

GEOPHYSICAL AND GEOLOGICAL SURVEYS ALONG THE NORTHEASTERN FLANK OF MOUNT ERROR, NORTHWESTERN INDIAN OCEAN

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Abstract

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Bathymetry, multichannel continuous seismic reflection, magnetic and gravity surveys and sampling were carried out over Mount Error in the northwestern Indian ocean and along the northeastern flank of the seamount, to study the nature of its basement. Preliminary interpretation of the seismic data indicate a 330 ms sedimentary sequence over the summit of the mount and approximately 880 ms of sediments in the valley at the base. Analyses of magnetic and gravity fields over the northeastern flank of the seamount suggest an igneous basement consisting of lamprophyre occurring as a thin slab(sill). Further, the average bathymetric contour of 4500 m and the magnetic model studies suggest that the lower boundary of the magnetisation contrast perhaps coincides with the thickness of the continental crust below the seabed.

Introduction

During the maiden voyage of ORV *Sagar-kanya* from West Germany to India (April–June, 1983), geophysical surveys were carried out over the Error seamount and along its northeastern flank (Figs.1 and 2). About 85 line kilometers of continuous seismic reflection profiling was carried out over the seamount and approximately 258 line kilometers of bathymetry, magnetics and gravity data were collected along the northeastern flanks. In this study the geophysical data are interpreted in the light of known geology in the vicinity of the area.

Methods

Bathymetry

Detailed bathymetric charts of the Mount Error have been published in the geological and geophysical Atlas of the Indian Ocean by Udintsev (sheet.3, 1975). In this study an ELAC narrow-beam echosounder was used for depth measurements. The instrument has a beam width of $\pm 1.4^\circ$, and a frequency of 30 kHz. The echograms were used in conjunction with the existing bathymetric charts and an updated bathymetry chart was prepared (Fig.3) for the northeastern flank of the seamount. Figure 4

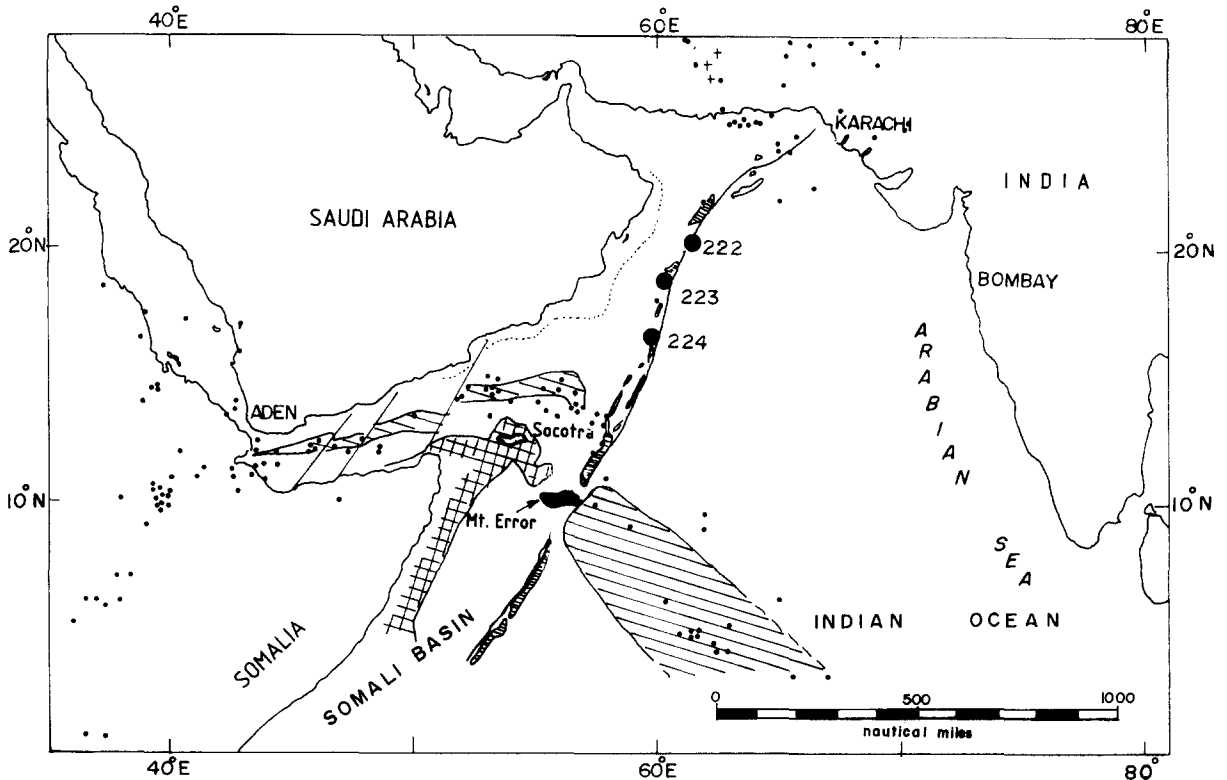


Fig.1. Map showing the study area Mount Error and northeastern flank (shaded) along with the Carlsberg Ridge (hatched) and earthquake epicenters shown as dots (after Matthews, 1966). Numbers 222, 223 and 224 indicate the DSDP sites.

represents the topography of Mount Error. The position of the cruise tracks were obtained by an integrated navigation system (Magnovox Satellite Navigation System, accuracy ± 30 m).

Continuous seismic profiling

Seismic reflection profiling was carried out over Mount Error (Fig.5) employing a 24-channel recording with a DFS V system. The acoustic source is a seven-gun D array with an approximate volume displacement of 8 l.

Magnetics

The total intensity values were recorded with the help of a Geometric Proton precession magnetometer model 801/3. The data have been reduced by subtracting the regional field and

the residual magnetic anomalies were plotted perpendicular to the track charts (Fig.6); the modelled anomalies over the source rock are shown in Fig.7.

Gravity

Free-air and Bouguer anomalies were obtained with a sea gravimeter KSS 30 of Bodenseewerk, West Germany. The Bouguer anomaly contour map prepared at 10 mg/l is shown in Fig.8 and a meridional profile in Fig.9.

Description of the study area

General physiography and areal geology

Mount Error is situated approximately at the northwestern boundary of Carlsberg Ridge

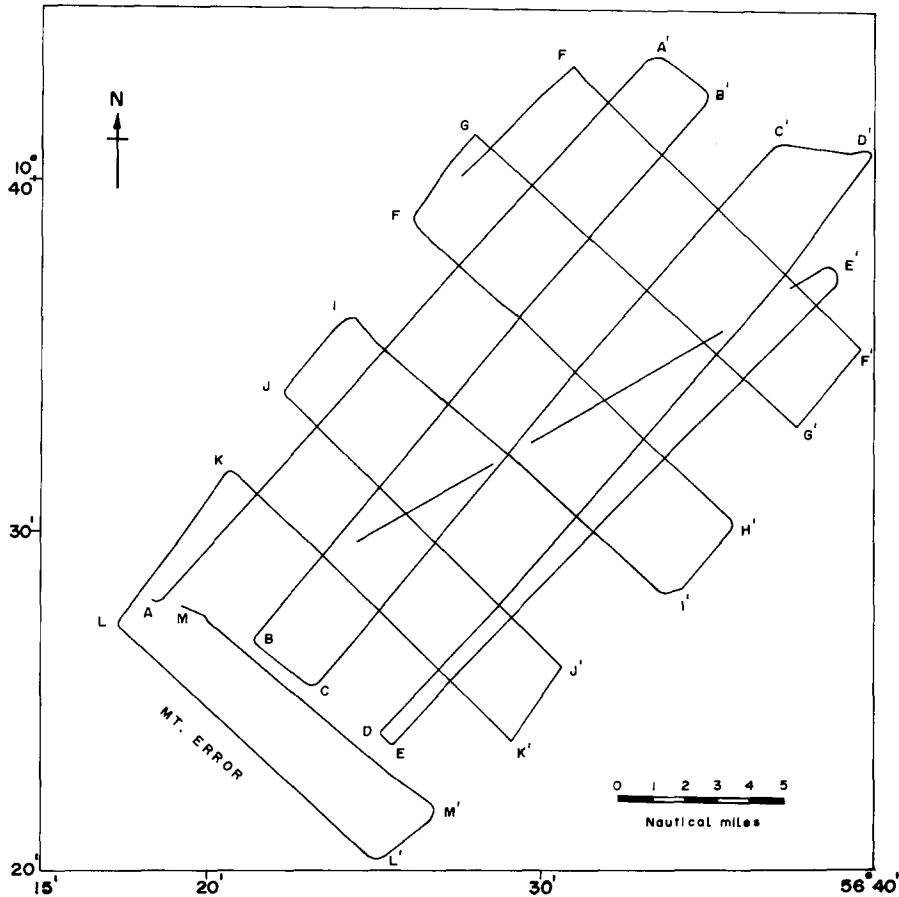


Fig.2. Track chart over the study area.

where it is transected by the Owen Fracture Zone (Fig.1). It rises from 4600 to 360 m (Fig.4). Most of the seamounts along Owen Fracture Zone trend in NE-SW direction (Matthews, 1966). However, Mount Error strikes ENE-WSW or more or less parallel to 10°N . There are some seamounts south of Socotra of which Mount Error is the largest.

Results and discussion

The echogram indicates an apparently symmetrical rise from -4600 to -360 m (Fig.4). The summit of the seamount is flat and extends from $56^{\circ}35'\text{E}$ to $56^{\circ}40'\text{E}$. A very thin (330 ms, two-way travel time) veneer of sedimentary

layer is present over the summit of the seamount. Very steep gradients were noticed on both flanks of the seamount upto a water depth of -3500 m. The analog record of the continuous seismic profile across Mount Error (Fig.5) shows that the material forming the seamount gives strong reverberant returns of the echo and no stratified sedimentary deposition below 330 ms from the top of the seamount. The seismic energy attenuation below this thin sedimentary sequence suggests the presence of massive rock. Sediment pools of about 880 ms (two-way travel time) along the base of the seamount are also present. The age of the basal sediments in this region of Mount Error is Eocene (Bunce et al., 1967). Dredging

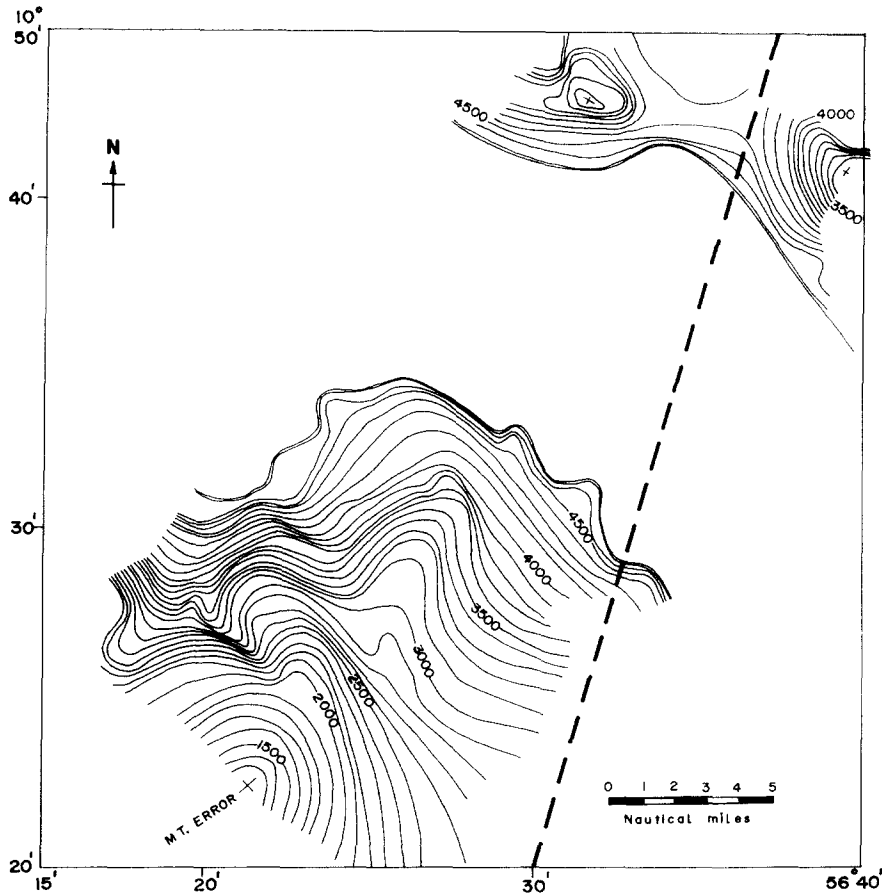


Fig.3. Bathymetry of the study area. The thick dashed line represents the Owen Fracture Zone.

has been carried out after a thorough inspection of the multichannel seismic record and locations were selected on the summit and the slopes of the seamount. The occurrence of dense irregular laminated limestones and brownish to yellow slabs of phosphorites over the summit of the seamount indicate that its top was at shallower water depths in the past. The seamount might have subsided during the processes of continental rifting, drifting and other tectonic activities, as Rao (1986) reported the occurrence of phosphorites of Tertiary times over the summit of the seamount. In general phosphorites occur at shallower marine environments. Based on this fact, and

unless the mount was exposed or situated at shallower depths during the past, such occurrences could not have been possible. The echogram (Fig.4) clearly indicates that the summit of the mount is at about 360 m, which suggests that the seamount might have situated at a shallower depth during the past, and subsided consequently. The rocks dredged from the slopes are peridotites, with varying degrees of serpentinization and alteration, vesicular basalts, sedimentary rocks and laminated limestones (Rao, 1986). Bonatti (1978) and Hekinian (1982) suggested, from the interpretation of seismic profiles across the Owen Fracture Zone, the presence of transverse ridges which

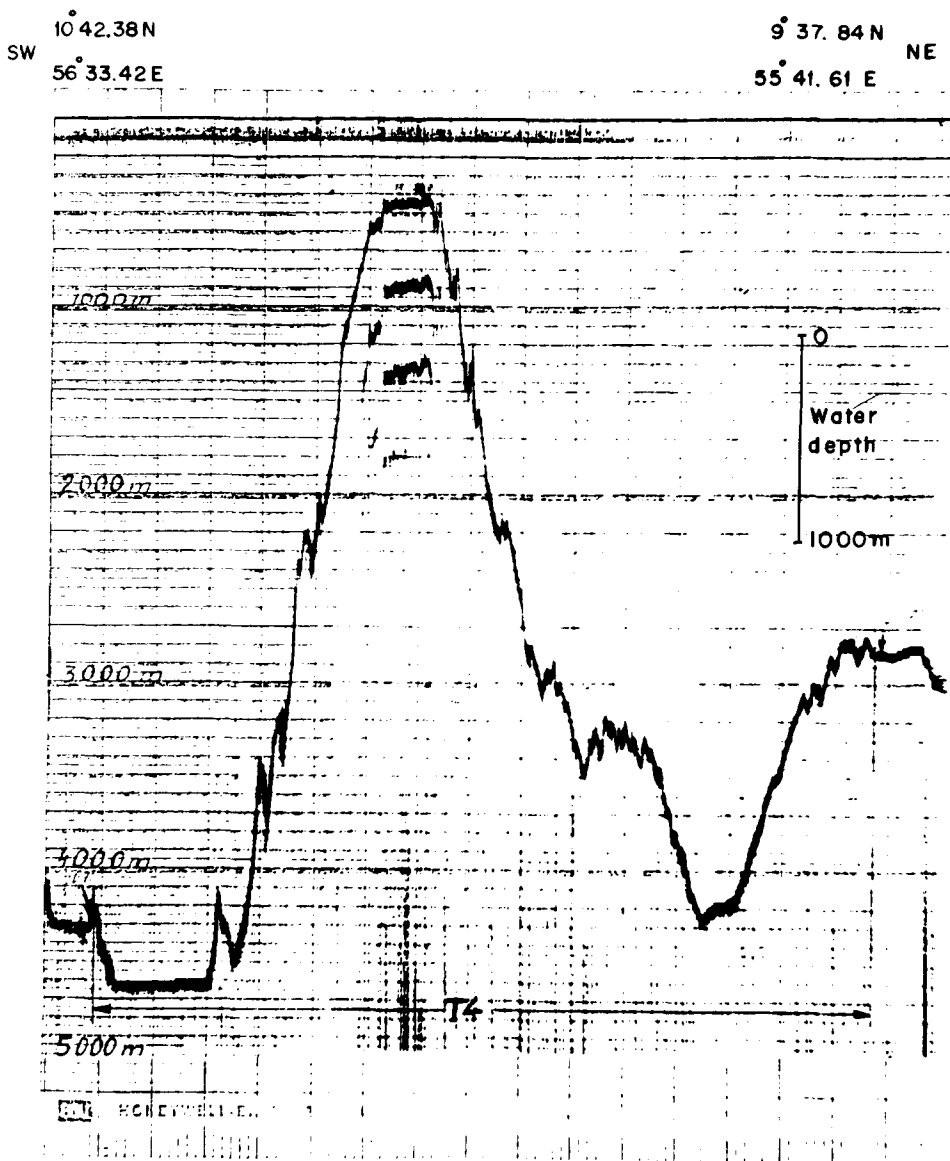


Fig.4. 12-kHz echogram showing the topography over the Mount Error.

represent uplifted upper mantle and crustal blocks. Mount Error perhaps represents such a transverse ridge along the fracture zone.

The residual magnetic anomaly profiles along the northeastern flank of Mount Error (Fig.6) indicate that the central portion of the study area is dominated by a low-amplitude, broad wavelength positive anomaly, and is

flanked by negative anomalies on either side. The broad wavelength anomaly might be an expression of a deeper source, having a slab/plate like geometry. It has been documented that the Mount Error is of continental origin along with Socotra Island (Mckenzie et al., 1970). Heezen and Tharp (1966) assumed that the microcontinents, which are distributed in

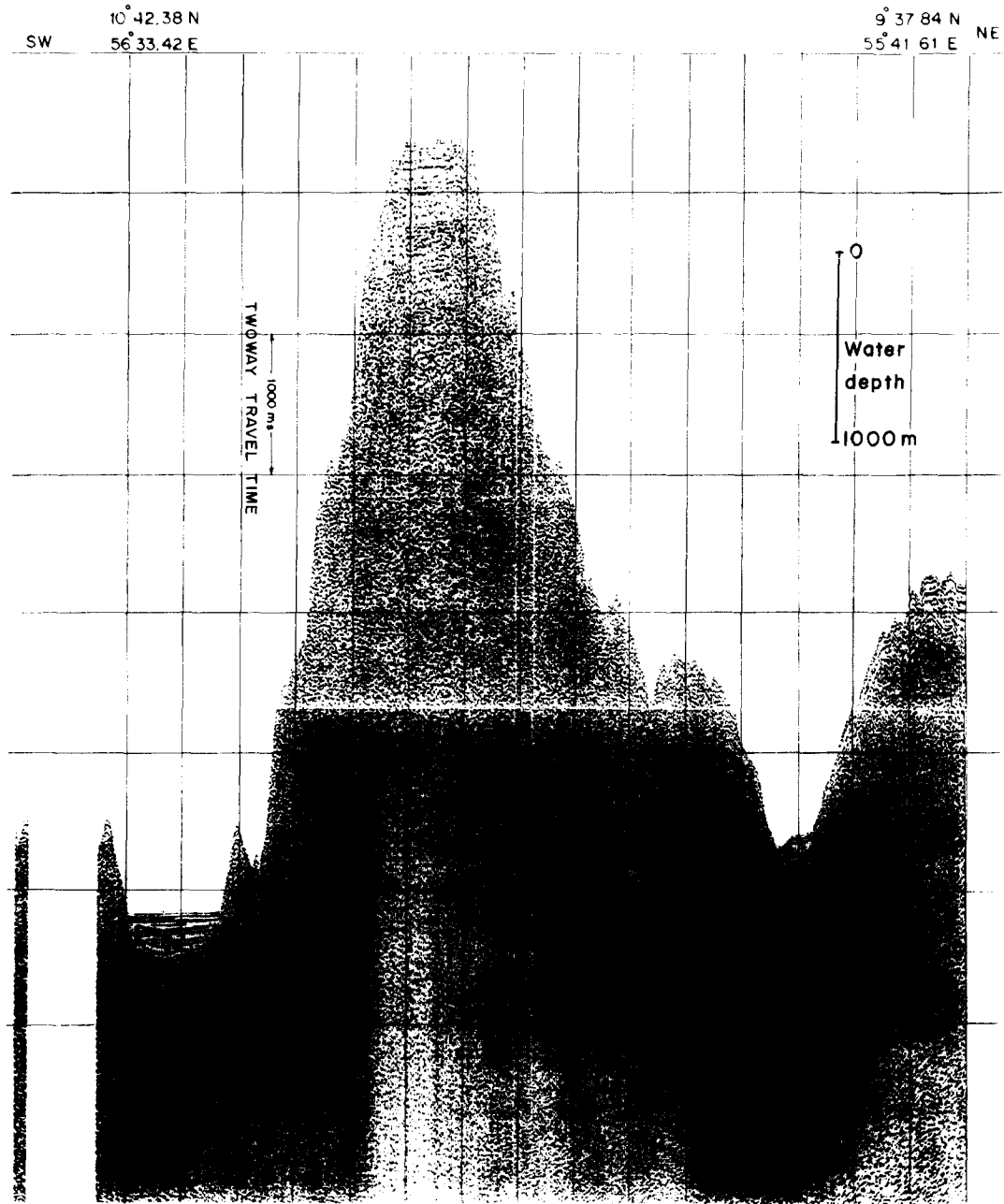


Fig.5. Multichannel seismic reflection profile over the Mount Error. A very thin sedimentary sequence over the summit of the seamount and in the valley at the base is identified.

such a strikingly meridional pattern throughout the Indian Ocean, are fragments of the continental crust. Mckenzie et al. (1970) in their reconstruction of the Arabian and Somali

plates either from transform faults and magnetic lineations or by fitting the 500 fathoms bathymetric contour on each side of the Gulf, clearly indicated that neither Socotra nor

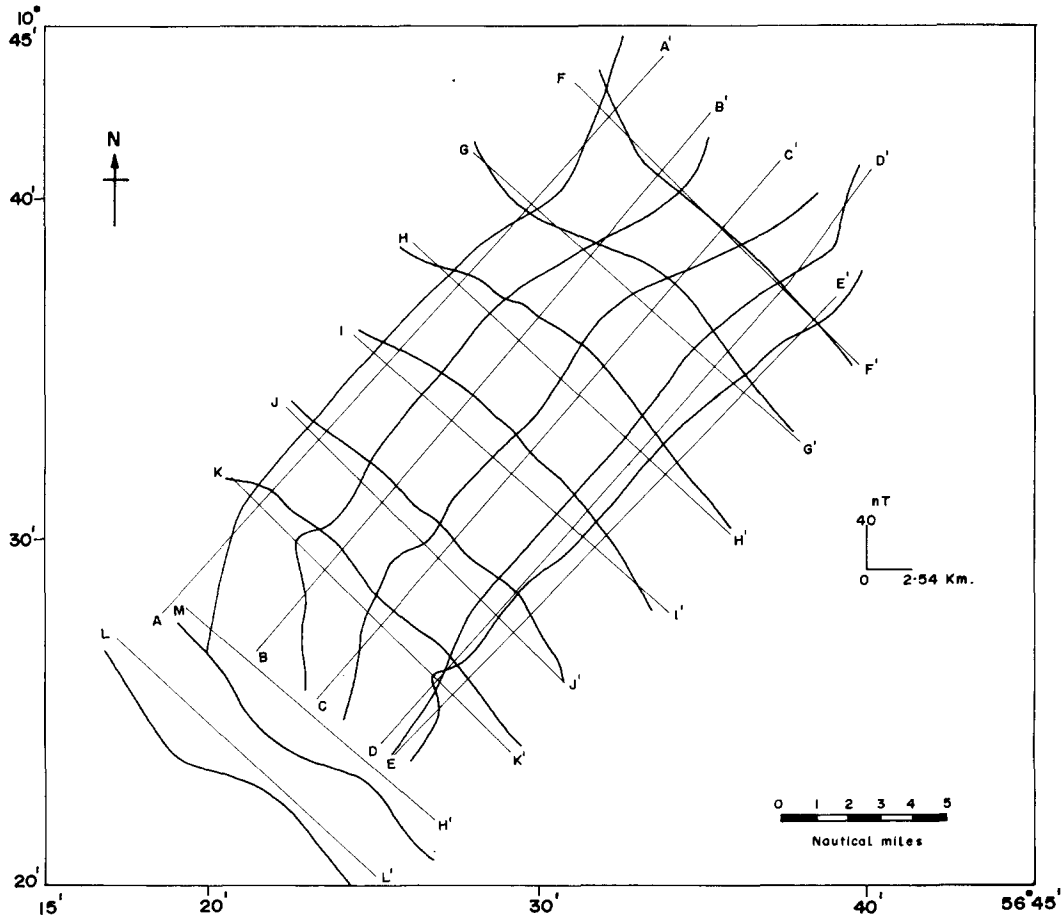


Fig. 6. Projected magnetic anomalies across the cruise tracks.

Mount Error fit back into Arabia and therefore were broken off from Africa before the Arabian plate. Bonatti (1978) described anomalous topographic rises along the Owen Fracture Zone as transverse ridges which are not volcanic in origin (Barker, 1966). Since very little information is known about the exact nature of subsurface geological formations in the study area the available geological information from the DSDP Site 224 was incorporated in deriving the basement models. At Site 224, the igneous basement (Eocene) was met at a depth of 783 m below the seabed and petrographic studies confirmed the rock as lamprophyre. In general, lamprophyres occur as basic dykes or sills (Whitmarsh et al., 1974), and Jackson

(1970), based on the chemical composition, classified lamprophyres as feldspathoidal basalts. The lamprophyres cored at Site 224 possess a low magnetisation and weak susceptibility. Also Matthews (1966) indicated that the seamounts along the Owen Fracture Zone are relatively weakly magnetised. The low-amplitude and broad wavelength anomalies observed in this study might have originated from such a weakly magnetised layer below the seabed. Similar low-amplitude anomalies (< 50 nT) were observed while crossing the Owen Fracture Zone near DSDP Site 224 indicating a low magnetic relief (Whitmarsh et al., 1974). The low-amplitude magnetic anomalies in this study do not correspond to the

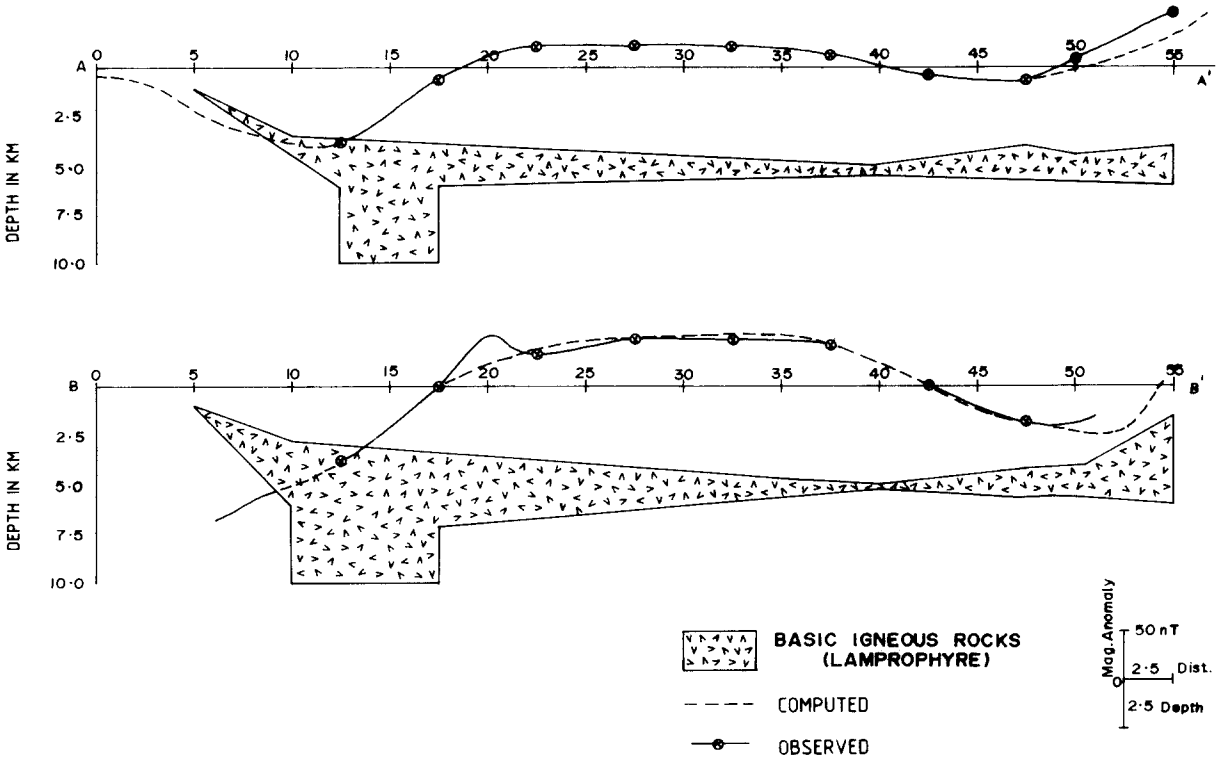


Fig. 7. Computed and the observed magnetic anomalies over the igneous basement. A-A' and B-B' are the tracks shown in Fig. 2.

seafloor spreading type anomalies as the latter one is associated with large amplitude fluctuation events. Geomodel studies following the method of Talwani and Heirtzler (1964) and incorporating the available paleomagnetic information (Whitmarsh et al., 1974), yielded the magnetic basement configuration as shown in Fig. 7. Towards Mount Error, the basement is shallow and is more than 10 km thick. The same block thins down at a water depth of 4700 m, and thickens towards the east, approximating in shape to a slab/plate. This slab-like feature suggests that the basement occurs as a sill. The boundary of the magnetisation contrast nearly coincides with the crustal thickness, as the crustal thickness in Somali Basin and the adjacent Arabian sea is estimated at around 6-7 km and more than 10 km in exceptional cases (Bunce et al., 1967). This anomalous crustal thickness of 10-12 km near the

base of Mount Error shown in model studies perhaps confirms the seamount as of continental origin. Since the shape of the magnetic anomaly depends on latitude and the product of susceptibility and the thickness of magnetised layer, no major changes were made in deriving the desired basement model.

No quantitative interpretation has been attempted with the Bouguer anomaly map (Fig. 8). Figure 9 depicts a 200 mGal amplitude marginal high on either side of the seamount. Bonatti and Hamlyn (1978) located anomalous topographic highs along the Owen Fracture Zone and proposed that these highs are due to tectonic uplift of the upper mantle and crustal blocks along tectonically weak zones. From the meridional profile (Fig. 9) it can be surmised that the high-amplitude gravity anomaly is not due to the surface or subsurface manifestation but due to the undulations in deeper layers

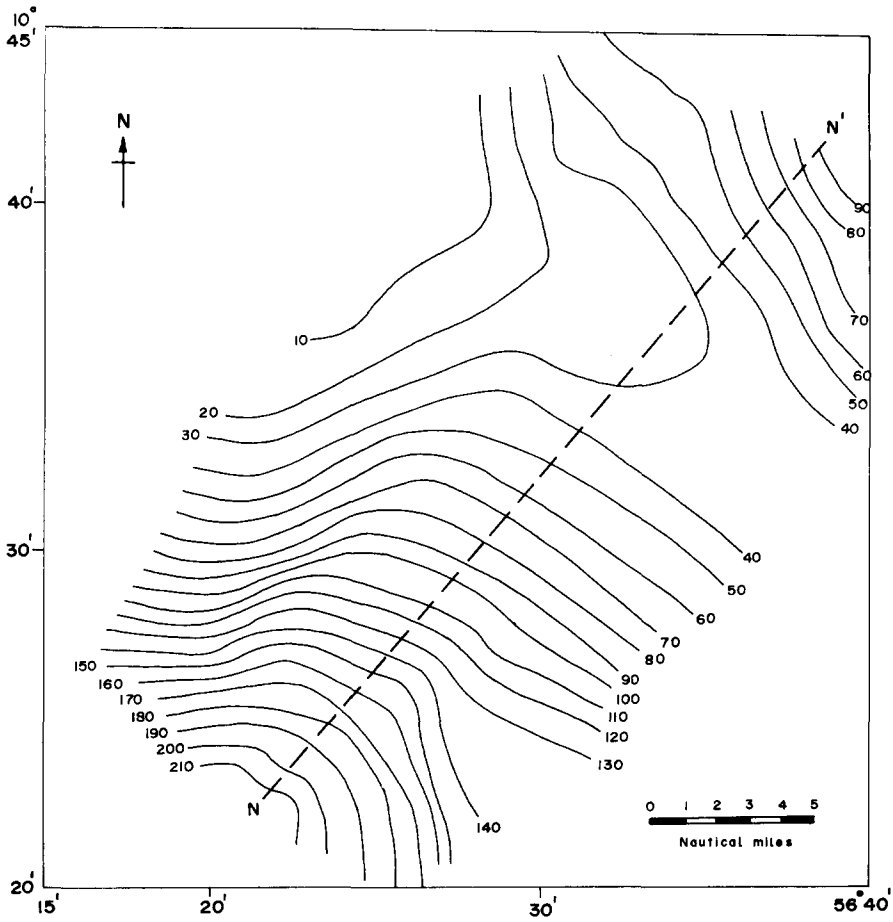


Fig.8. Bouguer anomaly map contoured at 10 mGal. *N-N'* represents the meridional profile direction.

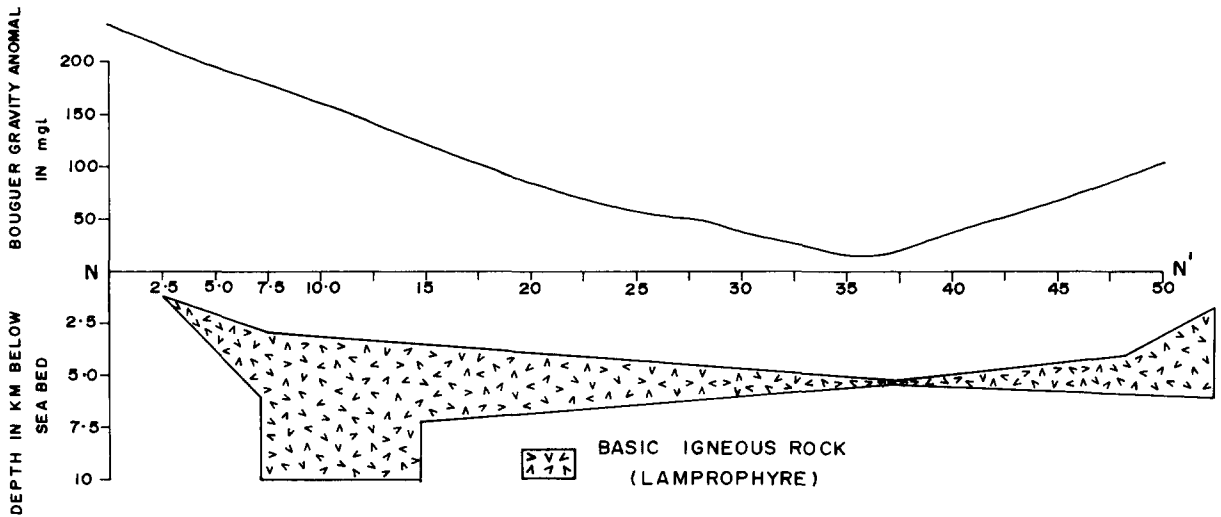


Fig.9. Meridional gravity profile across *N-N'* (Fig.8) over the magnetic basement.

(crust and mantle). Analogous features have been reported by Christopher et al. (1971) who has shown thickening of the crust and deepening and thinning of low-velocity zones within a lateral distance of 50–100 km over the Great Basins of the western United States. Similar thickening and thinning of the crust might be the reason for the remarkable amplitude differences in the present study. Thus, the gravity high perhaps is due to a shallow mantle or intracrustal dense mass, whereas in the middle of the profile the thin crust or upper mantle has an abnormally low density.

Conclusions

Integrated geophysical study over Mount Error and along its northeastern flank suggests that the seamount is an apparent topographic high composed of weakly magnetised rocks of continental origin. A thin sedimentary layer of approximately 330 ms is present over the summit of the seamount and about 880 ms of sediments along the valley situated at its base. Magnetic model studies suggest lamprophyre as the magnetic basement occurring as a thin slab/plate. This lamprophyre basement might have a genetic link with other lamprophyres (DSDP Site 224), as low-amplitude magnetic anomalies were observed while crossing the Owen Fracture Zone and Carlsberg ridge on the approach to DSDP Site 224. The boundaries of magnetic basement appear to coincide with the crustal structure below the study area with a thin crust (6–7 km thick) similar to that reported in the western Arabian Sea. The anomalous crustal thickness below the adjacent northeastern flank of Mount Error is an indication of the continental origin of the seamount. Bouguer gravity anomalies indicate thinning of the crust at a water depth of 4700 m, but a shallow mantle or thickening of the crust on either side of the Valley.

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