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SEISMIC REFLECTION RESULTS FROM CESAR

H.R. Jackson[1]
Geological Survey of Canada

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Abstract

The seismic reflection information collected on CESAR is presented to provide a continuous record of sedimentary horizons and basement relief. The sedimentary reflectors on the highs are flat lying and layered while those in the topographic lows are less regular and probably slumped. Faults predate and postdate the sediment. The age of the Alpha Ridge is estimated from its magnetic character and fossil information. The ridge's topography, sedimentary and basement structures and bedrock samples resemble those of an oceanic plateau.

Résumé

Le rapport présente les données prélevées par sismique réflexion au cours de l'expédition CESAR en vue de fournir un enregistrement continu des horizons sédimentaires et du relief du socle. Les réflecteurs sédimentaires sont stratifiés et reposent à plat sur les hauteurs; dans les dépressions topographiques par contre, ils présentent un aspect moins régulier, vraisemblablement en raison de glissements. Des failles se sont produites avant et après l'accumulation des sédiments. La nature magnétique de la dorsale Alpha ainsi que les fossiles qu'elle contient permettent d'évaluer l'âge de la structure. La topographie, les structures sédimentaires, le relief du socle et les échantillons rocheux sont similaires à ceux d'un plateau sous-marin.

METHOD

A seismic reflection record was collected at main camp (Fig. 3.1). The record is presented here to provide control and insight for interpreting the cores and understanding the tectonic development of the Alpha Ridge. The sound source for the seismic reflection survey was a 40cu.in. airgun that was received by a single hydrophone. Analogue recording was used. The lack of ship's noise and towing turbulence enabled this simple system to record good sedimentary and basement reflections.

Some problems were encountered making the reflection system operational; no record is available to accompany piston cores 1 and 2, as the airgun was not sealing properly. This problem was eventually solved by heating the airgun untouchably hot before immersing it in the cold Arctic water. The airgun was fired once every five minutes; therefore, apparent distances on the record depend on the drift rate. The seismic reflection record must be carefully interpreted in conjunction with the navigation. The detailed track of the main ice station plotted with true distance is shown in Figure 3.2.

RESULTS

The seismic reflection record (Fig. 3.3, in pocket) shows from 0.2 to 0.5s of layered, generally flat-lying and internally conformable sediment overlying acoustic basement. In cases where basement is irregular the sedimentary horizons follow its trend (1200z-(GMT)/134). From 1200z/123 to 1200z/134 a bottom simulating reflector (BSR) is mapped 0.15s later than the seafloor arrival. A characteristic transparent interval occurs before the onset of the B.S.R. The temperature-depth range is compatable with a gas hydrate producing the B.S.R. In some locations the bottom is offset in a step-like fashion (1200z-/111 and 0000z-/125) that is probably fault controlled. Faults with greater offsets are also observed at 0000z-/120 to 0000z-/122. At these locations sedimentary reflectors terminate against basement and suggest the faults postdate the deposition of the sedimentary reflectors. The sediments on top of the uplifted block conform to basement and are gently dipping. CESAR core 6, retrieved from the sediments on the edge of this faulted portion of the ridge, contains Cretaceous fossils (Barron, 1985; Bukry, 1985).

The major valley crossed (1200z-/135 to 1200z-/140) exhibits 750m relief and is 30km across. This valley is ori-

[1]Atlantic Geoscience Centre, Bedford Institute of Oceanography, Box 1006, Dartmouth, Nova Scotia, B2Y 4A2

ented roughly parallel to the northern side of the Alpha Ridge as indicated on the bathymetric map of the Arctic Ocean (Johnson et al., 1979). Uplifted basement rims on the valley (0000z-/105 and 1200z-/134) occur on the northern wall which is a steep sediment-free scarp. The sediments in the valley are thicker and more chaotic than those on the plateau. The apparent flat-lying sequence in the valley between 0000z-/138 and 1200z-/138 does not exist and is an artifact of varying drift rates; that is, no motion occurred during this interval. The sediments on the southern wall and in the valley appear to be slumped. The sedimentary reflectors adjacent to the northern scarp have an onlap relationship to it (1200z-/135); truncation of sediment is more typical of a fault-produced feature which suggests the faulting here occurred prior to the deposition of the sediments. Thus, this valley may be a primary feature formed by the processes that produced the Alpha Ridge.

The seismic reflection record illustrates that basement topography is rough and irregular. One probable outcrop of basement is a dome-shaped feature indentified on day 123. A photograph of the outcrop is shown in Figure 3.4A. It has an irregular surface texture due to thick manganese coating indicative of its long term presence on the ocean floor. It is contrasted to an ice-rafted dropstone with smooth surface and angular outline (Fig. 3.4B).

Using the available information: magnetics, refraction, dredge material and cores, it is possible to interpret the age and type of basement. Sublinear magnetic anomalies of amplitude up to 1500nT with many irregular peaks are associated with the Alpha Ridge. Basement topography and the magnetic anomalies have been shown to be correlatable (Hall, 1970), and this is also evident on the aeromagnetic map of the Arctic (Kovacs et al., in press). Thus the topographic expression of the valley is reflected in the magnetic characteristics of the ridge. If the magnetic anomalies are due to oceanic basalts the ridge must have formed during a long period of non-reversals such as the Cretaceous positive polarity chron from 80 to 120 Ma (Harland et al., 1982).

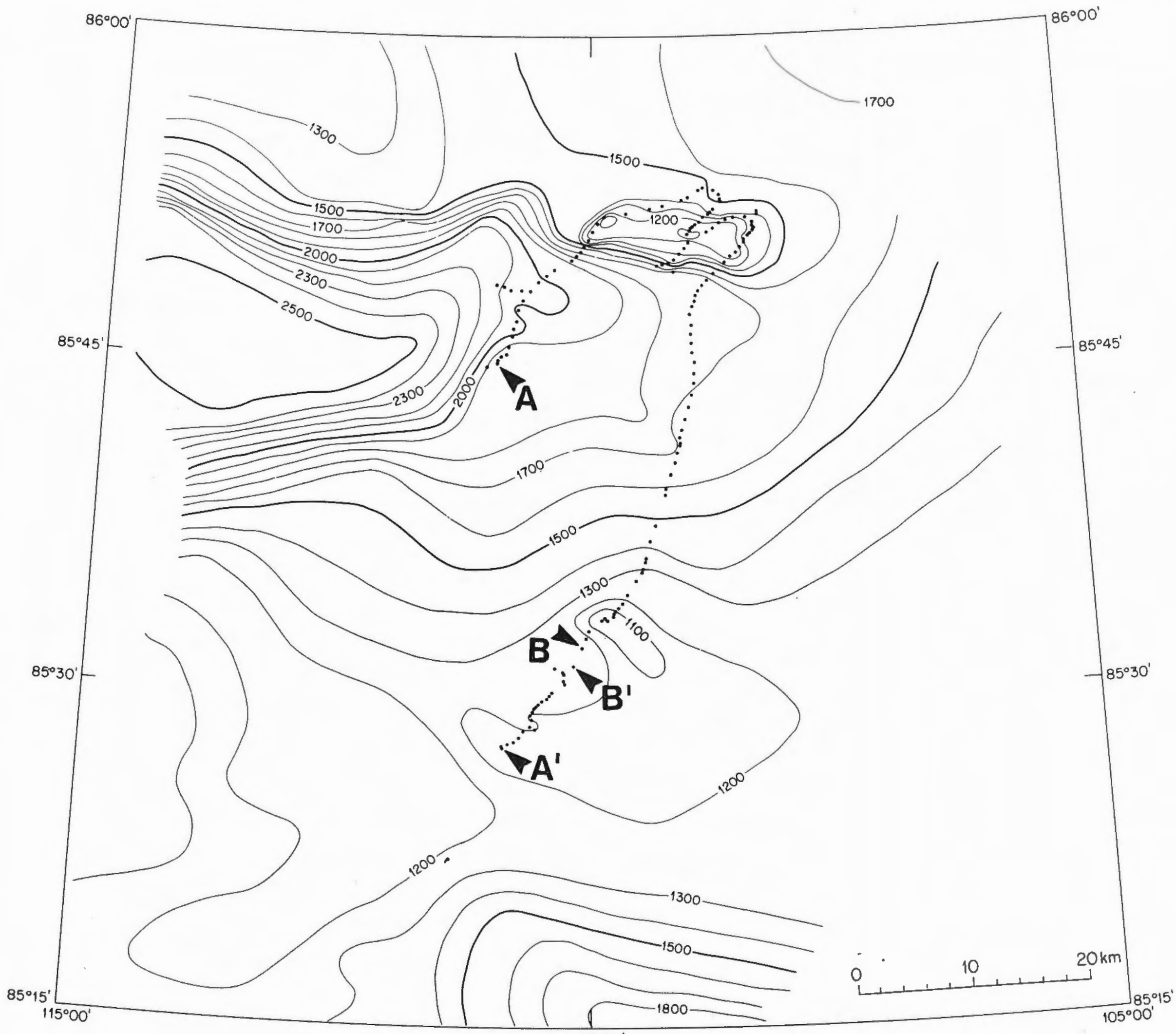

Fig. 3.1 The drift of the ice station from A to B is the region where the seismic reflection record was recorded.

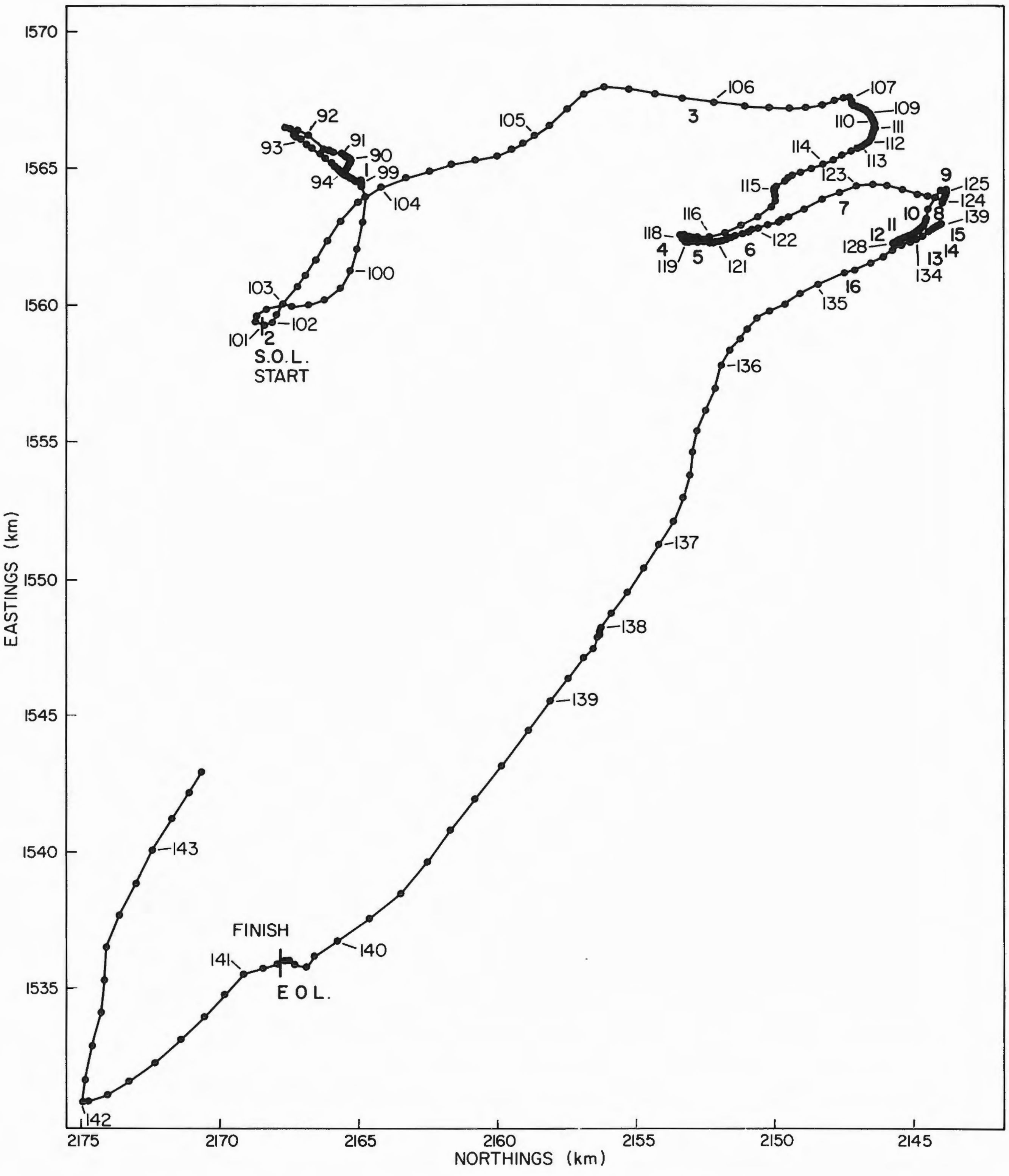

Figure 3.2 A detailed track plot with distance in kilometres is shown. The heavy type numbers are the core locations. The lighter type number are the ice camp position at 0000z- of each day. The dots are the position of the camps as a three hour mean. The start (S.O.L.) and finish (E.O.L.) refer to the seismic reflection line.

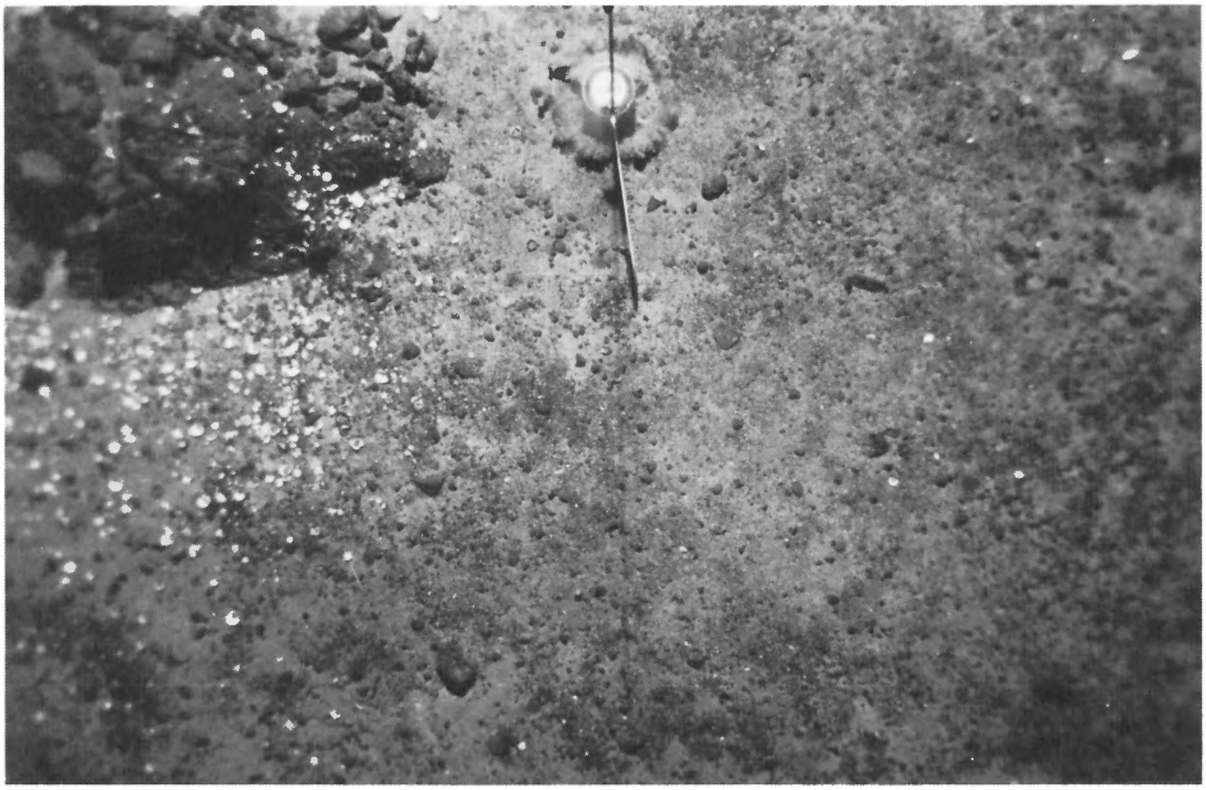

Figure 3.4A Bottom photograph, 1m by 2m, showing basement outcrop.

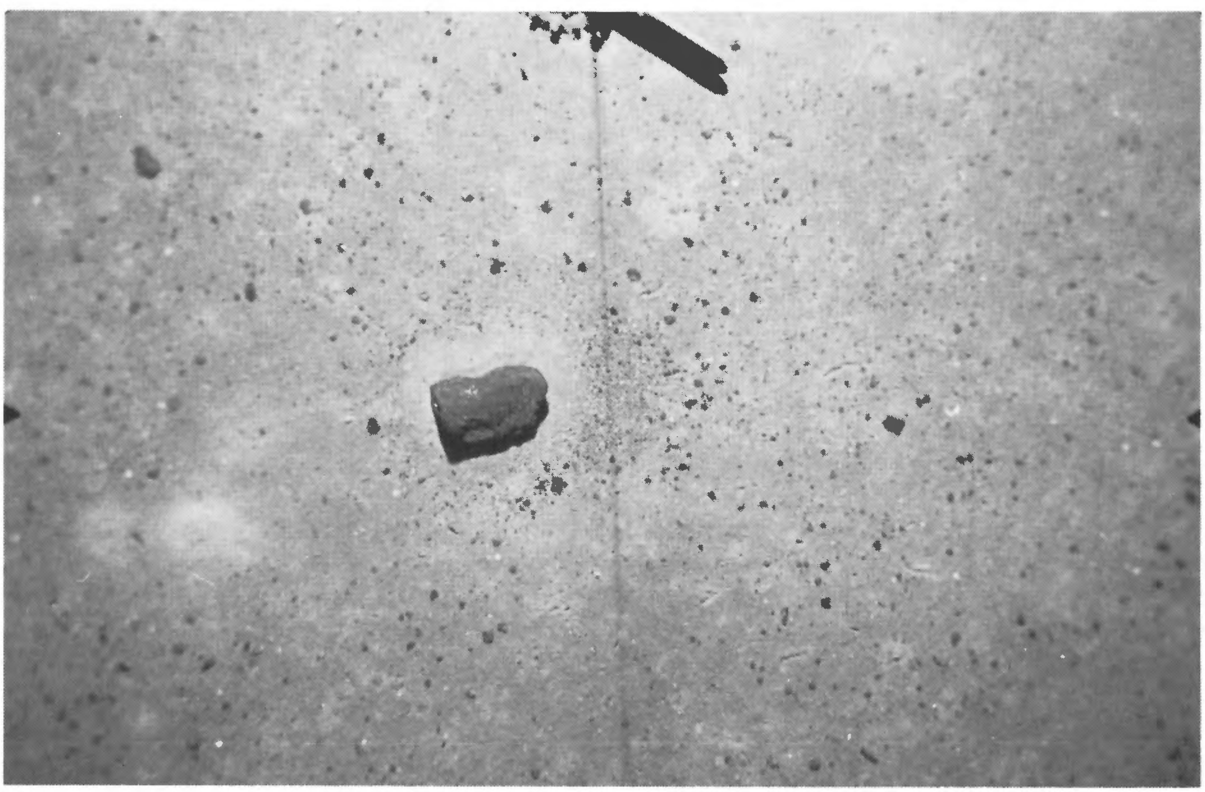

Figure 3.4B Bottom photograph, 1m by 2m, showing ice-rafted dropstone.

Preliminary refraction results show P-wave velocities for basement in the range of 4.7 to 5.2kms (Forsyth, personal communication), which is typical of oceanic basalts (Christensen and Salisbury, 1975). The in situ rocks from the ridge are highly altered but the texture and relict minerals suggest that they were originally an alkaline basalt (Van Wagoner and Robinson, 1985). The available information is consistent with a basaltic basement.

Information from the cores as well as magnetic data can be used to place limits on the age of the basement. Sedimentation rates of about 1mm/1000yr are reported (Aksu, 1985) for the upper 5m of the section. If this rate is extrapolated through the sequence with an assumed 2.0km.s^{-1} velocity for the thin 0.2s of sediment observed in the vicinity of core 8, then the age of the oldest sediment is 200 Ma. However, if the average sedimentation rate is adjusted upward to 1.5mm/1000yr for the 0.1s of sediment observed on the reflection record above and adjacent to CESAR core 6, then this first 100m can be estimated to be 65 Ma. This is consistent with the age of the fossils in the core. Extrapolating for the age of the lower portion of the sedimentary sequence near core 8 would produce an estimate of 130 Ma. This estimate is consistent with the magnetic anomalies which suggest Cretaceous during the positive polarity chron between 80 and 120 Ma (Harland et al., 1982).

The topography and sedimentary and basement structure of the Alpha Ridge are similar to that observed on the Manihiki Plateau. The Manihiki Plateau is a large area (0.5 x $10^6 km^2$) of shallow water depth in the Pacific. The plateau has a system of deep internal troughs that are oriented roughly parallel to one of the boundaries of the plateau. In cross-section the troughs are similar to those observed on the Alpha Ridge; that is, they are steep-sided basins with basement rims. The troughs on the Manihiki Plateau are thought due to dip-slip motion or to be grabens formed along transform faults. On this plateau faulting is frequent and it is difficult to assess the amount of it that is due to the process that formed the feature and the degree of tectonism that occurred subsequently.

The rocks dredged from the Manihiki Plateau have all been highly altered basalts and volcanic breccias; in situ samples of the Alpha Ridge are weathered fragmental volcanic rocks. Segments of the Manihiki Plateau are associated with magnetic amplitudes of 1000nT. The anomalies follow the trends in basement relief. Magnetic anomalies caused by topography suggest the plateau formed during a time interval with no magnetic reversals. Seismic refraction measurements revealed an oceanic layer two velocity 10km thick overlying layer three of undetermined thickness (Winterer et al., 1974).

The sediments on the highs of the Manihiki Plateau are about 0.5km thick and are layered and continuous. In contrast, in the troughs the sediments are 1km thick and have clastic reflectors thought to be deposited by slumping. The deeper reflectors and basement are offset by faulting. The top of the sedimentary section is not always disturbed by the faults (Winterer et al., 1974).

The resemblance of many features from the reflection profile of the Alpha Ridge to those observed on records from the Manihiki Plateau provides an analogue for comparison and insight into the structure of the Alpha Ridge. Although even the better studied Manihiki Plateau is not well understood it is considered to be oceanic crust of Cretaceous age (Winterer et al., 1974).

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