (1994) and, like that unit, probably grades basinward into the Chert Member of the Hazen Formation.

CONCLUSIONS AND RECOMMENDATIONS

It is recommended that the Hazen Formation be raised to group status and the lower four of its five subdivisions be given formational rank as each can be correlated and mapped over at least 100 km on Ellesmere Island and their limits are governed by the extent of ocean and ice cover rather than by facies constraints. First consideration should be given to extending the use of stratigraphic terms erected for more or less identical strata in adjacent portions of North Greenland. These include: subdivision A = lower part of Aftenstjernesø Formation; subdivision B = upper part of Afternstjernesø Formation; subdivision C = Henson Gletscher Formation; our subdivision D = Kap Stanton Formation. Subdivision ‘E’ (map unit $CO_{H1\text{-}lam}$) should remain informal until the relationship of this unit to the Chert Member of the Hazen Formation and the Amundsen Land Group in North Greenland is better understood.

The primary intention of this paper was to provide new field results about the stratigraphy and correlation of the Hazen Formation. Although stratigraphic revisions may be appropriate, readers should note that the comments here on this subject are only recommendations. The formal adoption of any of these revisions must await the future publication of a more complete document dealing with the Paleozoic strata of northeastern Ellesmere Island.

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