33. MAGNETOSTRATIGRAPHY OF PLEISTOCENE SEDIMENTS OF BANKS ISLAND, NORTHWEST TERRITORIES: A FEASIBILITY STUDY

Project 740065

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Abstract

Stratigraphic sections on Banks Island in the Canadian Arctic record successive Quaternary glacial and nonglacial episodes. A feasibility study was undertaken in order to establish if paleomagnetism could be used to improve a chronostratigraphic framework for these episodes. It is demonstrated that the sediments collected fulfil the necessary criteria for the application of paleomagnetism. Even though the study was not aimed at defining magnetostratigraphic time zones, one of the suite of samples has revealed upon alternating field cleaning a shallowly, negatively inclined magnetic vector which could relate to a geomagnetic excursion. The samples indicating this possible excursion are from marine sediments belonging to an interglaciation that precedes the Sangamonian interglaciation and therefore is at least older than ca. 225 Ka. If this excursion can be validated during intensive paleomagnetic investigation, it means that a chronostratigraphic marker horizon has been found which possibly could be used for correlation purposes in the Arctic.

Introduction

A long stratigraphic record of Quaternary glacial and nonglacial events is present on Banks Island in the Canadian Arctic (Fig. 33.1). Mapping of surficial deposits (Vincent, 1978a) and stratigraphic investigations (Vincent, 1978b) have led to the recognition of at least three full glaciations with associated marine and glaciolacustrine phases (Vincent, 1978c).

One of the problems in the investigation of the Quaternary history of Banks Island is that of obtaining absolute ages for the recognized events. Radiocarbon dating is useful only for dating the most recent Quaternary units present on the island. Amino acid dating was attempted but up to now has been useful mainly as a correlating tool. As they are developed further, the uranium-series method for dating shells and the thermoluminescence method for dating glacial sediments may be more useful in the future. It was felt that paleomagnetism studies could help, at this time, in providing at least a rough chronostratigraphic framework.

Numerous paleomagnetic investigations have been conducted in the Arctic. Among others, Steuerwald et al. (1968) studied Late Tertiary and Quaternary sediments of the Arctic Ocean. Vilks et al. (1977) and Noltimier and Colinvaux (1976) respectively studied Late Quaternary Beaufort Sea sediments and Late Quaternary sediments from Lake Imuruk, Seward Peninsula, Alaska; in both these studies a geomagnetic excursion is thought to be recorded. Recently Richardson (1978) investigated lacustrine and raised marine sediments on Ellesmere and Devon islands while Locke (1978) studied raised marine sediments on Baffin Island.

This feasibility study was undertaken: (1) to establish if sediments adequate for paleomagnetic work could be sampled in a frozen state, thawed, and then reliably measured; (2) to establish if the sediments carried enough magnetic grains to make them paleomagnetically measurable, and (3) to establish whether the magnetic grains were of a grain size and composition that would faithfully record geomagnetic fields.

Acknowledgments

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Location and Description of Sampling Site

Samples for paleomagnetic studies were collected from a section, on the Amundsen Gulf coast, situated 4 km east of the mouth of Nelson River at 71°14'20"N, 122°20'20"W (Fig. 33.1). The precise stratigraphic locations of the sampled units are indicated in the geological section showing the lithostratigraphy of the Quaternary sediments (Fig. 33.2).

Samples 1 to 6 (location 1) were taken in a frozen clayey silt till which lies below seven different till sheets and two suites of sediments interpreted as being interglacial on the basis of preliminary paleoecological and geological evidence. Samples 7 to 12 (location 2) were collected in frozen marine silty clay at the base of the lower interglacial sequence. The upper interglacial suite is possibly Sangamonian in age, and the age of the lower suite is that of an older interglacial of undetermined age.

Field Sampling

Six samples were collected from each of the two stratigraphic horizons. Each of the six samples yielded two, and sometimes three, specimens for paleomagnetic analysis. Because the sediments sampled were located in permafrost, some difficulties in sampling were encountered and hence small errors probably were introduced during the sampling procedure. The samples were collected using a U-channel driven into the permafrost. The direction of the channel was oriented by sun compass; however, because the bottom of the U channel could not be kept perfectly horizontal during sampling, some small errors were introduced. This could cause errors in declination for magnetizations with steep inclinations and in inclination for sediments with shallowly inclined remanences. After extrusion in the field the samples were wrapped tightly while in a frozen state in clear plastic and aluminum foil and permitted to thaw.

Laboratory Treatment

Prior to laboratory treatment the specimens had dried into firm cubes. They were sliced dry with a diamond wheel to produce uniform specimens; each was coated with a plastic film to prevent further crumbling during paleomagnetic

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processing. Because of the friable nature of the specimens, only alternating field demagnetization was permitted; each specimen was demagnetized in 10 or 50 Oe steps to a maximum of 200 Oe. All demagnetizations which exhibited significant directional shifts were analyzed for multicomponent magnetizations by vector subtraction. Individual vectors were recognized from vector diagrams of directional changes during demagnetization (Roy and Park, 1974).

General Considerations on Paleomagnetic Studies

The variation with time of the local magnetic field direction at any spot on the Earth's surface arises from three variables. In order of increasing time duration these variables are secular variation, field reversal, and polar wander. Relative to the time frame involved in the paleomagnetic study of Pleistocene sediments, only the first two variables need be considered. Of these, by far the most important is field reversal which provides a globally applicable chronostratigraphic marker horizon.

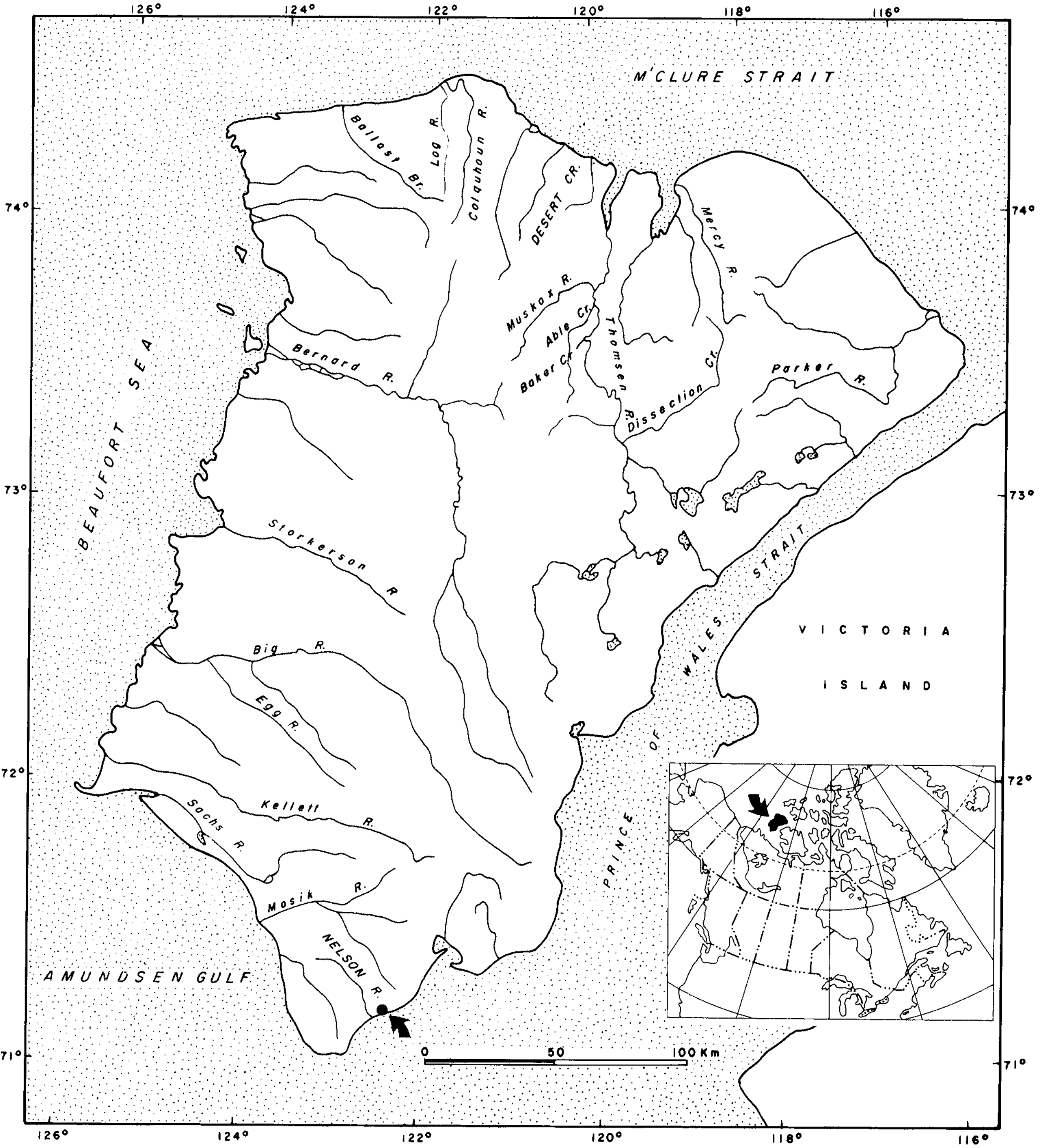

Figure 33.1. *Map of Banks Island showing the location of the section studied.*

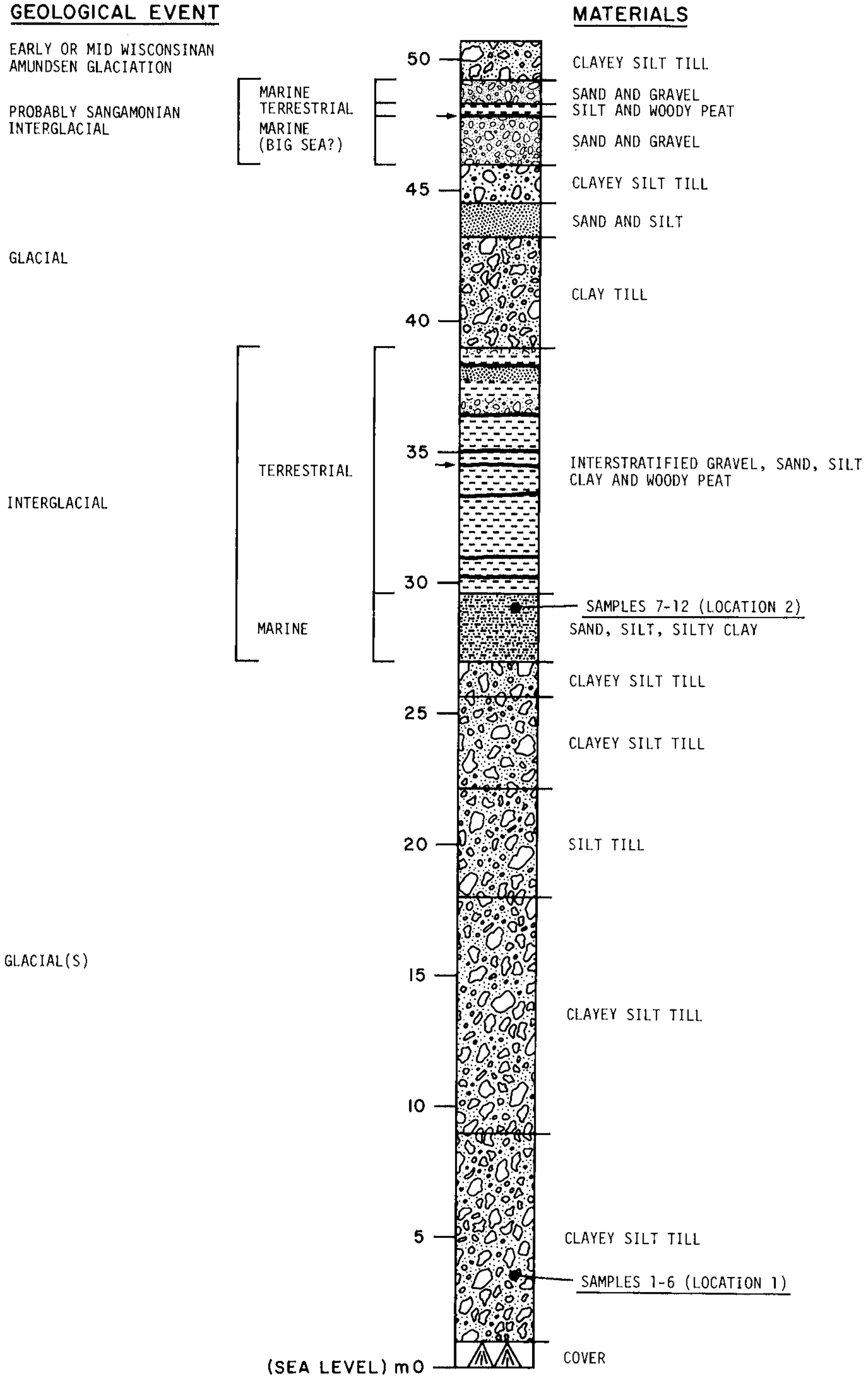

Figure 33.2. *Generalized section showing the lithostratigraphy of the sediments east of Nelson River and the location of the two units sampled for geomagnetic study. Arrows point to the two organic units discussed in the text.*

The geomagnetic field however does not always execute a complete reversal; rather the field apparently begins to migrate towards the opposite polarity, but then instead of completing this migration it returns to its initial starting position. A number of these geomagnetic "excursions" have been reported in the literature (e.g., Clark and Kennett, 1973; Denham and Cox, 1971; Noel and Tarling, 1975). Due to inexactitudes in the estimated ages of these excursions, it is uncertain whether the excursions have either global or just local significance. A recent review of Quaternary excursions (Verosub and Banerjee, 1977) however shows that they are not sufficiently well established.

Results

Preliminary Comments

All criteria necessary for the use of paleomagnetism are fulfilled by the samples collected from Banks Island. All samples contain sufficient magnetic grains to make them readily measurable on presently available commercial magnetometer systems. In most cases it can be shown, based on the demagnetization characteristics, that the principal remanence carrier is a multi-domain titanomagnetite. Traces of hematite (some intensity surviving tougher alternating fields) and possibly goethite (some large intensity decays

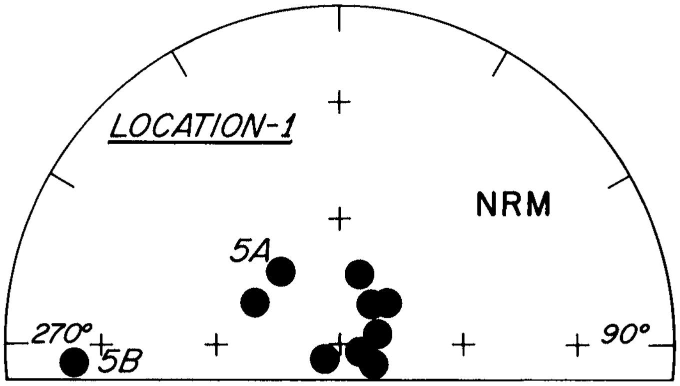

Figure 33.3. *Stereonet plot of the NRM directions of specimens 1 to 6 collected at the lower locality (1). Black circles indicate downward (positively) inclined magnetic vectors.*

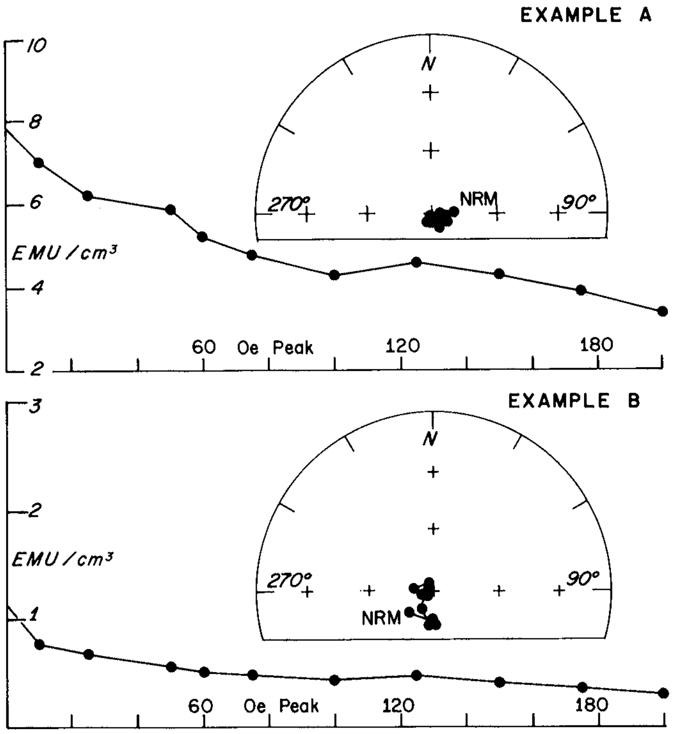

Figure 33.4. *Stereonet plot of the sequential changes of remanence direction upon AF demagnetization together with a graphical representation of the change of remanence intensity with increasing demagnetization. The NRM direction is shown by the symbol N. Example A shows no change of remanence direction upon demagnetization; example B shows a small, steep northerly migration of remanence direction.*

during the initial demagnetization steps) remanences were observed in some of the specimens. Remanence directions are well grouped for samples of the same site. The lower samples (1-6, location 1) have retained a remanence direction that is similar to the present field direction of the Earth, while samples (7-12) from the upper locality (location 2) have a shallowly inclined magnetic vector. The most notable feature of these shallowly directed remanences is that after AF (alternating field) cleaning they are negatively inclined. Whether this was part of a real geomagnetic excursion cannot be definitely established from the present limited data base.

Magnetic Observations

The average NRM (natural remanent magnetization) intensity of specimens (1-6, location 1) from the lower locality is 6.24 ± 2.82 emu/cm^3. NRM of most specimens is loosely grouped around D = 030° (declination), I = +75° (inclination) (see Fig. 33.3). Only one specimen 5B appears to carry a divergent remanent direction. Upon AF demagnetization most specimens exhibit only small changes of remanence direction. In all cases the direction changes, which do not seem to have systematic pattern, are towards steeper inclinations (Fig. 33.4). The average median destructive field of the specimens is 80.0 ± 10.0 Oe. After demagnetization above 200 Oe less than 20 per cent of the NRM intensity of most samples remained. This level of loss of NRM intensity is consistent with the main remanence carrier residing in a fairly coarse grained titanomagnetite. The mean direction of the samples after cleaning was D = 070°, I = +85°, a direction closely approximating the present field direction of the Earth at the sampling locality.

Throughout the AF treatment specimen 5B continued to give anomalous remanence directions. Moreover, its NRM intensity (9.42 emu/cm^3) was noticeably greater than the average; its median destructive field was 125 Oe, again quite distinct from the other specimens. In contrast, specimen 5A, the other part of this sample, behaved similarly to all other specimens from this locality. Whatever explanation is invoked to explain the anomalous direction of specimen 5B, the fact is that only a single specimen is affected. One explanation is that the remanence of specimen 5B is dominated by the inherited remanence of some rock fragment contained within the till matrix whose magnetic vector was not aligned along the Earth's field direction at the time of till deposition. Other paleomagnetic problems in measuring till samples have been discussed by Stupavsky and Gravenor (1975).

Except for specimen 8A, all specimens (7-12, location 2) from the upper locality have NRM directions with much shallower inclinations of approximately +30° (Fig. 33.5). There appears to be some variation in declination with a mean around D = 075°. A similar variation is not observed in inclination. It therefore appears that some errors were introduced during the sampling and measuring procedure. Except for specimen 7A, which is more strongly magnetized than the other specimens, the mean NRM intensity of 0.706 ± 0.15 emu/cm^3 is noticeably lower than that recorded by specimens from locality 1. Upon demagnetization all specimens, including specimen 8A, exhibit a systematic trend towards a shallower and negatively inclined direction. Most of these changes are shown during the first 50 Oe AF treatment (Fig. 33.6). The direction change is associated with only relatively small changes of remanent intensity. Vector subtraction of the $\overrightarrow{\text{NRM}} - \overrightarrow{(D,I)}_{50}$ suggests that the vector removed during this direction change is aligned very closely with the present magnetic field direction of the Earth. Because of this directional similarity, it is difficult to decide whether this steeply inclined vector arises from viscous remanent buildup or postdepositional formation of goethite which has retained a chemical magnetization associated with hydration.

The median destructive field of 130 ± 20 Oe is significantly higher than that for specimens of the lower locality, probably reflecting the lower mean average grain size of this locality. Upon demagnetization all specimens exhibit slightly negative remanence inclinations with a declination of approximately D = 065° (Fig. 33.6). AF treatment produces an improved grouping between the remanence vectors of these specimens suggesting that the error introduced by the sampling and measuring difficulties is probably of the order of 10° in declination.

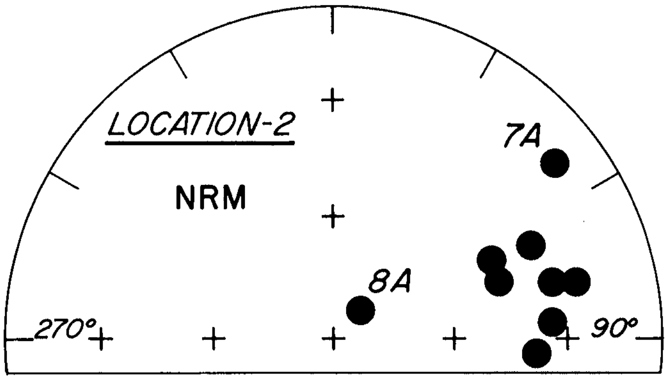

Figure 33.5. Stereonet plot of the NRM directions of specimens 7 to 12 collected at the upper locality (2). Black circles indicate downward (positively) inclined magnetic vectors.

The mean remanence vector of the upper specimens, after AF cleaning at D = 065° I = -05° is highly divergent from that expected from sediments of Quaternary age (Fig. 33.6). The direction cannot be explained by postdepositional compaction, as the required compaction would be at least 25:1 (Blow and Hamilton, 1978) which would only produce extremely shallow positive inclinations. One possible mechanism that could produce such shallow negative inclinations is a postdepositional bedding slump. Other mechanisms have been discussed by Verosub and Banerjee (1977); most of these however appear inapplicable to this study, and the most logical explanation is that the specimens have recorded a portion of some geomagnetic excursion. To confirm this, a full paleomagnetic study must be completed. During a field reversal the strength of the Earth's field decays and then builds again in the opposite polarity (Creer and Ispir, 1970). In keeping with this model, it is noted that the NRM intensity of the upper specimens (location 2) is much lower than that of the lower specimens (location 1). Remanence saturation tests indicate that at least some of this difference is caused by the presence of phases carrying differing amounts of remanence. These tests also indicate, however, that the differences in magnetic mineral content cannot fully explain the differences in remanent intensity at the two localities. It is suggested therefore that part of this difference originates from sediment deposition during a period of weaker magnetic field – a geomagnetic excursion.

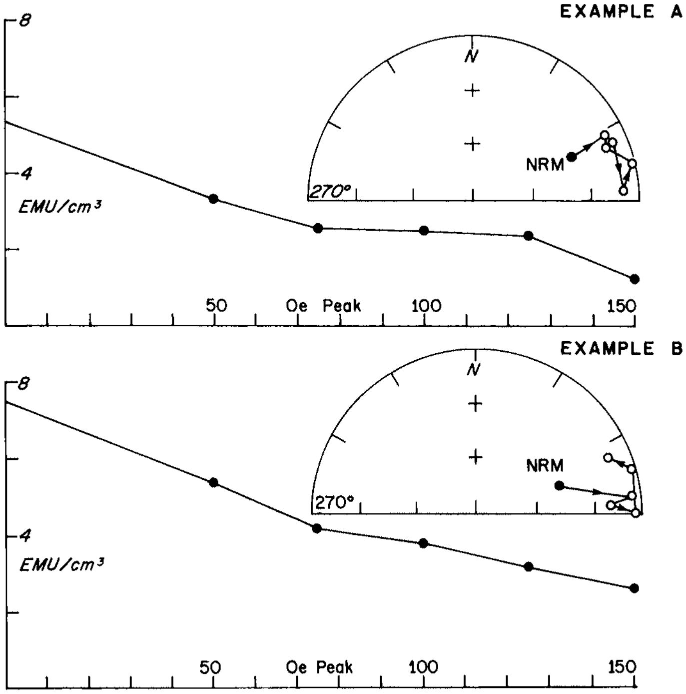

Figure 33.6. Stereonet plot of the sequential changes of remanence direction upon AF demagnetization together with a graphical representation of the change of remanence intensity with decreasing demagnetization. Black circles denote positive remanence directions, and open circles denote negative remanence directions. Both examples show the migration away from the present field direction of the Earth towards a shallowly negatively inclined vector directed towards the east.

Age of Samples

The gravels immediately underlying the upper organic bed (Fig. 33.2) are believed to have been laid down in the Big Sea, a marine transgression that followed the retreating ice of the Thomsen Glaciation (Vincent, 1978c). Amino acid ratios on shells from Big Sea deltaic gravels that were lithostratigraphically correlated with the gravels in the section discussed here provided an estimated age that predates the last (Sangamonian) interglaciation (G.H. Miller, pers. comm., 1978). Based on various paleoecological studies[1], the organic bed is believed to have formed during a climate somewhat warmer than that at present and therefore may be interglacial in character. The lower suite of organic deposits (Fig. 33.2) also is believed, based on the paleoecology[2] of the flora and fauna, to represent an interglacial episode. Because the marine sediments from which samples 7-12 were collected underlie the lower suite of organic sediments, it can be said that the marine sediments possibly record an excursion that is at least older than the glaciation and part of the interglaciation which precede at least the last interglaciation (Sangamonian). Oxygen isotope stratigraphy shows that the interglaciation (stage 7) preceding the Sangamonian occurred ca. 225 Ka (Shackleton and Opdyke, 1973). The youngest possible known excursion that could be recorded in the upper specimens would then be older than Biwa I "event" (ca. 180 ± 0.02 Ka, McDougall, in press). Since the lower samples (location 1), which have normal polarity, cannot give any indication of the age of the till sheet from which they were collected, no limiting age for this till can be put forward.

Conclusions

The paleomagnetic specimens examined in this feasibility study fulfil all the necessary criteria for the application of paleomagnetism as a tool for magnetostratigraphy on Banks Island. Most significant is the fact that the specimens from the upper locality appear to have recorded a segment of a geomagnetic excursion. Although it seems unlikely that these shallowly negatively inclined vectors could have arisen from any mechanical depositional mechanism, two simple tests could confirm that this is definitely a geomagnetic excursion. First, one could establish the sequential change of remanence vector with time by sampling a number of closely spaced horizons above and below those sampled at this locality. Secondly, by taking paleomagnetic samples from the same stratigraphic unit in another section, a different sequence of remanence directions should be exhibited if the deposit could be shown to be diachronous. The information then available would conform

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[1] Unpublished GSC Fossil Arthropod Report 76-16 and Plant Macrofossil Report 78-6, J.V. Matthews, Jr.; unpublished GSC Palynological Report 79-6, R.J. Mott.

[2] Unpublished GSC Fossil Arthropod Report 78-6 and Plant Macrofossil Report 78-6, J.V. Matthews, Jr.

to the format suggested by Verosub and Banerjee (1977) for the definition of a geomagnetic excursion. If similar geomagnetic excursions can be substantiated for deposits of similar ages by these types of tests, then natural processes (slumping, burrowing organisms, etc.) can be eliminated as causes of anomalous remanence directions.

Although these data do not permit any firm conclusions to be drawn, they show that the section studied has excellent potential for defining magnetostratigraphic time zones. Because the upper samples possibly may have recorded a geomagnetic excursion, which is commonly of geologically short duration, this provides the possibility of a chronostratigraphic marker horizon for precise correlations in the Arctic.

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