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Preliminary observations on the Cenozoic outliers of northeastern Ellesmere Island, Nunavut: sedimentology and stratigraphy of the syntectonic conglomerate units

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Abstract

Statistical and paleocurrent evidence provides insight into the origin of three (?) Late Paleocene conglomerate units of the Eurekan Orogen on Ellesmere Island. Point-count data display three distinct compositional trends within each area and reveal that the Cape Lawrence and Cape Back conglomerate units were likely derived from carbonate and siliciclastic rocks of Ordovician and Cambrian age, respectively. An abundance of siliciclastic rocks in the upper half of these successions suggests a normal unroofing scenario, as younger Ordovician carbonate clasts prevail below. A similar sequence (in addition to Silurian carbonate clasts) is observed at Franklin Pierce Bay, where paleocurrent directions show an east and southeast transport direction. In contrast, north to northeast directions dominate at Cape Lawrence whereas northeast, southwest, and northwest directions dominate at Cape Back. These paleocurrent variations correspond to changes in rock types.

Résumé

Dans la région de l'orogène eurékien, dans l'île d'Ellesmere, de nouvelles données statistiques et des preuves de l'existence de paléocourants donnent un meilleur aperçu de l'origine de trois unités conglomératiques du Paléocène tardif. Des données de comptage de points ont mis en évidence trois tendances de composition distinctes dans chaque secteur et révèlent que les unités conglomératiques du cap Lawrence et du cap Back dérivent vraisemblablement de roches carbonatées et silicoclastiques, respectivement de l'Ordovicien et du Cambrien. L'abondance des roches silicoclastiques dans la moitié supérieure de ces successions semble indiquer qu'une séquence d'érosion normale s'y est produite, puisque les fragments de roches carbonatées plus récents de l'Ordovicien prévalent dans la moitié inférieure. Une séquence semblable (en plus de clastes carbonatés du Silurien) s'observe dans la baie Franklin-Pierce. À cet endroit, les orientations des paléocourants montrent que le transport s'est effectué vers l'est et le sud-est. Au cap Lawrence, elles témoignent d'un transport allant de vers le nord à vers le nord-est, tandis que, au cap Back, elles permettent d'interpréter un transport vers le nord-est, le sud-ouest et le nord-ouest. Ces variations dans l'orientation des paléocourants correspondent aux changements lithologiques.

INTRODUCTION

Cenozoic syntectonic conglomerate units form impressive cliffs along the northeastern coast of Ellesmere Island. Their age and depositional history are not well known despite previous work at Cape Back, Cape Lawrence, and Franklin Pierce Bay by Miall (1979, 1982, 1984, 1988, 1991), Mayr and deVries (1982), Ricketts (1988, 1994), de Freitas et al. (1997), and de Freitas and Sweet (1998). This paper describes the composition and stratigraphy of these conglomerate units from detailed measured sections, systematic point counts, and paleocurrent measurements carried out during the 1999 and 2000 field seasons in three areas on northeastern Ellesmere Island (Fig. 1). The work was done in conjunction with the Geological Survey of Canada as part of their objective to produce a 1:250 000 bedrock geology map of the area.

These conglomerate units have been designated to the Cape Lawrence Formation as suggested by Miall (1986) and to the Buchanan Lake Formation as suggested by Ricketts (1994). Miall's nomenclature was adopted for this paper and the conglomerate units are be referred to herein as the 'Cape Lawrence Formation'.

LITHOLOGY

Cape Back area

The conglomerate at Cape Back occurs at the southern end of the Judge Daly Basin and forms resistant cliffs along the coast of Nares Strait. This polymictic orthoconglomerate is 711 m thick (the top is eroded) and comprises mainly carbonate clasts with lesser siliciclastic content. It is bounded to the east by a northeasterly striking (?)normal fault and to the west by a steeply dipping reverse fault (Miall, 1982) that brings Ordovician and Silurian carbonate rocks to the surface.

The clasts are poorly sorted, angular to rounded with low sphericity. Concavo-convex grain boundaries are prevalent with local point-to-point contacts. The maximum clast size is 60 cm. Clast types vary greatly and can be grouped into four siliciclastic varieties including mudrock, sandstone, quartzite, and conglomerate, and eight carbonate varieties including micrite, laminated limestone, wackestone-packstone, grainstone, dolostone, breccia, chert, and burrow-mottled limestone. These clasts are encased in a calcareous, coarse-grained sandstone matrix with abundant angular chert and carbonate fragments. Local calcite veins and fractures with slickensided surfaces crosscut the unit. The conglomerate is thickly bedded, and subtle variation in weathering between red resistant units and more recessive greenish-grey units are identified. The red beds make up 25% of the total thickness. Lenses of red-weathering, fine- to medium-grained sandstone occur locally.

Cape Lawrence area

The conglomerate at Cape Lawrence forms inaccessible cliffs, which reach a height of approximately 1000 m and lie adjacent to the Rawlings Bay thrust fault that brings Cambrian carbonate rocks to the surface. Overall the conglomerate is horizontal, thickly bedded polymictic orthoconglomerate that can be divided into three units, a red-weathering resistant unit, a green, less weathered, recessive unit, and a moderately sorted, crossbedded, polymictic cobble conglomerate unit. From a distance, the resistant and recessive intervals are more apparent. The cobble conglomerate unit occurs only at the base of the measured section (note that this is not the base of the formation), whereas the other units are interbedded with one another and occur throughout the measured section.

Red-weathering unit

The clasts in this red-weathering, resistant unit are subangular to rounded with planar, point-to-point, concavo-convex boundaries. The unit is predominantly poorly sorted with some moderately sorted, locally matrix-supported areas. There is no imbrication. The bedding is horizontal with local centimetre-scale, fining-upward cycles and centimetre- to metre-scale coarsening-upward cycles. The average maximum clast size is 18.5 cm. Clast types include burrow-mottled wackestone, micrite, crinoidal wackestone, laminated (dolomitic and silty) limestone, siltstone, quartzite, flat-pebble conglomerate, grainstone, dolostone, chert, limestone with quartz overgrowths, sandstone, and one oolitic clast. The matrix is calcareous, with very little clay. The grains are moderately to well sorted, rounded to well rounded, with planar, point-to-point, or concavo-convex boundaries. The unit is composed of mainly carbonate with lesser amounts of chert and siliciclastic grains. Centimetre-scale fining-upward cycles were also observed. Rare sandstone lenses occur as well. This unit makes up 54% of the total thickness of the measured section.

Green-weathering unit

Polymictic orthoconglomerate dominates this unit. Clasts are angular to rounded, poorly sorted, with planar or point-to-point boundaries, and do not appear to be imbricated. The maximum clast size is 18.8 cm. The unit appears to possess a crude coarsening-upward trend. Clast types consist mainly of crinoidal wackestone, burrow-mottled wackestone, flat-pebble conglomerate, laminated limestone, sandstone, quartzite, sandy limestone, dolostone, dissolution breccia (common in the Lower Cambrian Scoresby Bay Formation?), siltstone, micrite, dolomitic limestone, shell-debris grainstone, limestone with coarse quartz overgrowths, chert, and limestone. The matrix is calcareous and makes up less than 5% of the unit, which consists mostly of medium- to coarse-grained sand with minor clay. Well sorted, well rounded quartz sandy lenses occur locally. The sand fines upward from medium to fine grained with faint symmetrical current ripples. Overall centimetre-scale upward-fining cycles also occur. Well exposed, more recessive, intervals appear to be channels tens of metres wide. Overall bedding is lenticular. Here, the green-weathering units make up 33% of the total thickness of the measured section.

Cobble conglomerate unit

This unit occurs only in the lower part of the Paleocene succession at Cape Lawrence. These rocks are monomictic ortho- to paraconglomerate. Unlike the upper section of the succession, these deposits contain cobble-sized material, are imbricated , and have abundant planar and trough crossbeds. The clasts are poorly sorted and clast supported. Locally, well sorted, matrix-supported fabrics are present. Subangular to rounded carbonate clasts dominate with micrite, laminated limestone, burrow-mottled wackestone, and other wackestone. Very few chert and siltstone clasts are present. Clast boundaries are slightly concavo-convex and point-to-point. The maximum clast size is 9.2 cm. Centimetre-scale planar crossbeds and local trough crossbeds 1.5 m long and 40 cm deep are also present. The contact between the trough crossbeds and the planar crossbeds is erosional. Four centimetre-scale upward-fining cycles were observed. The matrix is calcareous and contains abundant quartz and carbonate fragments ranging in size from 0.25 mm to 2 cm. Overall, the unit is poorly sorted with rare crosscutting calcite veins and appears to fine upsection. It varies from resistant to friable and makes up the lower 13% of the measured section.

Franklin Pierce Bay area

The Franklin Pierce Bay conglomerate, farthest to the south of the three outliers, also forms high cliffs along the coast. Unlike the other conglomerate units, numerous rivers dissect the outlier, allowing for better access to the outcrop. This polymictic orthoconglomerate is 737.5 m thick. Three units are identified, a lower green-weathering unit, a middle orange-weathering unit, and an upper resistant brown unit.

Lower green-weathering unit

This lower unit is a clast-supported, or locally matrix-supported, subangular to subrounded, poorly sorted boulder conglomerate. Clast boundaries vary from point-to-point to concavo-convex. Centimetre- to metre-scale, fining- and coarsening-upward cycles are also present within the unit. A variety of clast types are present including wackestone, crinoidal grainstone, burrow-mottled crinoidal packstone to wackestone, current-rippled sandy limestone, laminated limestone, siltstone, quartzite, flat-pebble conglomerate, and micrite. Bryozoans, crinoids, corals, brachiopods, and shell fragments are the dominant fossils in the limestone clasts. The maximum clast size is 18.8 cm. The matrix is composed of fine- to coarse-grained, well rounded quartz sand and poorly sorted, angular to rounded carbonate clasts. It also contains an abundance of shell debris and other fossil fragments as well as pockets of pebbly sandstone. This unit is 320 m thick.

Middle orange-weathering unit

This unit is a thickly bedded, poorly to moderately sorted polymictic orthoconglomerate. Clasts are angular to rounded with rare concavo-convex, mostly point-to-point boundaries. The matrix is calcareous with subangular to rounded, poorly to moderately sorted, medium- to coarse-grained sand with point-to-point and concavo-convex contacts. Subtle centimetre-scale fining-upward packages are observed. Carbonate clast types consist of mainly grey wackestone, sandy limestone, and laminated limestone. Gastropods, shell fragments, and corals are the dominant fossils within the clasts. Siliciclastic clasts are mostly siltstone and sandstone. The maximum clast size is 15.9 cm. Thinly bedded red- or green-weathering sandstone lenses are present in the unit. The sandstone is medium- to fine-grained, well sorted, well rounded quartz sandstone with parallel laminations. Small lenses and/or pockets of pebbles are also found scouring into the sandstone. The unit has a total thickness of 294 m.

Upper resistant brown unit

This conglomerate is poorly sorted (locally to well sorted), polymictic orthoconglomerate with local paraconglomeratic fabrics. The clasts are angular to rounded with point-to-point or concavo-convex boundaries. Clast types are predominantly micrite and wackestone, with rarer green siltstone and white fine-grained sandstone. The maximum clast size is 14.7 cm. The matrix is calcareous, well cemented, well to poorly sorted, subangular to well rounded, fine- to coarse-grained, mainly quartz sand. Point-to-point, planar, and concavo-convex boundaries are present. Centimetre-scale fining-upward cycles also occur locally. Overall the unit is thickly bedded with alternating recessive and resistant layers. Thin lenses of red-weathering sandstone occur. The contact between resistant and recessive units is irregular and erosive. This upper unit is 123.5 m thick.

AGE OF CONGLOMERATE CLASTS

Franklin Pierce Bay conglomerate can be divided into three main units (**Fig. 2**). The lower unit consists of mostly micrite, laminated mudstone, and sandstone clasts that are possibly Ordovician to Cambrian (de Freitas and Sweet, 1998). The middle unit is dominated by crinoidal wackestone to grainstone boulders of possible Silurian age (de Freitas and Sweet, 1998). The upper unit has mostly clasts of possibly Ordovician burrow-mottled wackestone to packstone (de Freitas and Sweet, 1998). Paleocurrent direction varies from west and northwest in the lower unit, west in the middle unit, and northwest for the upper unit (*see* Fig. 2, **3**).

Cape Lawrence conglomerate can be divided into two prominent groups (Fig. 2). Approximately halfway through the sequence, a significant shift occurs in the abundance of siliciclastic rocks including quartzite and flat-clast conglomerate that are commonly seen within Cambrian and Lower Ordovician formations along Judge Daly Promontory (Trettin, 1994). The lower unit contains mostly carbonate clasts representative of the Middle to Upper Ordovician carbonate rocks in the area. Paleocurrent direction varies from north-south at the base to northeast to east toward the top (**Fig. 3**).

The Cape Lawrence Formation at Cape Back also revealed a shift in the abundance of siliciclastic rocks toward the upper part of the succession (*see* **Fig. 2**). This also corresponds to a change in flow direction to the northeast in the lower half and to the southwest and northwest in the upper half (*see* Fig. 3). Observed siliciclastic and carbonate rocks are representative of the Cambrian and Ordovician rocks seen in the area (Trettin, 1994).

INTERPRETATION

By comparing the stratigraphy of the clast types and the known adjacent Paleozoic stratigraphy, the Cape Back and Cape Lawrence conglomerate outliers are interpreted to exhibit normal unroofing sequences. Point-count data from the conglomerate units at Cape Back and Cape Lawrence reveal that siliciclastic varieties dominate in the upper part of the succession and carbonate varieties dominate below. There is also a significant shift in paleocurrent direction from northeastward at the base to northwestward and southwestward toward the top as seen at Cape Back. This suggests that a shift in source from the southeast and northeast deposited predominantly older siliciclastic sediments that may have been exposed where the Kennedy Channel now lies. If the paleocurrent data is correct, then these transport directions conflict with a simple inversion model of the uplifted hanging-wall stratigraphy to the northwest. At Cape Lawrence, a marked shift in transport direction from northerly to northeasterly and northwestly occurs where there is an increase in the abundance of siliciclastic clasts. Clast compositions in the conglomerate units are similar to those in Ordovician and older Ordovician and Cambrian rocks west of the conglomerate units (Trettin, 1994). A normal unroofing sequence sourced from the south and southwest is interpreted here. In both these localities, an overall increase in the maximum clast size occurs where there is a relative change in abundance in the siliciclastic and carbonate clasts (Fig. 4). Coarsening-upward cycles seen in the maximum-sized clasts may be the result of reactivated or continued thrusting.

At Franklin Pierce Bay, older Ordovician and Cambrian rock types, in particular micrite, sandstone, laminated mudstone, and wackestone, occur at the bottom with dominant transport directions from the west and northwest. Part way through the succession the paleocurrents shift to a predominantly westerly direction. Common clast compositions here are crinoidal grainstone, wackestone, and packstone of probable Silurian age (de Freitas and Sweet, 1998). At the top, the prevalent transport direction is from the northwest; burrow-mottled crinoidal wackestone to packstone dominate and are currently thought to be representative of Upper Ordovician carbonate rocks, possibly the Thumb Mountain Formation (de Freitas and Sweet, 1998). This sequence is currently interpreted to be a result of low-angle thrusting of the adjacent hanging-wall Paleozoic units such that Ordovician–Cambrian units were thrust over Silurian and Upper Ordovician strata before incision and deposition occurred. This allowed for the older sediments to be deposited first followed by younger Silurian then Upper Ordovician sediments as incision worked its way through the hanging-wall sediments. Unlike at the other two localities, the clasts here appear to have been transported from the west and northwest away from the hanging-wall source areas. Fining-upward cycles in the maximum-sized clasts correspond to changes in rock types and could also reflect a change to a more fluvial-dominated environment (*see* Fig. 4).

DISCUSSION AND FUTURE WORK

All three conglomerate outcrops lie adjacent to major north-trending thrust faults. These deposits are interpreted to be local as all the outcrops contain clasts typical of the adjacent Paleozoic strata and exhibit maximum clast size up to 60 cm (long axis), suggesting that the clasts were not transported far. Conodont ages for the carbonate clasts have not been obtained. Hopefully, ages from conodonts will help identify the specific provenance of some carbonate clasts. Additional statistical analyses may help further define how these conglomerate units were deposited.

CONCLUSIONS

Cenozoic syntectonic conglomerate units at Cape Back and Cape Lawrence record a normal unroofing trend of the adjacent Paleozoic strata. A more complex unroofing trend is observed at Franklin Pierce Bay. What produced this sequence is unclear, but it may be a result of local complexities in the tectonic regime. A local source for detritus in each outlier is indicated with uplift on adjacent east- and northeast-striking faults playing a significant role. Clast types observed are similar to rocks from adjacent formations.

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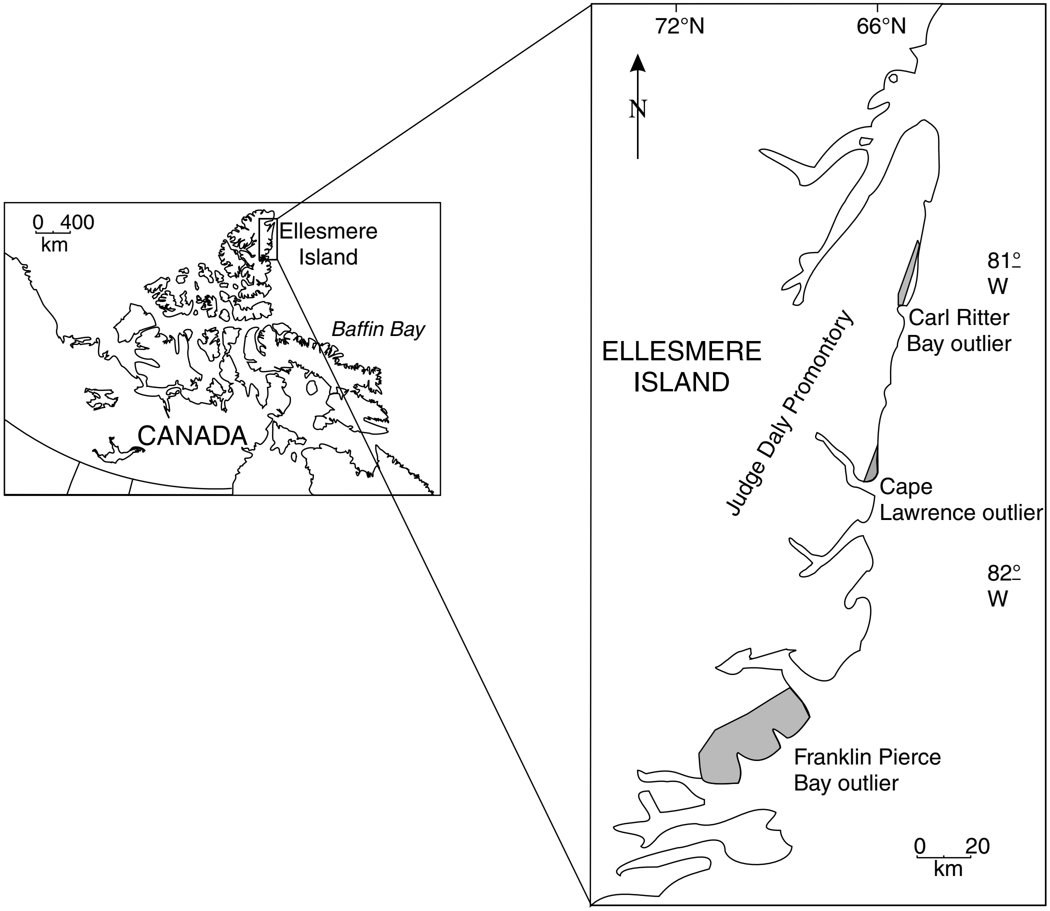

Figure 1.

Map of the study area. Grey shaded areas show the location of Cape Lawrence Formation conglomerate units along the northeastern coast of Ellesmere Island.

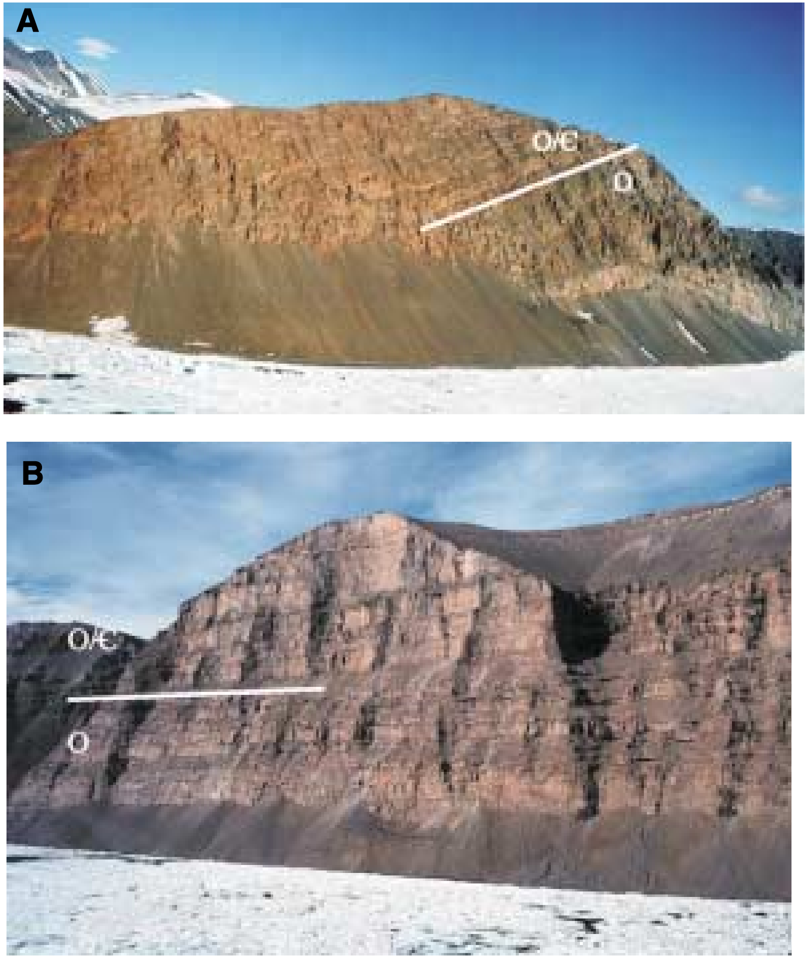

Figure 2.

Cape Lawrence Formation. **A**) Cape Back conglomerate (farthest north) annotated with the approximate location of change in lithology, showing Cambrian (Є) and Ordovician (O) clasts over younger Ordovician (O) varieties. **B**) Cape Lawrence conglomerate, illustrating a similar normal unroofing sequence at Cape Back. **C**) Franklin Pierce Bay conglomerate (farthest south); three units identified as Ordovician/Cambrian (O/Є), Silurian (Sil), and Ordovician (O) appear more obvious in outcrop than the other two.

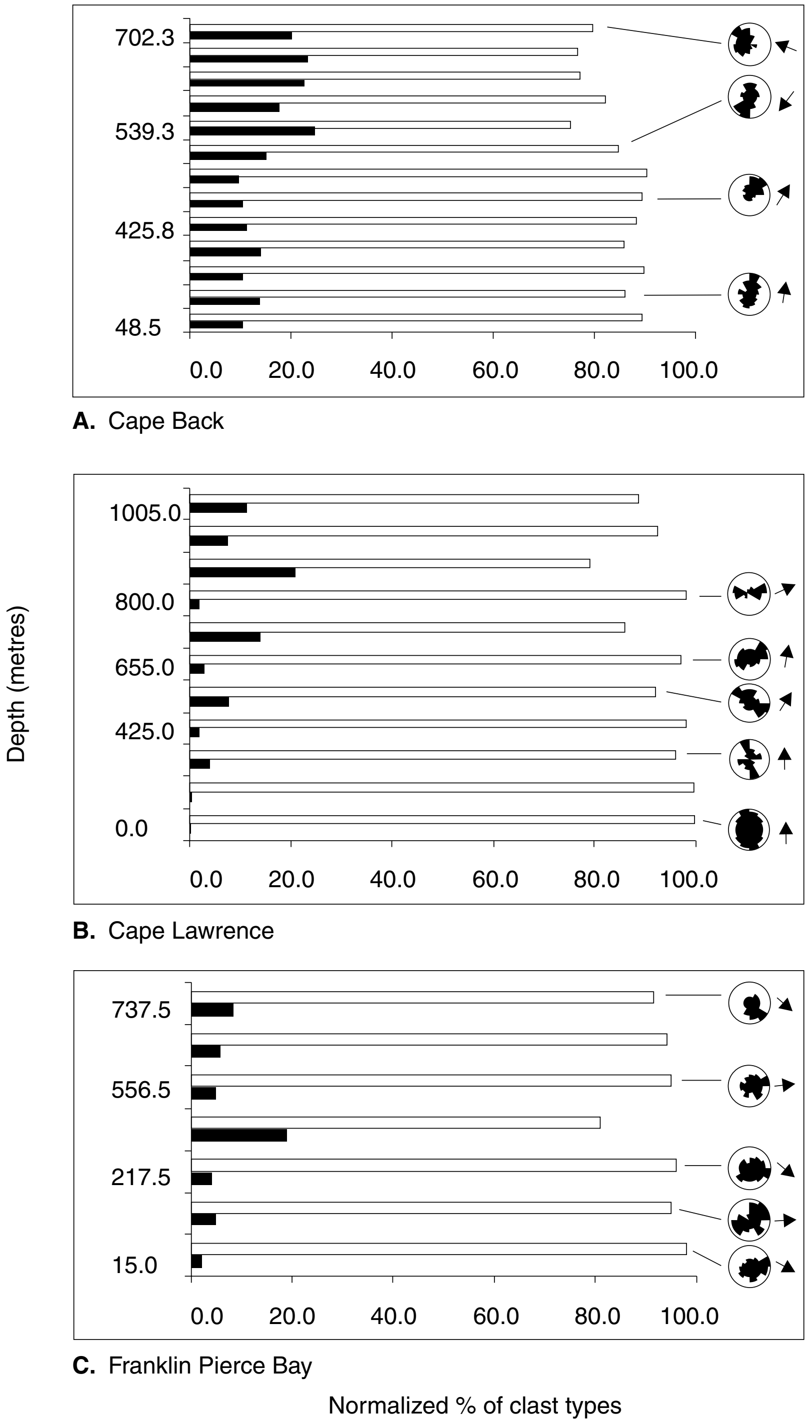

Figure 3. Histogram showing the relative abundance of siliciclastic (black bar) and carbonate (white bar) clast types from point-count data for Cape Back (**A**), Cape Lawrence (**B**), and Franklin Pierce Bay (**C**) with corresponding paleocurrent data.

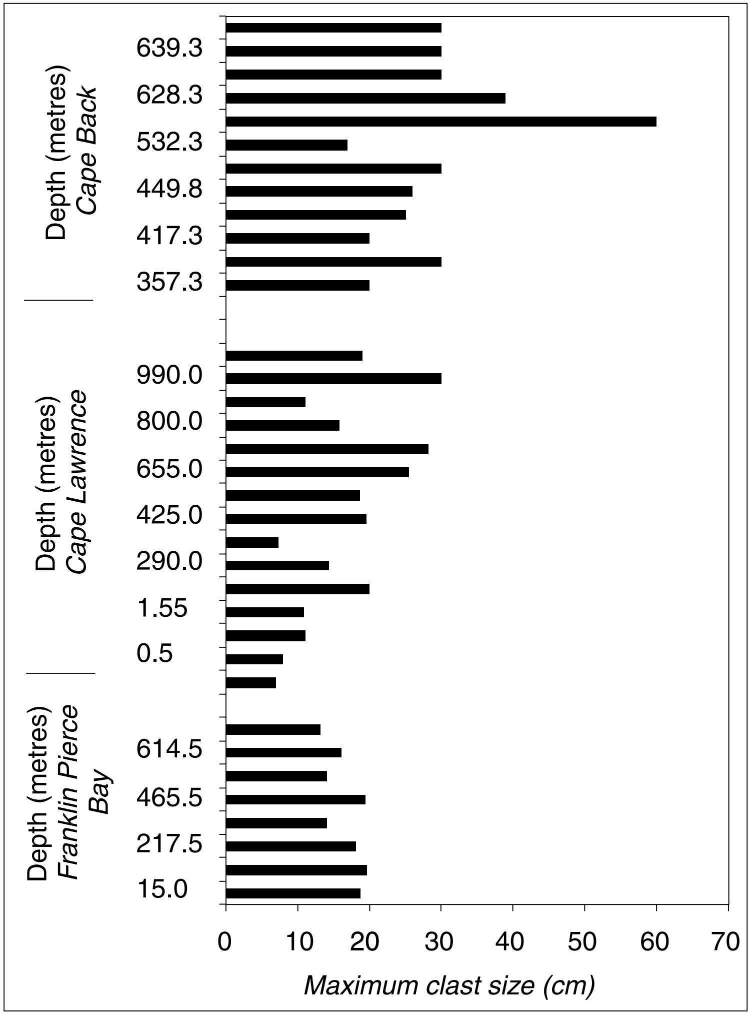

Figure 4.

Plot of maximum clast size (centimetres) versus depth (metres) from the northernmost outcrop (Cape Back) to the southernmost one (Franklin Pierce Bay). An overall decrease in clast size occurs from north to south.