PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Preliminary Results of the 1964 Cruise of R.V. Chain to the Indian Ocean

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Preliminary results of the 1964 cruise of R.V. *Chain* to the Indian Ocean*

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[Plates 4 and 5]

Geophysical investigations of the northern Somali Basin and the Seychelles–Mauritius Ridge conducted aboard R.V. *Chain* of the Woods Hole Oceanographic Institution are described and some results presented. Gravitational and total magnetic fields and bathymetry were measured continuously, and continuous seismic reflexion profiles were recorded over a major portion of the track. Cores, dredge samples, heat flow measurements, and underwater photographs were also obtained.

It is considered that the northern portion of the Somali Basin is a deep sedimentary basin partially enclosed to the east by a submarine ridge from which alkaline gabbro has been dredged and to the south by partially buried abyssal hills.

On the evidence from seven crossings of the Seychelles–Mauritius Ridge, it is proposed that the Ridge comprises two sections. The northern section, composed of nearly horizontally stratified rocks, extends from near the northern part of Saya de Malha Bank to the Seychelles Platform. The southern section is a linear, probably volcanic ridge that extends from north of Mauritius through Saya de Malha Bank, and may continue as a subsurface feature to the northeast. The two sections abut near Saya de Malha Bank, forming a continuous topographic feature.

A broad area of the northwest Indian Ocean was investigated during April and May 1964 on a voyage of R.V. *Chain* (figure 1). This report presents preliminary results and some conclusions concerning structural relationships for two particular areas: the northern Somali Basin and the Seychelles–Mauritius Ridge.

Underway observations discussed here are measurements of free-air gravity anomaly and total intensity magnetic field with a LaCoste-Romberg gravimeter and proton magnetometer respectively, bathymetric profiles determined by precise echo-sounding, and continuous seismic profiling (spark source) to record the deeper subsea-floor structure (Hersey 1963). Cores, dredge samples, and underwater photographs also contribute to the findings.

Northern Somali Basin

A number of traverses were made across the Owen Fracture Zone, near the eastern border of the northern Somali Abyssal Plain. The traverses were planned to determine whether separated hills or seamounts shown on an earlier version of the diagram of figure 1 are instead part of a ridge and to investigate the associated magnetic anomaly. The ridge was traced as a topographic feature of 1000 to 1700 fm. relief above the abyssal plain as far south as 3° 30′ N latitude. The magnetic anomaly associated with the ridge is lower than would be expected for a recent volcanic feature. This interpretation is reinforced by samples of alkaline gabbro, a rock of deep-seated origin, dredged from the southeastern slope of the ridge between the depths indicated as 5·75 and 6·75 s reflexion travel time (figure 2, D).

* W.H.O.I. Contribution no. 1575

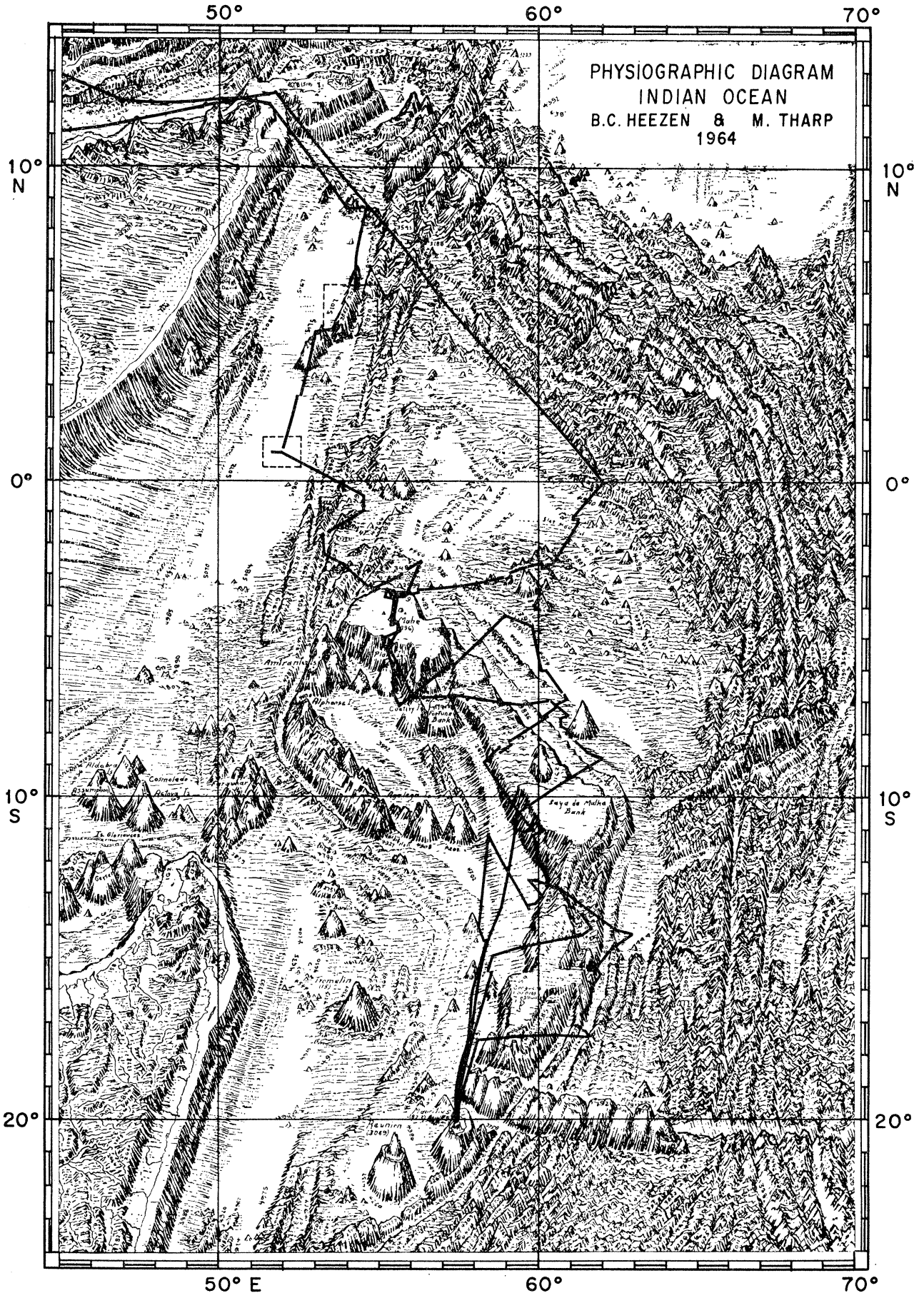

FIGURE 1. Track of R.V. *Chain*, 31 March to 3 June 1964. The track is drafted on a portion of the Physiographic diagram of the Indian Ocean, published by the Geological Society of America. (Copyright 1964 by B. C. Heezen and M. Tharp. Reproduced by permission.)

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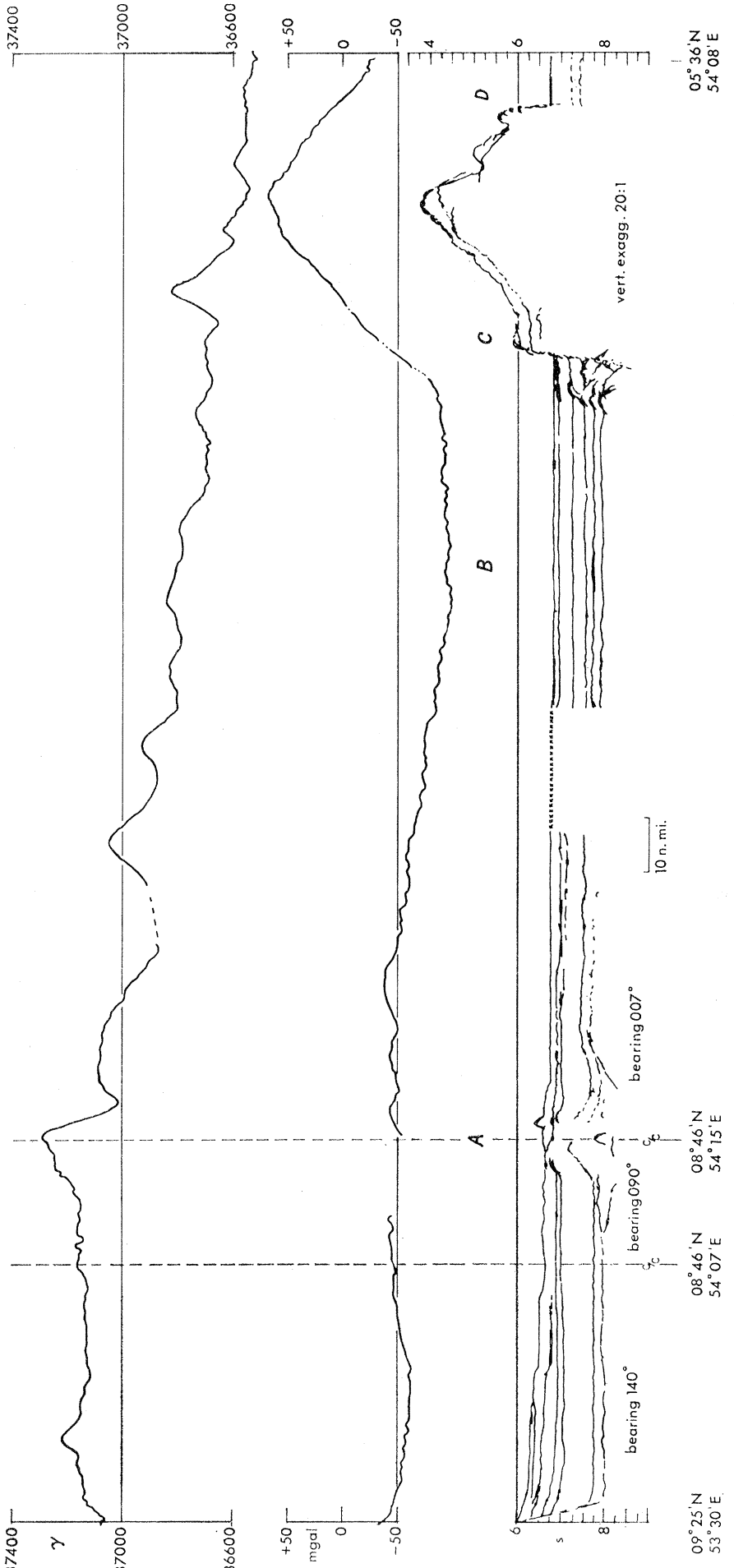

FIGURE 2. Northern Somali Basin: Continental rise and abyssal plain. Total intensity magnetic field, free air gravity anomaly, and seismic reflexion profiles.

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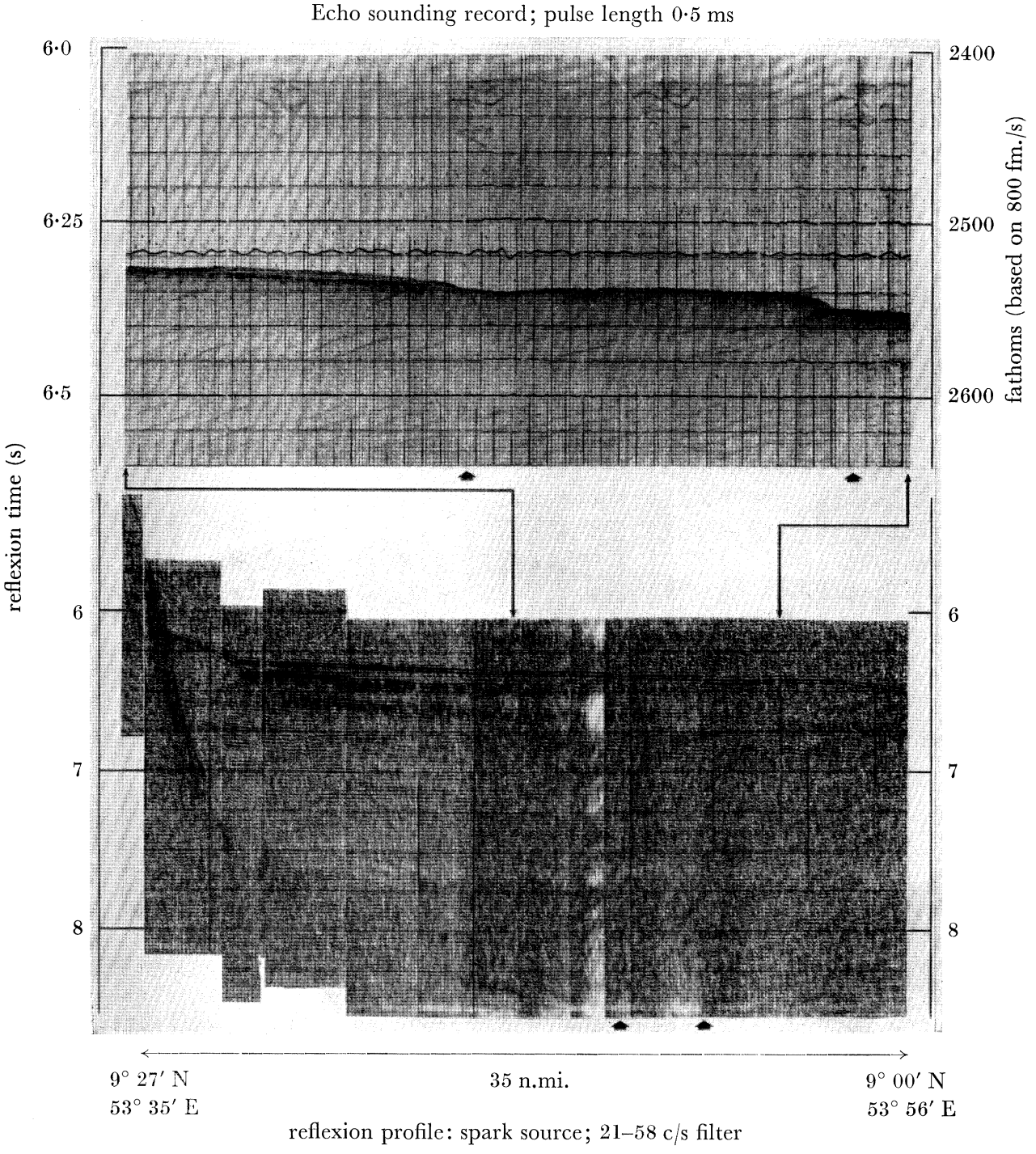

FIGURE 3. Somali Abyssal Plain: echo sounding record (top) and reflexion profile (bottom).

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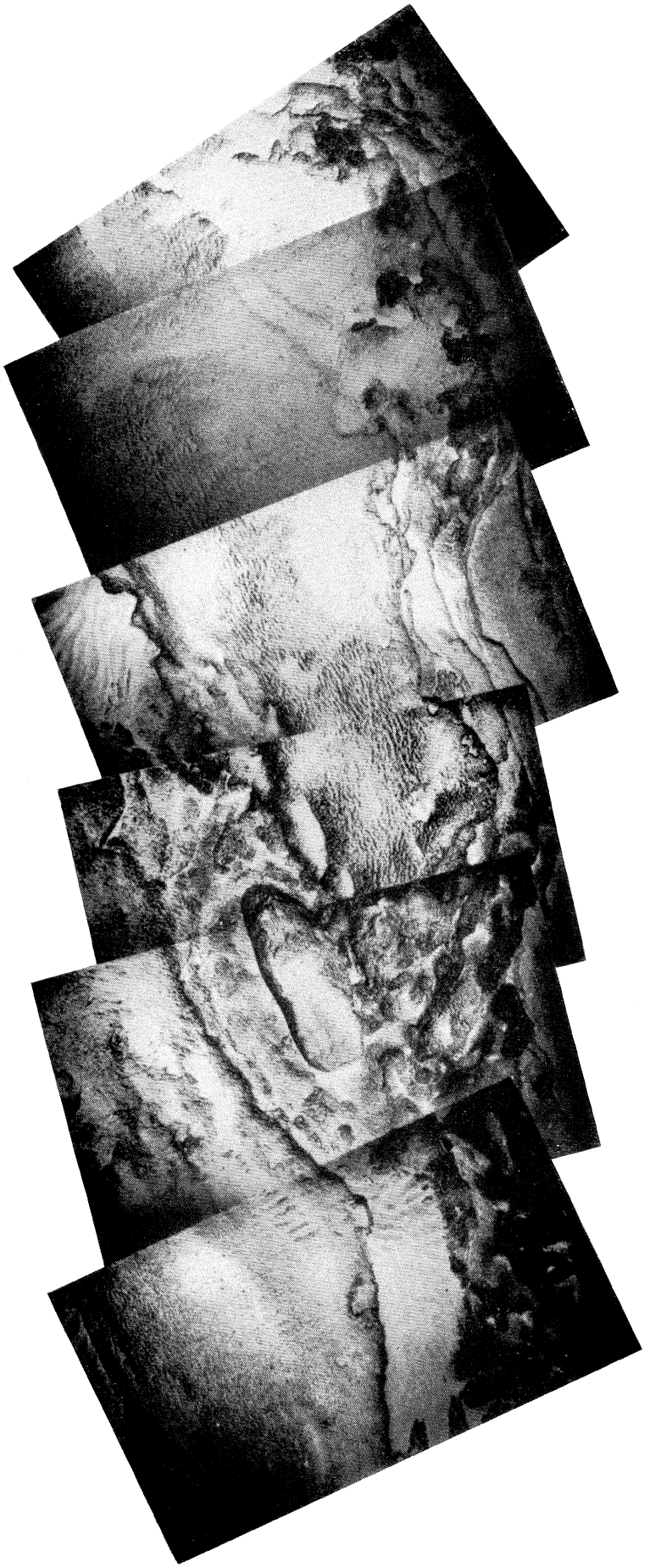

FIGURE 7. Mosaic of underwater photographs; western slope of the Seychelles–Mauritius Ridge at lat. 8° 30′ S, long. 58° 51′ E, water depth 1100 fm. (1 in. = 7·65 ft., horizontal scale).

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Profiles of the total-field magnetic intensity, free-air gravity anomaly, and subsea-floor structure of the continental rise south of Socotra and of the Somali abyssal plain as far south as Owen Fracture Zone are shown in figure 2. The significant departures from regional trends are a magnetic anomaly of 300 γ associated with the subbottom structure (A), the increase in the negative free-air anomaly over the deep, uniform layers of the abyssal plain (B), and the relatively low amplitude magnetic anomaly over the northwestern slope of the Owen Fracture Zone (C).

Echo soundings made with very short pulses reveal sequences of thinly layered sediments at the top of the subbottom sequence which are continuous over great distances on the continental rise (figure 3, top, plate 4) and on the abyssal plain to the south. The deeper structure of the northern basin, which extends as far south as Owen Fracture Zone, is shown by the seismic reflexion profile. Flat uniform layers 2 s of travel time below sea-bottom are evident. A photograph of a portion of the original record, obtained over the continental rise, is shown in figure 3 (bottom).

There is a marked difference between the subbottom structure north and south of Owen Fracture Zone. The topography to the south is slightly rougher than to the north, although some shallow stratification occurs between small hills (50 to 200 fm.) rising above the bottom. A reflexion more or less continuous at 0·25 s after the bottom echo is shown on the reflexion profiles, but the deep echoes from uniform reflectors similar to those of the northern part of the basin are not present. Instead, echoes suggesting a rough reflecting surface at an average delay of 1 s after the sea-bottom echo, with relief of 0·5 s or greater, suggests buried and partially buried hills. The section resembles those found in areas of abyssal hills in the North Atlantic.

It appears that the northwest portion of the Somali Basin is a deep sedimentary basin partially enclosed to the east by Owen Fracture Zone and to the south by buried and exposed abyssal hills. Corroboration of this hypothesis is furnished by seismic reflexion profiles recorded during two traverses made by R.V. *Vema* of Lamont Geological Observatory (Langseth, personal communication, 1964). The *Vema* profiles show the structure west of Owen Fracture Zone to be the same as that to the north, already described, while to the southwest it resembles the section of abyssal hills. These structures to the south may be an extension of the Fracture Zone.

The Seychelles–Mauritius Ridge

Seven crossings were made of the ridge lying between the Seychelles Islands and the island of Mauritius. The bearings of the crossings vary, some being less normal to the trend of the Ridge than others.

The profiles of figure 4 present sections across the northern part of the Ridge, from the Seychelles Platform to Saya de Malha Bank. The effects of the regional gradient on total intensity magnetic field and those of topography on the free air gravity anomaly are clearly to be seen. A possible magnetic anomaly is associated with the Ridge or series of hills which rise from the western slope of the central Ridge. This anomaly is small on profile 1 but more distinct on profiles 2 and 3.

The seismic reflexion profiles over the central Ridge on the three northern crossings

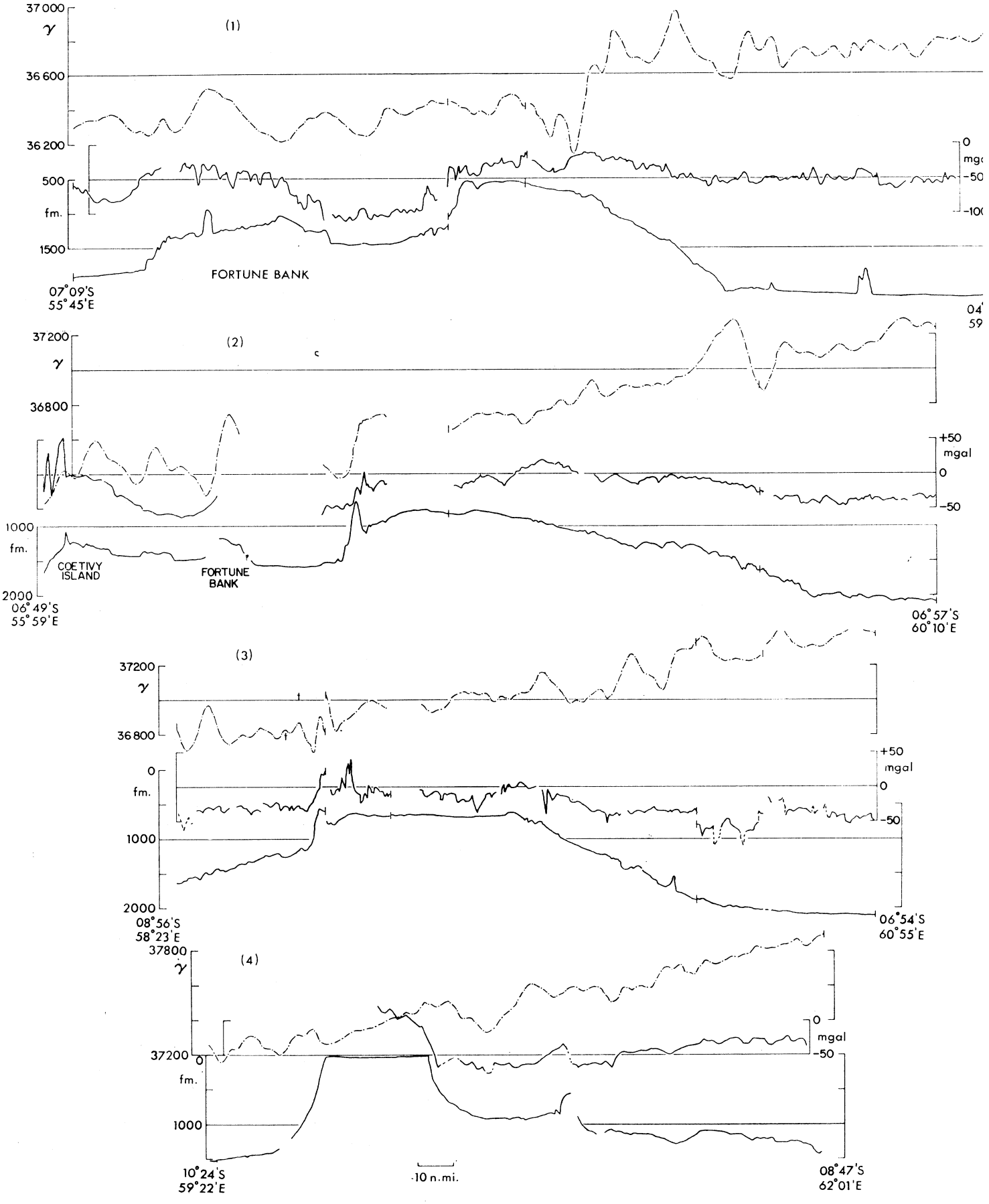

FIGURE 4. Seychelles–Mauritius Ridge: profiles immediately south of Seychelles Platform to north part of Saya de Malha Bank. Total intensity magnetic field, free air gravity anomaly, and bathymetry. (1) Immediately south of Seychelles Platform (bearing 045°); (2) midway between Saya de Malha Bank and Seychelles Platform (bearing 090°); (3) between Saya de Malha Bank and Seychelles Platform (bearing 050°); (4) north part of Saya de Malha Bank (bearing 050°).

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(profiles 1 to 3), although not presented in figure 4, show rather uniform echo sequences suggesting subsea-floor layering. The echoes arrive up to 0·5 s after the bottom echo.

In profile 4, across the northern section of Saya de Malha Bank, and in the three profiles to the south of it shown in figure 5, the central part of the Ridge has relatively steep slopes and a flat top. The seismic reflexion records contain no evidence that the flat top is underlain by flat lying sediments: although the water depth is shallow, the bottom reflects sound so poorly that only one multiple of the bottom reflexion is detectable on the records, and it would be possible to detect flat-lying subbottom reflectors if they existed.

In the three southern profiles (nos. 5 to 7, figure 5), as on Saya de Malha Bank, there is no seismic reflexion evidence for layering of the flat, high central part of the Ridge. However, reflecting horizons with echo delays as great as 0·65 s beyond the bottom echo can be traced east and west up the flanks of the ridge to the 1000 or 700 fm. level on each of these crossings. Therefore it is tentatively concluded that the flat top is a product of erosion, not deposition. The fourth magnetic profile shows no high intensity anomaly over the central part of the Ridge. The corresponding gravity profile and others to the south are incomplete because rough seas encountered in this area prevented uninterrupted operation of the gravimeter.

The high amplitude magnetic anomalies associated with the centre of the flat top of the Ridge in profile 7 and with its western edge in profiles 5 and 6 are in contrast with those of relatively low amplitude in profile 4.

Profile 7, shown again in figure 6, presents the structure shown by the seismic reflexion record. The distinctive feature is the layering suggested beneath the lower eastern part of the Ridge by echo sequences at 1·75 s (700 fm.) water depth. A layered section of the same thickness is suggested by the seismic records at the foot of the eastern slope of the Ridge, at a depth of over 2000 fm. Thus the eastern slope of the Ridge in this area may be a zone of faulting. It is also possible, however, that the higher layered sequence consists of sediments derived from the central part of the Ridge, and, further, that the deeper sequence is not related to it, but is derived from the area south of the Ridge (figure 1), or from elsewhere.

Twenty-five dredge lowerings were made, on and along the flanks of the Seychelles–Mauritius Ridge. Except for one small piece of granite southeast of Seychelles Platform and one pebble of volcanic (?) rock obtained northeast of Saya de Malha Bank, all the samples obtained are limestone, coral fragments, or calcareous sand whose foraminifera have been identified as Recent by Dr Wm. A. Berggren (personal communication, 1964).

Figure 7, plate 5, shows a portion of a mosaic of underwater photographs covering about half a mile of the southwest slope of Saya de Malha Bank at 1100 fm. depth. The mosaic shows quite clearly that a considerable area of the bottom consists of outcrop of nearly horizontally layered rocks. In the light of the dredged material these rocks are considered to be limestone. Ripple marks indicate current activity at this depth.

Discussion

It is reasonable to postulate that the northern part of the Seychelles–Mauritius Ridge is structurally different from the southern part. In the former, layered structures, probably sedimentary in origin, occur beneath the central part of the Ridge. No evidence for

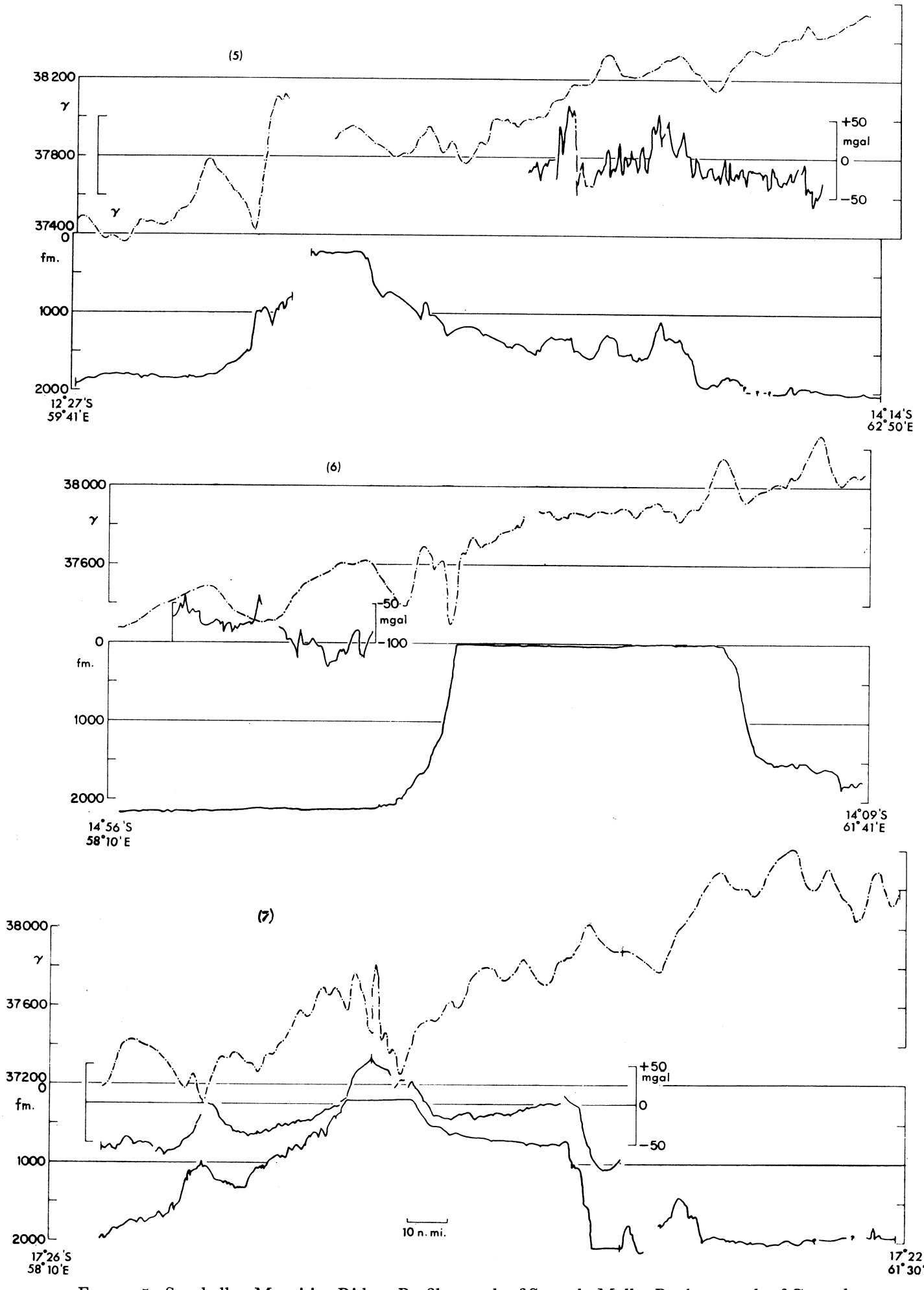

FIGURE 5. Seychelles–Mauritius Ridge: Profiles south of Saya de Malha Bank to south of Cargados Shoals. Total intensity magnetic field, free air gravity anomaly, and bathymetry. (5) Between Saya de Malha Bank and Nazareth Bank (bearing 130°); (6) Nazareth Bank (bearing 075°); (7) south of Cargados Carajos Shoals (bearing 090°).

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sedimentary layering is found on Saya de Malha Bank nor beneath the central part of the Ridge to the south. The magnetic anomalies associated with the northern Ridge (figure 4, profiles 1 to 3) are weaker than those to the south and are apparently associated with a local structure, a small topographic high near or on the western margin of the Ridge. South of Saya de Malha Bank magnetic anomalies of 400 γ or greater are associated with

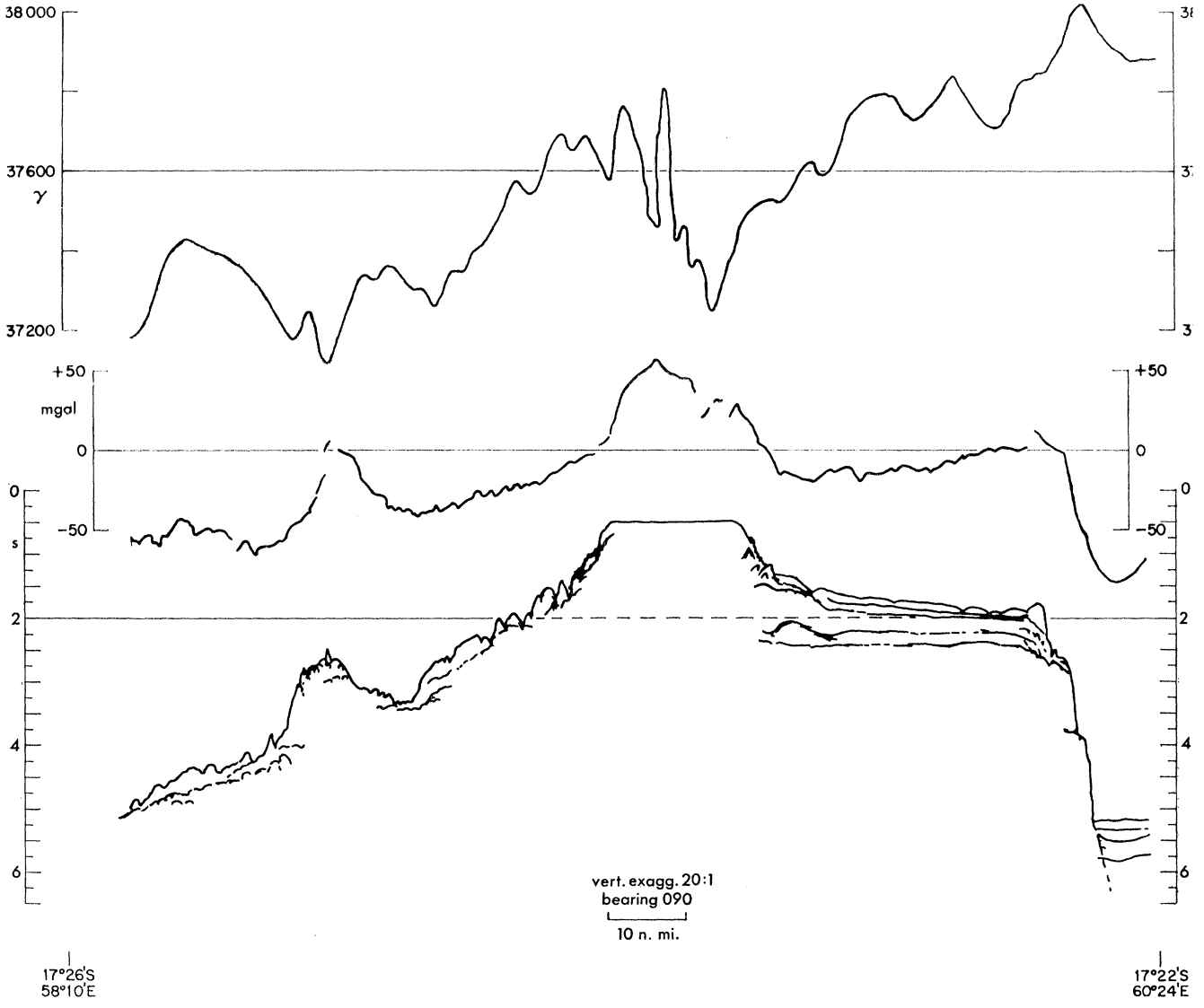

FIGURE 6. Seychelles–Mauritius Ridge: south of Cargados Carajos Shoals. Total intensity magnetic field, free air gravity anomaly, and seismic reflexion profiles.

the western margin of the Ridge and with the central portion south of Cargados Carajos Shoals (figure 5, profiles 5 to 7). Shor & Pollard (1963, p. 49), in a discussion of seismic refraction data from the Seychelles and Saya de Malha Bank, suggested that the difference between the two areas might be explained by the presence of a 'linear volcanic ridge (similar to the Hawaiian Ridge) extending from Mauritius through Cargados Carajos Shoals to Saya de Malha Bank, caused by volcanic outpourings from a line of weakness in the ocean floor'. They further suggested that the line continues north and passes close to the Seychelles granitic block, a feature probably much older. The hypothesis is presented

here that the magnetic anomaly over the centre of Cargados Carajos Shoals is continuous with those observed along the western margin of the Ridge as far north as Saya de Malha Bank and is indicative of the trend of a linear feature, probably younger than the Ridge, and possibly representing a more recent zone of weakness and volcanic outpouring. Further, the presence of layered structure on the northern part of the Ridge argues sedimentary origin, older than the volcanic section to the south.

It would be interesting to explore the possibility that the hypothesized younger volcanic ridge structure trends northeast, abuts the sediment covered feature extending south from the Seychelles platform, thus forming an apparently homogeneous topographic feature, and passes east of the older granitic structure, or alternatively that it continues along the arcuate line of the Ridge, becoming more deeply buried to the north, as far as the Seychelles Platform.

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Echo sounding record; pulse length 0·5 ms

reflexion profile: spark source; 21–58 c/s filter

FIGURE 3. Somali Abyssal Plain: echo sounding record (top) and reflexion profile (bottom).

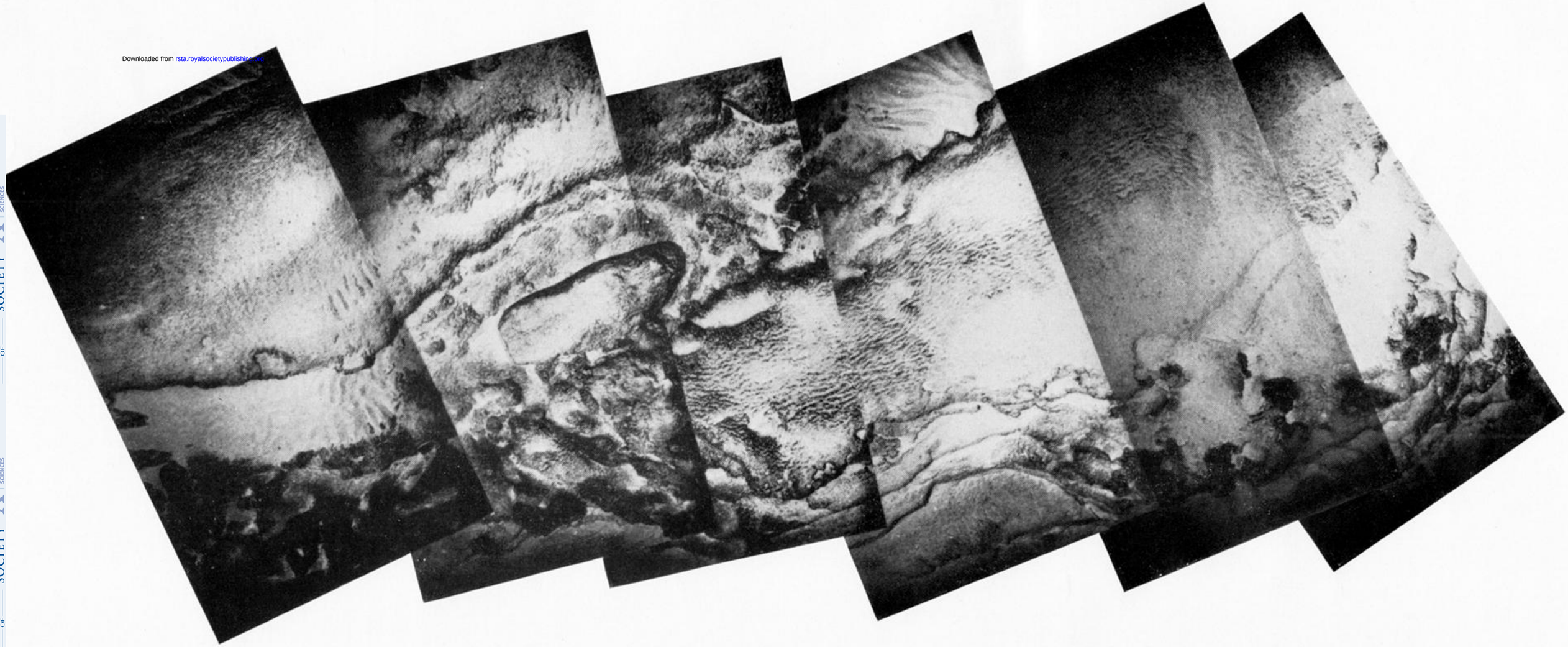

FIGURE 7. Mosaic of underwater photographs; western slope of the Seychelles–Mauritius Ridge at lat. 8° 30′ S, long. 58° 51′ E, water depth 1100 fm. (1 in. = 7·65 ft., horizontal scale).

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