17. CORRELATION OF A TRANS-TYRRHENIAN REFLECTION PROFILE WITH SITE 132

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INTRODUCTION

A continuous seismic reflection line across the Tyrrhenian Basin was recorded with 12-fold subsurface coverage as part of a cooperative program supported by the Consiglio Nazionale Delle Richerche (Italy) and the U. S. National Science Foundation.

The preliminary results of the seismic studies have been reported by Finetti *et al.* (1970). Since the continuous profile MS-1 (made aboard the *Marsili* in 1969) almost intersects Site 132, and because of the high quality of the multiple coverage, it seemed appropriate to present the digitally processed profile in this volume together with the drilling results, and to discuss briefly preliminary correlations between the seismic data and the drilled section.

The locations of the profile and the drill site are shown in Figure 1 on a morphological map of the Tyrrhenian Sea (Selli, 1970). The profile (Figure 2) extends from the Calabrian Basin westward into the bathyal plain crossing the Marsili Seamount and then turns northwestward, traversing the deep central basin and on to the Baronie Mountains just east of Sardinia. The ship's track was controlled by both Decca and Loran-C positioning systems.

INSTRUMENTATION

The seismic source utilized three synchronized Flexotir guns (Institut Francais du Petrole, 1969) each firing 50 grams of Geodin-B. The shot interval was maintained at 100 meters. The receiving equipment included a neutrally buoyant Seismic Engineering streamer, 24 traces of 20 piezoelectric ceramic hydrophones each, normally towed 25 meters deep. The data was recorded on board ship with a multichannel Texas Instruments Digital Field System and processed at the Bari Computer Center of the Osservatorio Geofisica Sperimentale with a commercial seismic data analysis program. The details of the field procedure, the digital seismic recording technique, and the data processing employed in the survey are given elsewhere (Finetti *et al.*, 1970).

CORRELATION OF THE PROFILE TO THE DRILL HOLE

Correlation of the drill site lithology with reflectors observed in the seismic profile can be made by calculating the depths to the various horizons from (1) the mean interval velocity function of the observed RMS velocity series, or (2) from *in situ* observation of sound velocities in the sedimentary units penetrated at the drill site. Unfortunately no direct sound velocity measurements were obtained during drilling operations. However, experience of the chief scientists (personal communication) with the soft unconsolidated ooze recovered from the first 183 meters of the section and with materials recovered at other drill sites in the Mediterranean where direct velocity measurements have been made, suggests that these materials have compressional wave velocities of less than 1.7 km/sec, and probably straddle 1.6 km/sec (see discussion in Chapter 13 on Site 132).

The interval velocities for the seismic section have been inferred indirectly by two methods:

1. From the multifold stack, velocity information was computed from the time difference of a given reflected arrival to the nearest and farthest trace on the hydrophone array. The input to the velocity analysis process is a collection of seismic traces from a number of adjoining common depth points, using twelve-fold coverage. The interval velocity functions were computed at each 10 km interval along the whole MS-1 profile. Eight functions were obtained along the elevated rise where Site 132 was drilled. They were computed at shot points 3940, 4040, 4140, 4240, 4340, 4440, 4540, 4640.

The actual drill site, at 40° 15.70′N, 11° 26.47′E, lies some 2.7 km to the SSW of the seismic profile, and normal to shot point 4110 (that is, 411 km from the origin of the profile). A simple projection of the drill site onto the profile would place it near the crest of a small knoll on the rise (Figure 3). However, comparison of the bathymetric depth of this location (3.55 seconds two-way travel time) is not in agreement with the known bathymetric depth of the spudding-in location observed on both seismic profiles and precision echograms obtained aboard the *Glomar Challenger*. The PDR depth of the drill site is 3.67 seconds. If we compare the *Challenger* reflection profile over the drill site (Figure 4) with the MS-1 profile, and project the drill site location according to bathymetric and subsurface similarities, a more representative alignment with the MS-1 profile would be near shotpoint 4140.

The interval velocity function obtained nearest Site 132 at shot point 4140 (approximately 4 km distant) is shown in Figure 5 with the velocity curve for shot point 4040 farther to the southeast.

Curve A of Figure 5 at shot point 4140 shows a very unusual velocity inversion with a relatively high interval velocity of 3.59 km/sec at a depth interval of 3.80 to 3.91 seconds. This interval clearly coincides with the unconsolidated sediment part of the drill column. Its computed velocity is believed to be unreasonably high and probably

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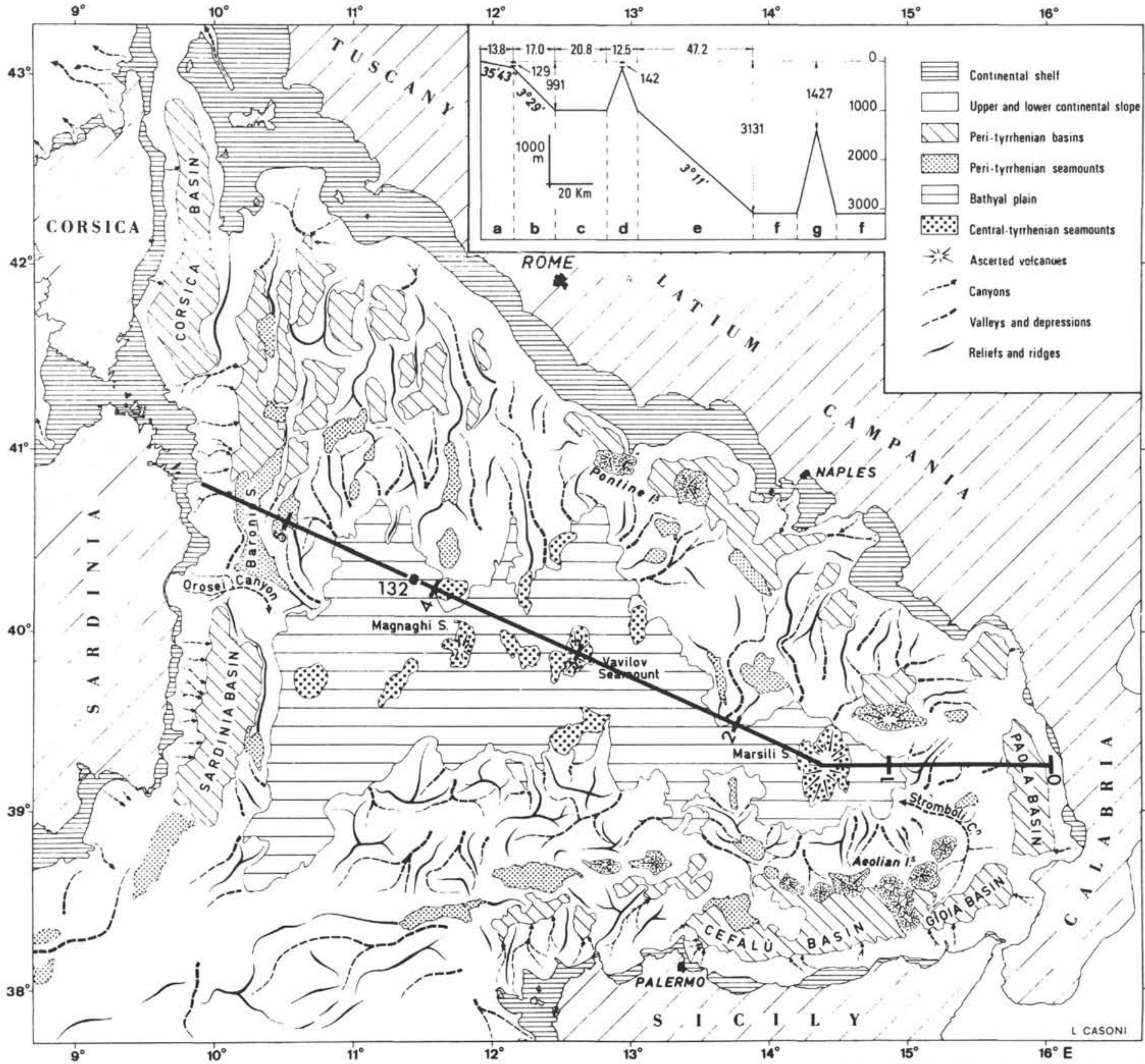

Figure 1. *Location of the MS-1 reflection profile and Site 132. The morphologic map is from Selli (1970). The distances along the seismic profile are given in intervals of 100 km (for example, 1000 shotpoints).*

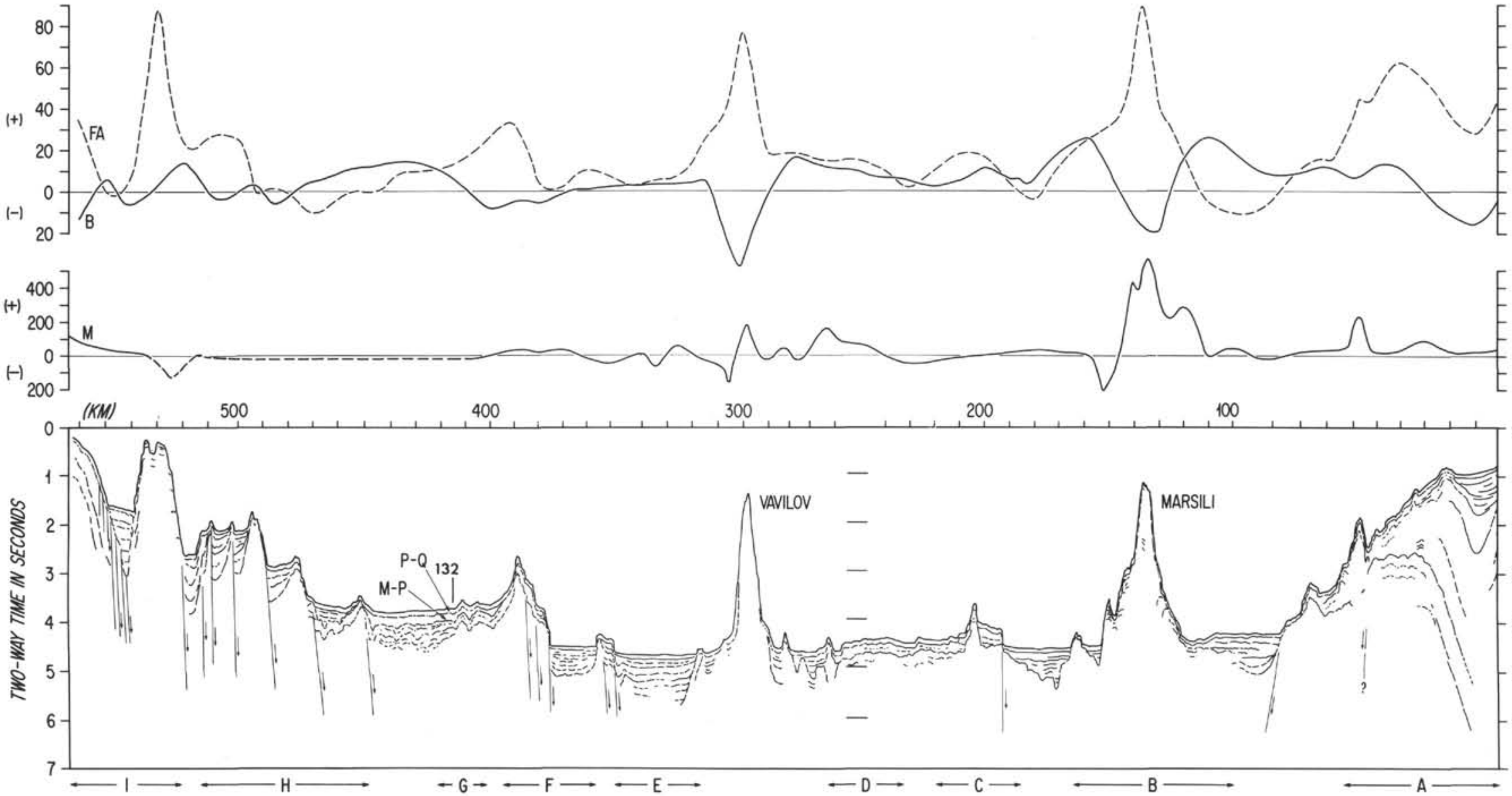

Figure 2. *The interpreted reflection profile MS-1 displays a number of normal faults, characteristically tilted sedimentary basins, sedimentary folds, volcanoes and associated aprons of the bathyal plain. This scheme seems to portray the surficial effect of the foundering of the Tyrrhenian crust. The resulting basin and range topography is characteristic of the collapse and rotation of crustal blocks (possibly continental–see Heezen* et al., *1971). Note the down-dropped structures from 350 to 540 km. Volcanic activity is shown most readily in the magnetic anomaly curve (M) and by seamount relief at 60, 140, and 300 km. The influx of terrigenous sediments to the bathyal plain is strongly controlled by a circum-Tyrrhenian fault system. Many of the faults are associated with linear basement ridges. Ridges near the top of the slope have dammed huge thicknesses of sediment (over 5 seconds) in peri-Tyrrhenian sedimentary basins (0-30 km and 540-550 km). The presence of the sedimentary basins is mirrored in the negative portions of the Free Air anomaly curve (FA). The Bouguer anomaly curve (B), when compared to the Free Air curve shows that the assigned density of 2.67 used on the gravity calculation is too large and overcompensates the structures. In fact, Morelli (1970) has shown that the density of the Tyrrhenian volcanoes averages about 1.7 g/cm*^{3} *indicating that the topographic expressions may be cones of pumice and ash. The correlations with the DSDP Site 132 are shown depicting the levels of the Pliocene-Quaternary (P-Q) and Miocene-Pliocene (M-P) boundaries as found in the drilled section. The distorted Miocene strata are suggestive of salt tectonics and are comparable to structures observed on the Balearic Basin. The original uninterpreted profiles appear in Finetti* et al., *(1970) and, additionally, discussion of the physiography and hypsometry is found in Selli (1970) and Selli and Fabbri (1971).*

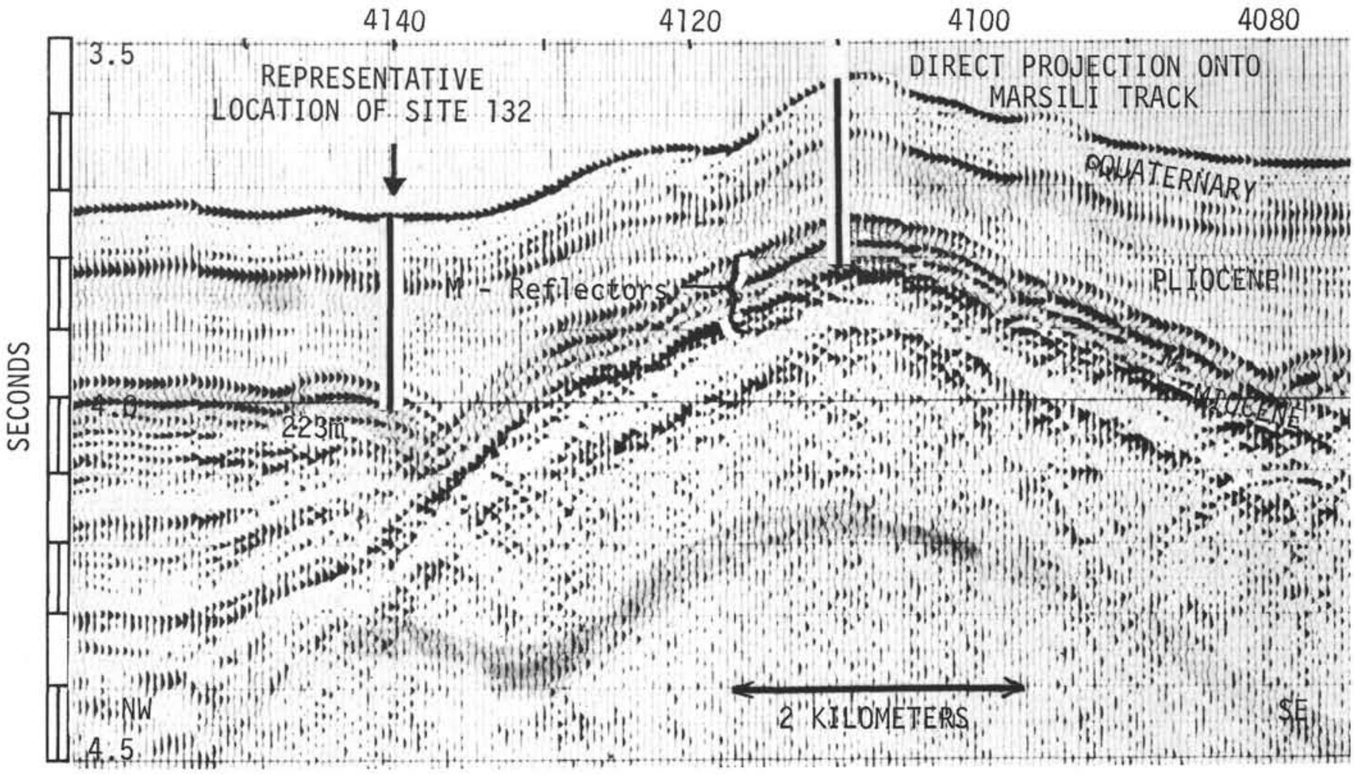

Figure 3. *Details of the digitally processed reflection profile MS-1 in the vicinity of Site 132. The horizontal scale is shown, where 10 shot points equal 1 km (vertical exaggeration = 6.5:1). Each vertical line represents a reflection point from a multiple coverage at 0.05 km intervals. The variable amplitude and variable area presentation shows marked details in the sea floor undiscernible in standard airgun reflection profiles (see Figure 4).*

Shown are the projected Site 132 onto the profile at shot point 4110 and the better estimate of its real relation to the observed structure at shot point 4140. Note the small relative thickness change of the Quaternary sediments and the marked thickness changes of the Pliocene. The Upper Miocene evaporites have a strong acoustic signature and are often broken up giving hyperbolic traces tangential to regionally smooth interfaces. Acoustic basement (bed rock) is not discernible in the vicinity of Site 132.

due to poor automatic velocity resolution during the processing procedure. In fact, even highly lithified deep sea limestones of Mesozoic age (Schreiber *et al.*, 1972) from drill sites in the North Atlantic do not have velocities in excess of 2.9 km/sec except at high confining pressures (greater than 2.5 kilobars). Accordingly, the velocity value of 1.77 km/sec calculated for the same relative interval at shot point 4040 seems more reasonable.

2. Interval velocities can be calculated by correlating sub-bottom reflecting horizons with lithologies in the drilled sediment column. In the case of the MS-1 profile, a very distinctive reflector at 3.98 seconds at shot point 4140 (0.25 second below the sea floor) can be traced laterally over extensive distances in the Tyrrhenian Basin. This horizon corresponds with the upper surface of a series of very strong reflectors in an airgun profile (*Glomar Challenger*, Figure 4) that has been identified as Reflector M (Ryan *et al.*, 1971; Biscaye *et al.*, 1971). The M Reflectors (plural, since the processed seismic signal on the *Marsili* profile shows several phases) generally lie immediately beneath an acoustically transparent zone. The strength of the energy return must signify a major change in acoustic impedance in the sub-bottom structure. A depth of about 204 meters below the sea floor is indicated for the horizon, assuming a 1.7 km/sec velocity for the transparent zone.

A significant break in lithology is marked in Section 2 of Core 21 (183 m below the sea floor) by a sharp contact between overlying soft Pliocene biogenic oozes and underlying stiff, dolomitic marls of an upper Miocene evaporite suite which contain thin sand lenses (see Chapter 13 for descriptions of the core material). Core 21, however, was not completely full. In fact only two out of the six sections were recovered. While DSDP convention puts the recovered sediment at the top of the cored interval, the shipboard drilling records (personal communication of the Chief Scientists) show a marked change in torque and penetration rate at approximately 188 meters below the sea floor, suggesting that the contact was encountered near the very end of the cutting of this core. Thus, we prefer to correlate the major acoustic horizon with this drill break, under the assumption that it doesn't violate the drilling data, only the project convention. Solid gypsum was encountered in Core 26 at approximately 216 meters. Preliminary velocity measurements on the gypsum core samples from Core 27 (see Chapter 18) gave values in the range of 4.94 to 4.96 km/sec at a confining pressure of one kilobar.

The top of Reflector M has been correlated with the top of the evaporite suite as shown in Figure 5, a graph of interval velocity for the seismic section at shot point 4140. The next strongest acoustic event below the top of

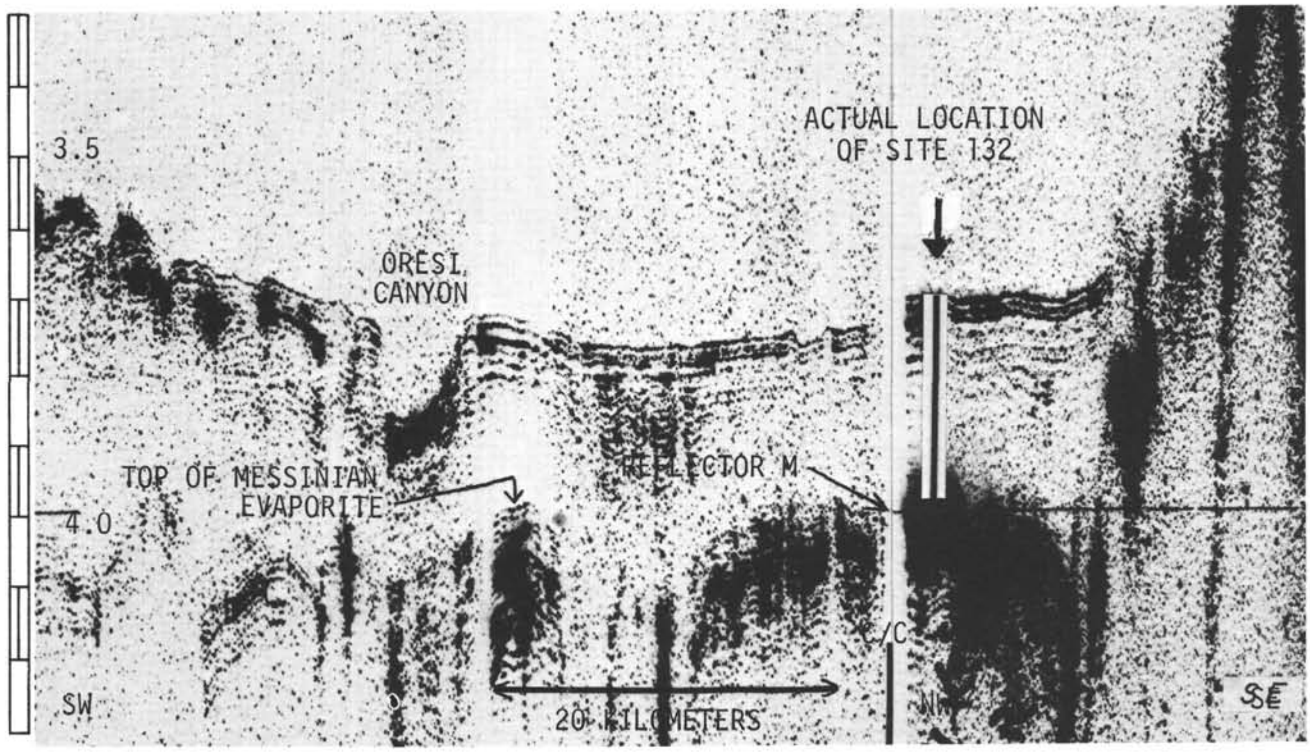

Figure 4. *Airgun reflection profile of the* Glomar Challenger *approach and departure from Site 132. Note the correlation of the highly reverberant M-Reflector to the marked subbottom reflective zone in the* Marsili *profile (Figure 3). The drilling location lies exactly on the* Challenger *profile as shown. Vertical exaggeration ≈ 50:1.*

Reflector M is at 0.265 second below the sea floor and is correlated with the first significant encounter with the massive gypsum in Core 26.

A series of continuous internal reflectors is seen higher in the section at 0.045, 0.065, 0.085 and 0.100 second. Each of the levels is correlatable with discrete beds of coarse volcanic ash in Cores 4, 6, 8, and 10 at 33, 49, 66, and 80 meters respectively (personal communication, W. B. F. Ryan). The ash is partly devitrified and semi-consolidated. The water content of the sediments immediately below the lithified ash beds is particularly high; this situation might account for an appreciable contrast in acoustic impedance. It is interesting that very little volcanic material has been noted deeper, where the section is acoustically transparent.

The sub-bottom reflector at 0.1 second extrapolates to an age of approximately 2 million years (see Chapter 46 of this volume for sedimentation rate information) and provides a convenient acoustic marker of the Pliocene-Pleisocene boundary (≈1.85 m.y.) (see Phillips *et al.*, 1968). Since beds of volcanic ash are believed to be responsible for the internal reflectors, their levels in the reflection profile are considered as time-synchronous horizons.

A single line in Figure 6 connects the five data points down to the top of the evaporite series and gives an interval velocity of 1.6 km/sec for the Pliocene-Pleistocene oozes. The upper dolomitic marls of Reflector M have a calculated velocity of 2.2 km/sec and apparently lie on solid gypsum of much higher velocity.

DISCUSSION

The subdivision of the seismic profile near Site 132 into an easily recognizable upper sequence of Quaternary and uppermost Pliocene pelagic ooze with tephra horizons, underlain by an acoustically transparent and apparently homogenous Pliocene section, provides convenient geostratigraphic criteria for interpreting other seismic sections along the same line or in different regions of the basin. Changes in thickness of the Pliocene interval in basins and across topographic highs seem much more prevalent than for the Quaternary section. Since the basic component (other than the volcanic ash) of the sediment column is calcareous skeletal debris of pelagic origin, it seems reasonable to infer that the variation in sediment distribution is caused by deep currents, and that this activity was more important in the Pliocene than in the Quaternary.

Velocity profile B in Figure 5 at shot point 4040 more nearly fits the observed geological section. The 2.56-km/sec layer at 4.0 seconds corresponds closely to the top of the evaporite series with its stiff dolomitic marls and gypsum stringers. The 3.24-km/sec layer beginning at 4.4 seconds suggests that the Upper Miocene (Messinian) evaporites form an extensive deposit in the Tyrrhenian Basin (>600 m in thickness) confirming the suggestions of earlier workers (Selli, 1954; Selli and Fabbri, 1971). The irregular attitude of the Pliocene-Miocene horizon (P-M) = Reflector M), often with a rough upper surface (between 210 and 260 km in Figure 2) suggest frequent distortions and displacements of the Messinian evaporites that may have resulted from basement tectonics.

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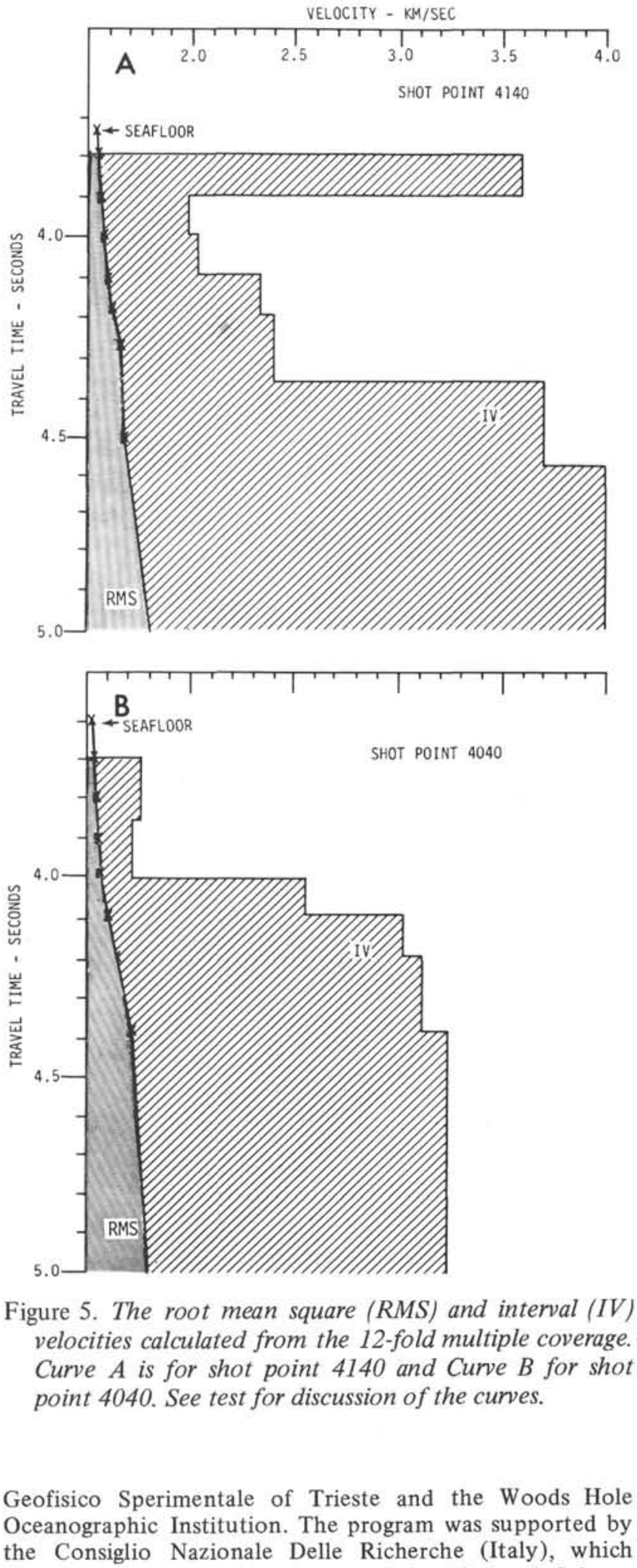

Figure 5. *The root mean square (RMS) and interval (IV) velocities calculated from the 12-fold multiple coverage. Curve A is for shot point 4140 and Curve B for shot point 4040. See test for discussion of the curves.*

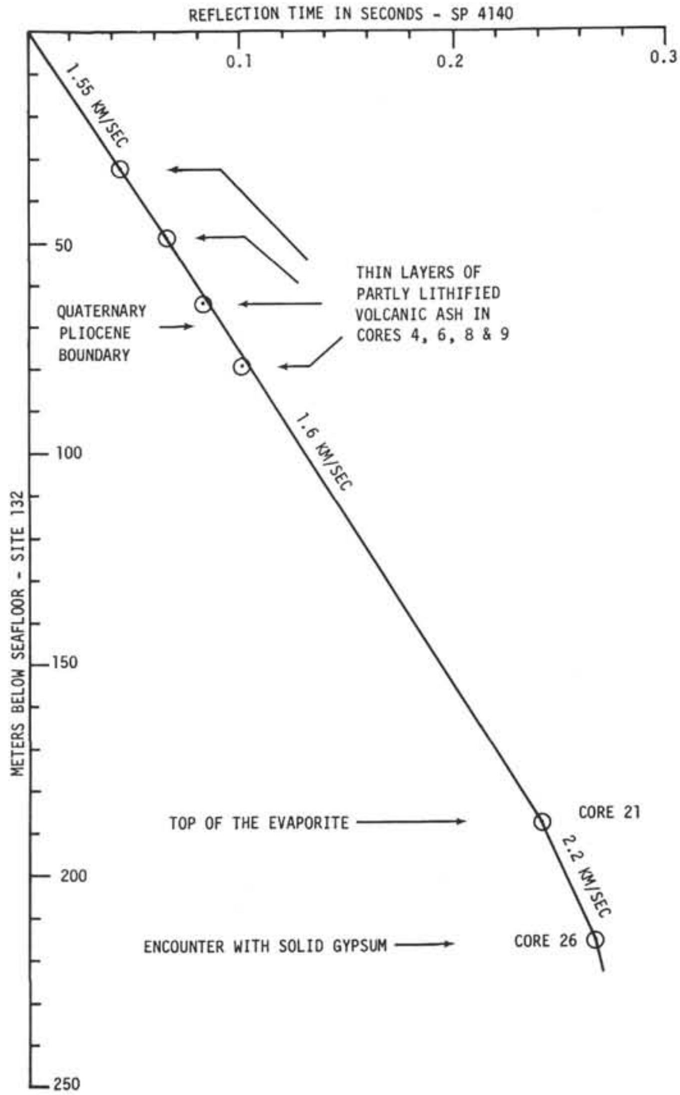

Figure 6. *Calculated interval velocities from correlation of subbottom reflecting interfaces at shot point 4140 with lithologic intervals in the recovered cores of Site 132. The data points in the upper section correspond to discrete levels of partly lithified volcanic tephra. The Upper Miocene evaporite was encountered by the drill string at 188 meters below the sea bed, and solid gypsum at 216 meters. The hole was terminated at 223 meters.*

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