A BATHYMETRIC AND GEOLOGICAL SURVEY IN THE MIDDLE ADRIATIC SEA

by Leopoldo TROTTI
Director, Istituto Sperimentale Talassografico, Trieste

The present research took place during oceanographic cruises in the Adriatic, and the area concerned lies WNW of Scoglio Pomo in the Mesoadriatic Deep.

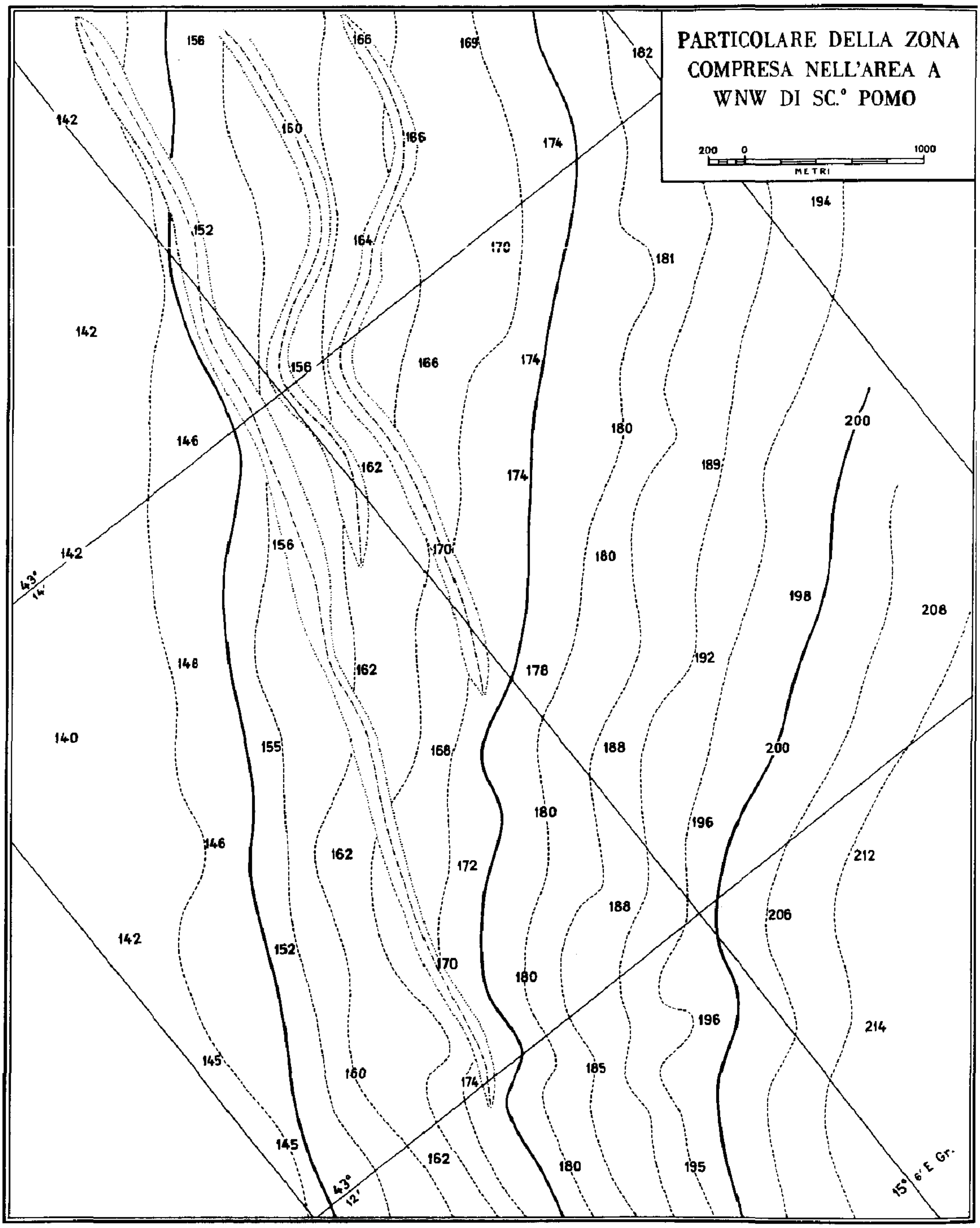
The deep consists of three depressions named Zirje, Jabuka and Ortona, lying one after the other in a line running NNE to SSW starting from Sebenic on the Yugoslavian coast; their maximum depths are, as far as is known, respectively 239 m, 270 m and 256 m.

North-west of this line, the Adriatic bottom tends to rise immediately in a continuous slope, the isobaths being very close together between 200 and 150 m, and further apart between 150 and 100 m. This last isobath can be considered as the boundary of the northern Adriatic continental shelf as, further to the north-west, the isobaths are more widely spaced.

South-west of these depressions, in the middle of the Adriatic, from the 170-m isobath the sea bottom slopes gently downwards until, off the Gargano Peninsula, it widens out and deepens rapidly to a maximum depth of about 1 200 m.

Still further south the bottom narrows again and connects with that of the Ionian Sea off the southern part of the Salentina Peninsula, with a central plain about 800 m deep following the contours of the two coastlines. The middle depression, south of the Mesoadriatic Deep, is bordered by two shelves. The eastern shelf (Lissa) appears to be a continuation of the meso-oriental Dinaric Alpine ridge, with a north-west direction away from the shore, and merging with the Sabbioncelo Peninsula. It then breaks off into a succession of islands, viz. Curzola, Lesina, Lagosta and Cazza and, further to the north-west, Lissa, Sant'Andrea and Scoglio Pomo, the last-named being fairly close to the Zirje and Jabuka deeps.

The western shelf — off the Gargano Peninsula — is marked by fewer islands (Tremiti, Pianosa, Pelagosa) and its submerged part is characterised by a submarine relief of varying shapes. The most north-westerly part of this submerged relief seems to be situated between the Ortona and Jabuka depressions (see van STRAATEN's echogram 2A, figure 67, 1965). The area in which we are interested can, therefore, be considered part of the north-west border of the Lissa shelf, and SEGRE's chart of the region shows a seaknoll between the Jabuka and Zirje deeps. According to echograms made in 1955 by the Italian Hydrographic Office's vessel *Staffetta* this knoll at its highest point is 192 m below sea level. It is not, however, marked on either Italian or foreign nautical charts.



RESEARCH METHOD

Soundings were carried out continuously between 2 and 8 December 1965 and again on 15-16 February 1966, using an EDO echo-sounder connected to a PGR (Alden Electronic and Impulse Recording Equipment Company); the ship's speed was between 6 and 7 knots, in favourable wind and sea conditions (Beaufort Force 1-2). Navigational control followed the usual procedures (recording of compass readings and ship's speed at 5-minute intervals), using Loran C (Loran C 963/SPN 30) and a specially prepared Loran chart (scale 1/46 000). The pattern of the survey consisted of equidistant parallel sounding lines ⅓rd of a mile apart, but where greater detail was deemed necessary the pattern took the form of a rectangular grid with ¼-mile spacings. The survey covered an area of 120 square miles. For greater accuracy — taking into account that in low depths, especially in the Adriatic, water masses present extremely variable physico-chemical characteristics, not only from area to area but also from season to season — corrections for velocity of sound were calculated (using the tables of Bark, Ganson and Meister) on the basis of mean values of temperatures and salinity observed in the area during the survey. Matthews' tables, therefore, cannot be applied (*).

The following formula was introduced (SUBOV) :

$$V_z = \frac{\int_0^p V_p \, d_p}{p}$$

The correction so obtained, reduced to the value of the PGR, was applied to the recorded data previously converted to metres. (PGR = 800 fathoms/sec = 1 463 m/sec).

For maximum precision the level of the transducer in relation to the ship's water line was checked at Ancona before departure for each series of observations.

MORPHOLOGICAL DESCRIPTION

The geographical position of the seaknoll is 43°10′16″ N, 015°09′52″ E, its minimum depth 173 m. The knoll is clearly delineated on the 200 m isobath, while to the south-west and north-east isobaths of 260 and 220 m form the boundaries of the Zirje and the Jabuka deeps. To the north-west the depth decreases sharply from the 230 m isobath, and the bottom merges

(*) "No table is given for shallow waters but sounding velocities have been calculated for the surface layers of deep water. The variations in the upper 400 m are so large that the velocities may be incorrect to as much as 2 %. As been said, frequent wire soundings are necessary if very accurate depths are required." (Matthews' Tables, pages 4 and 5).

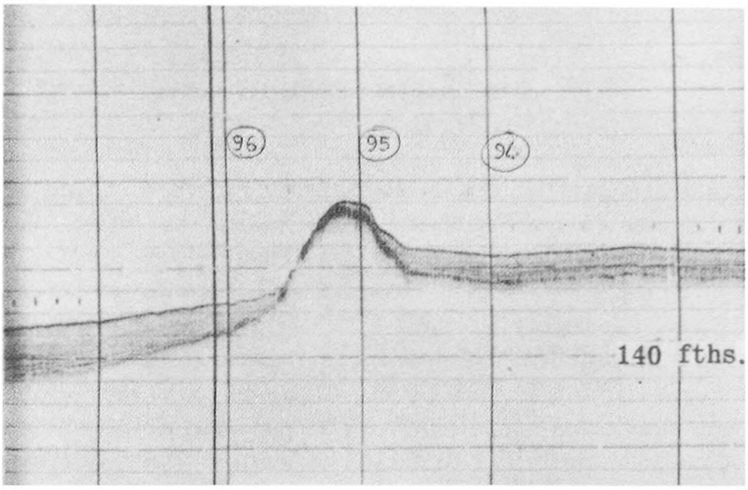


FIG. 1. — 2.12.1965 — Direction NE-SW — Viewed from SE.

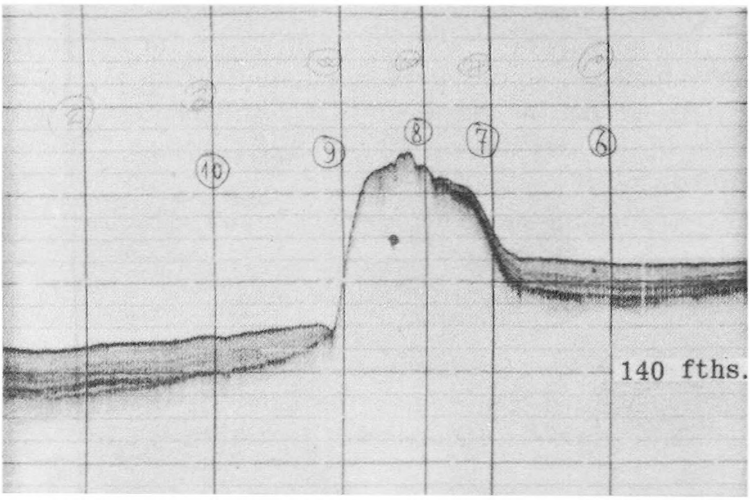


FIG. 2. — 2.12.1965 — Direction NE-SW — Viewed from SE.

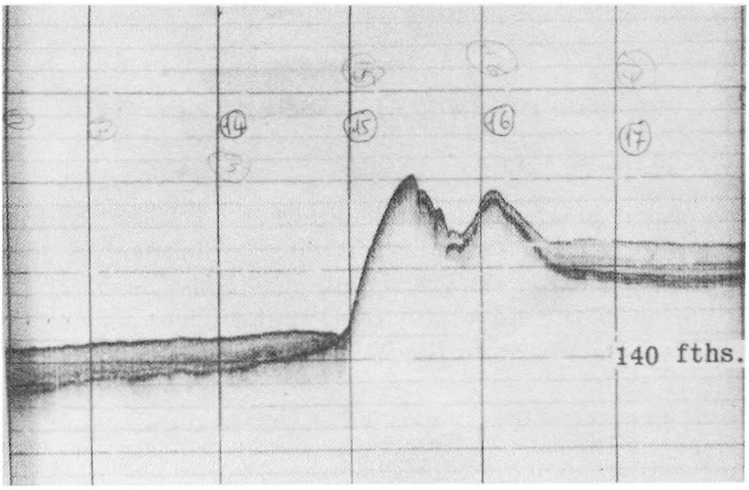
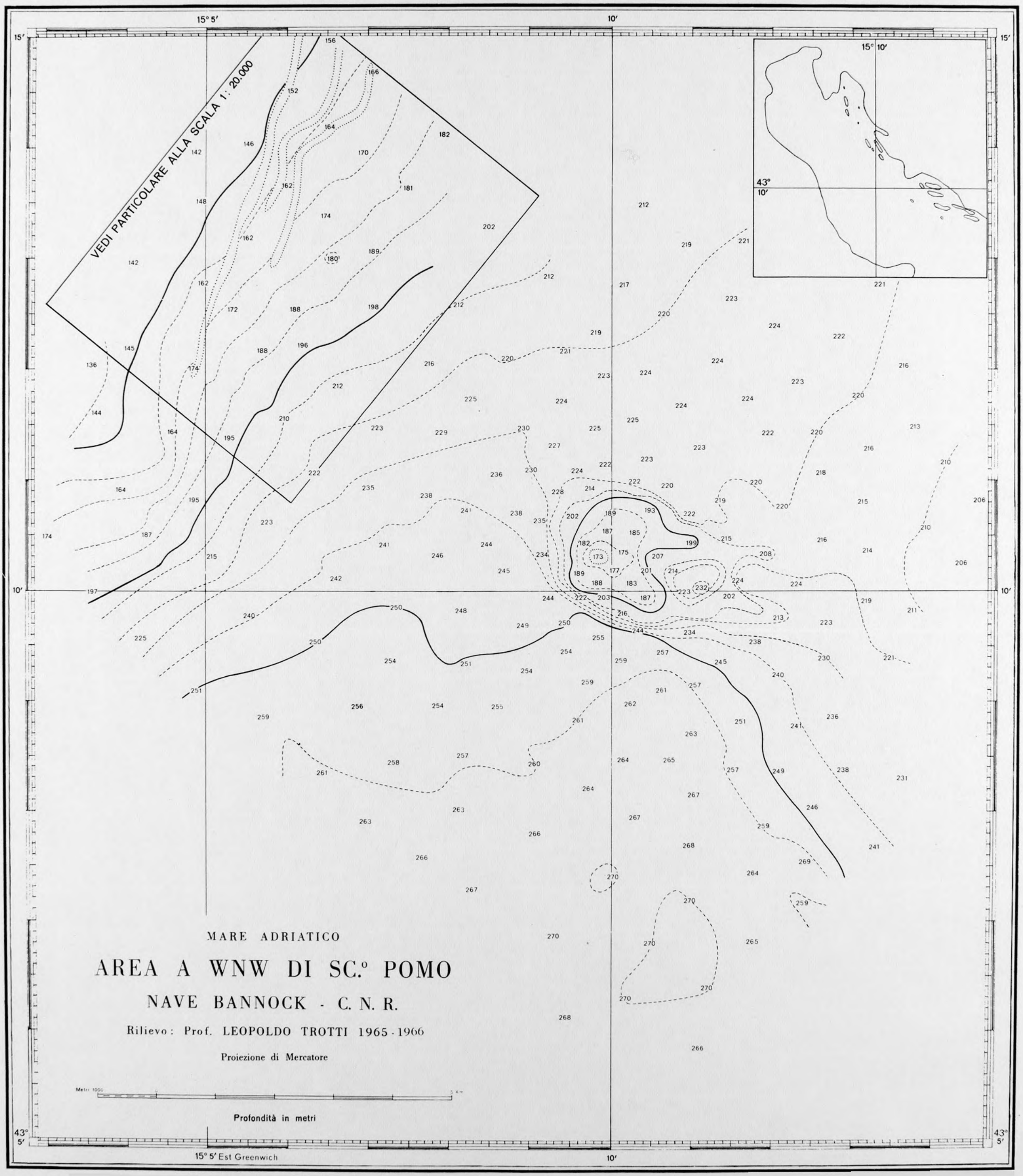


FIG. 3. — 2.12.1965 — Direction SW-NE — Viewed from SE.



MARE ADRIATICO
AREA A WNW DI SC.º POMO
NAVE BANNOCK - C. N. R.
Rilievo: Prof. LEOPOLDO TROTTI 1965-1966
Proiezione di Mercatore
Profondità in metri
VEDI PARTICOLARE ALLA SCALA 1: 20.000
15° 5'
10'
15'
43°
5'
15° 5' Est Greenwich
15° 10'
43° 10'
Metri 1000

into the Mesoadriatic shelf. To the south-east, towards Scoglio Pomo, the sea floor depth varies from 220 to 230 m. The seaknoll has a base diameter of approximately 1 nautical mile. Its west, south-west and south sides rise steeply to a peak at 173 m below the surface. The north-east side slopes down less markedly, especially between the 175 and 190 m isobaths. At the base of the knoll, to the south-west, runs a trench with accentuated sides; this peters out towards the south where a second and. shallower trench starts higher up the knoll (figure 5, station 31/32).

Terrigenous deposits are evident on the lower slopes of the south-west face (figure 5, station 30/31).

A ravine with steeply sloping walls runs down the south-east face starting from some distance below the summit, descending in jumps and ending in a sink-hole about 32 m below the level of the sea floor at that point (figure 6, station 3/4). At certain places in the ravine variable amounts of sediment are present (figure 5, station 31/32; figure 4, station 24).

Between about the 175 and 140 m isobaths on the mesoadriatic slope there are three twisting parallel V-shaped trenches running NE-SW, 2-6 m in depth, starting close to the border of the area under survey (see chart at 1/20 000); two of these trenches disappear on the 175 m isobath line, while the middle one ends on the 160 m isobath. All the trench terminals taper to a point (figures 7 and 8).

DESCRIPTION OF MULTIPLE ECHO

The floor surrounding the knoll shows :

1) Surface traces, mostly uniform and well-defined;
2) One or more sub-bottom traces, not well-defined, generally running parallel to those in 1);
3) Deep traces, well marked, with some diffusions to varying depths.

All the traces are within a layer of between 12 and 15 m. Those mentioned in 2) and 3) above stop at the foot of the knoll (figure 1, station 96/95; figure 2, station 10/9) on the north-west, west and south sides where they merge into the surface trace and remain as a sharp single line along the afore-mentioned slopes, showing very few diffusions on the strata beneath. The single line seems to us to be a continuation of 3) above. On the remaining slopes the traces 1) and 3) converge somewhat, while always remaining distinct. This tendency is also observed towards the summit of the knoll and in the ravine where one can see multiple echo traces and side echoes arising from the variable and fractured nature of the relief (figure 1, station 95/96; figure 3, station 15/16; figure 5, station 31/32).

The distance between the superficial echo and the deep echo is about 5 m on the north-east slope, decreasing to 4 m and then to 3 m (figure 3, station 16/17; figure 4, station 23/24).

The bottom of the ravine also gave two echoes, separated by an interval of 4 m in the upper part and 9 m at the lower end. When two

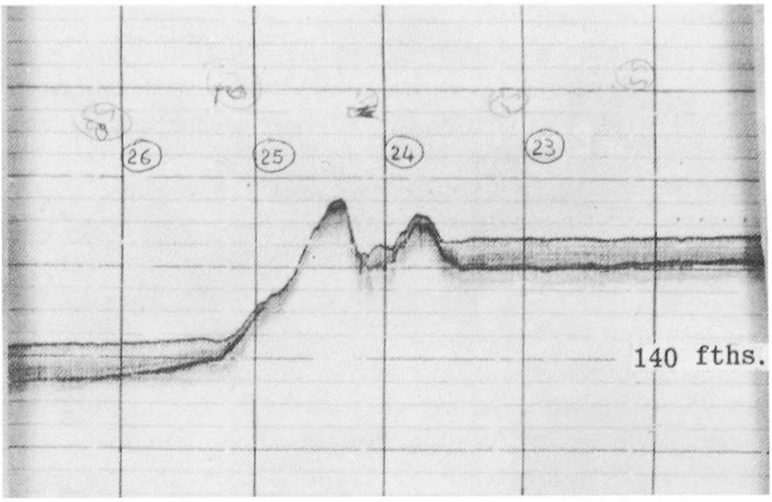


FIG. 4. — 8.12.1965 — Direction NE-SW — Viewed from SE.

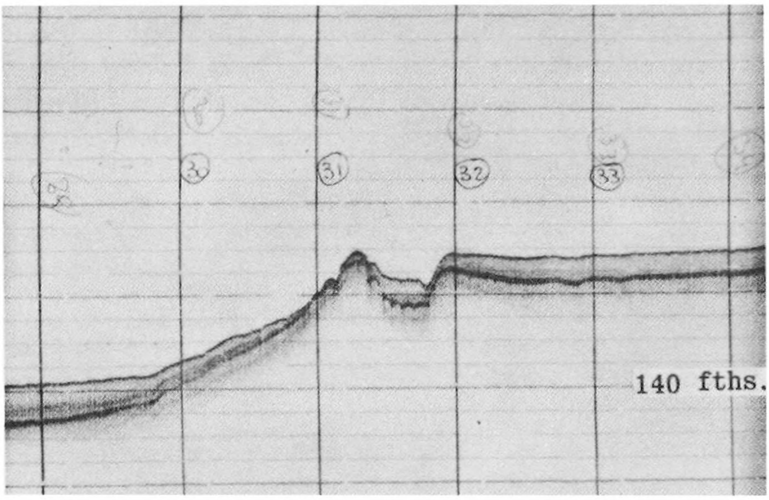


FIG. 5. — 2.12.1965 — Direction SW-NE — Viewed from SE.

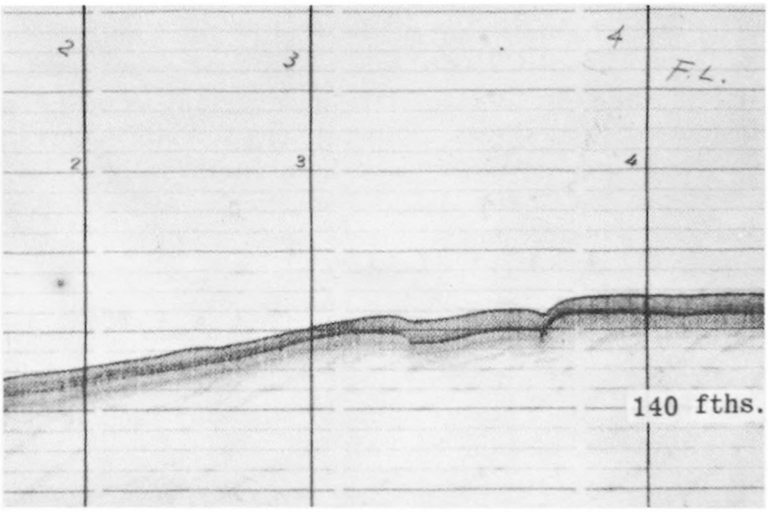


FIG. 6. — 16.2.1966 — Direction SW-NE — Viewed from SE.

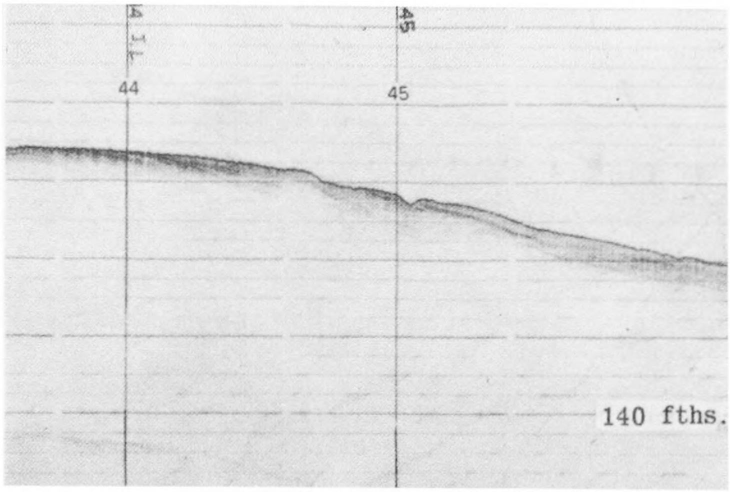


Fig. 7. — 16.2.1966 — Direction NW-SE — Viewed from SW.

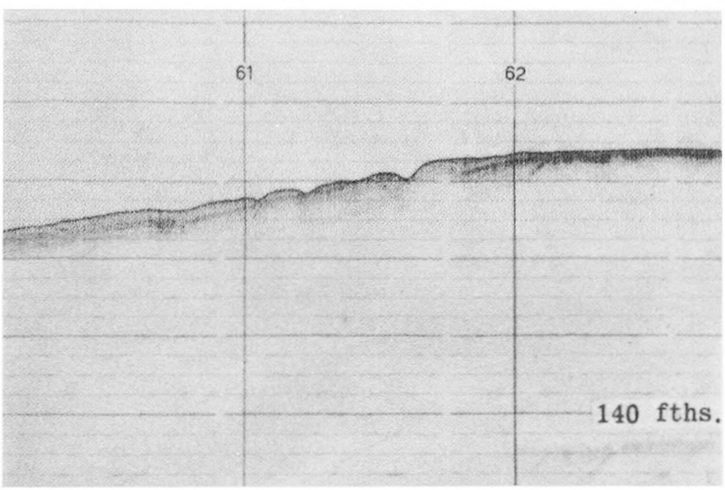


Fig. 8. — 16.2.1966 — Direction SE-NW — Viewed from NE.

echoes were registered from the south-west wall of the ravine they appeared very close together.

In the V-shaped trenches the continuity of the deep echo trace is broken at some points (figure 7, station 45; figure 8, station 62), and at others this echo trace passes just below the trench bottom (figure 8, station 61).

Using grabs, cores and dredges a series of bottom samples was made at the same time as the bathymetric survey. A preliminary description of the dredged material coming from two adjacent areas on the bottom (*) and from the summit of the knoll (**) now follows.

(*) Position 43°11'.7, 15°11'.7 — True bearing 340°, within a range of 8/10 nautical miles.
Position 43°11'.3, 15°11'.3 — True bearing 296°, within a range of 1 nautical mile.
(**) Position 43°10'.3, 15°09'.7 — True bearing 105°, within a range of 6/10 nautical miles.

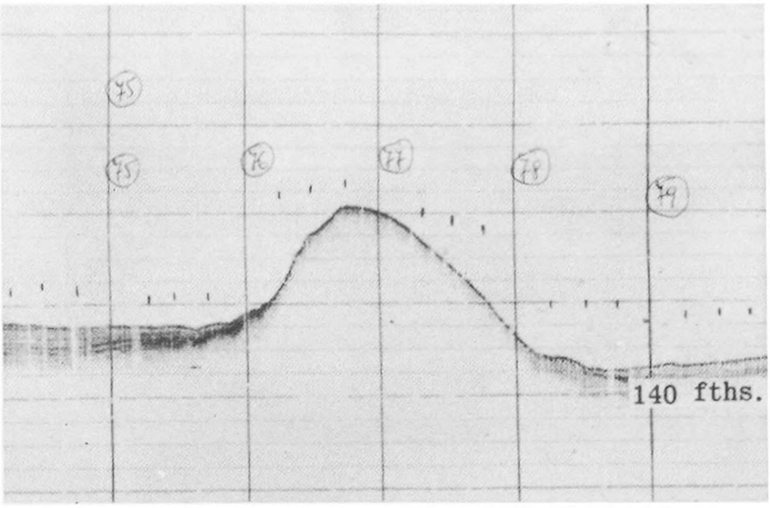


FIG. 9. — 8.12.1965 — Direction NW-SE — Viwed from SW.

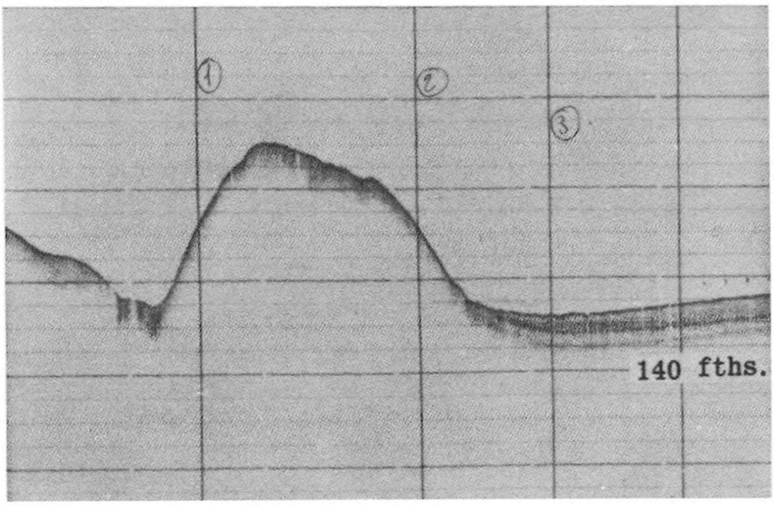


FIG. 10. — 8.12.1965 — Direction NW-SE — Viewed from SW.

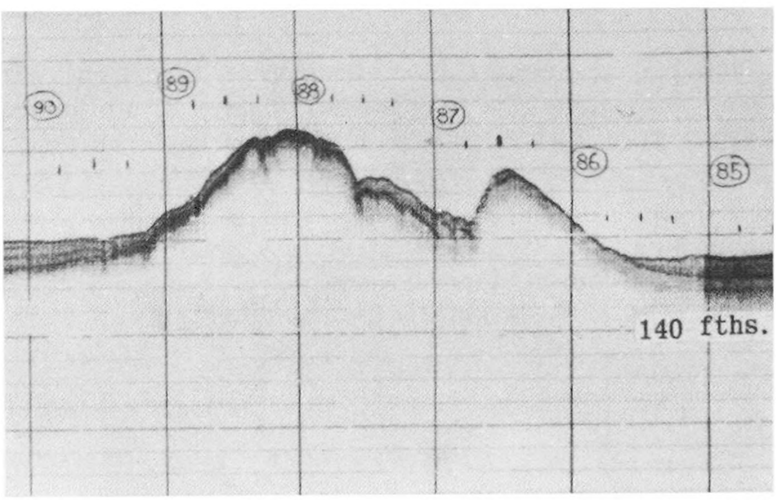


FIG. 11. — 8.12.1965 — Direction SE-NW — Viewed from SW.

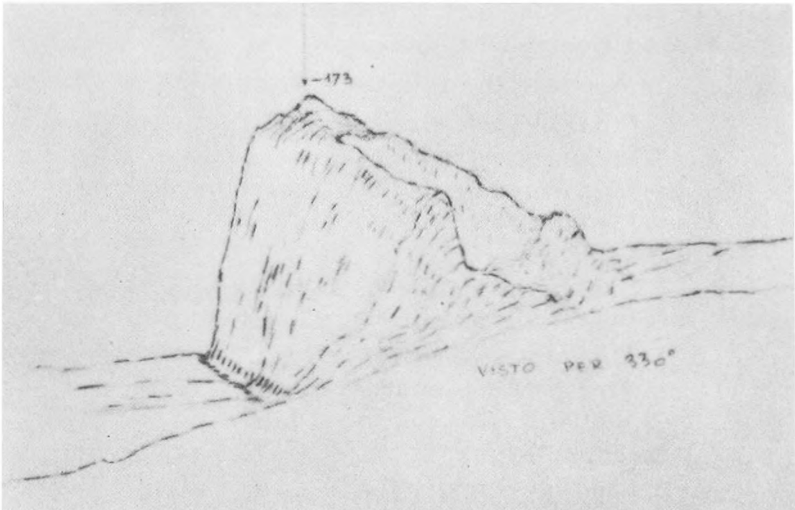


FIG. 12. — Physiographic diagram of the seaknoll.

Granulometric examination of sediments from the first two areas shows lime and clay, with a sorting coefficient of 1.5. Sediments from the summit area show lime with marked sand components and scarce clay, with a sorting coefficient of 3.7.

Mineralogical examination of sand fractions (grade limits 0.125-0.500 mm) — confined to the only sample taken from the summit since in the two sea bottom samples the sand fractions within these grade limits were so few as to preclude any classification — resulted in the following :

(1) Carbonate of organic origin, shells, fragments of Lamellibranchia, Gastropoda, Echinus, Foraminifera, etc., and coral.

(2) Siliceous deposits of organic origin (spicules of siliceous sponges).

(3) Detrital material, probably coming from Po and Apennine flysch (*marne-arenacee* and Pleistocenic yellow sand).

A list of heavy (> 2.84) (*) and light (**) minerals is given in the notes below.

Elements originating from the South Italy volcanic area (augite, magnetite, volcanic glass) are very noticeable.

Comparative chemical analysis shows that the $CaCO_3$ values are higher on the summit and slopes of the knoll than on the surrounding sea bottom, while the contrary is the case as regards the values for N and C (***).

Biological specimens dredged from the seaknoll (see list) are more plentiful than those from the surrounding bottom. So numerous are the Polycletus on the summit and north-west, west and south slopes that they can be classified as serpulid biostrome.

(*) Augite 31.21 %, Biotite 13.00 %, Hornblende-actinolite 9.04 %, Chlorite 6.14 %, Diopside 5.42 %, Garnet 4.51 %, Muscovite 3.97 %, and traces of others.

(**) Volcanic glass 70.37 %, K-Feldspar 12.74 %, Quartz 11.99 % ; Plagioclase 2.10 %, Muscovite 1.87 % ; and traces of others.

(***) Slopes and summit : $CaCO_3$ 38.09 %, N 0.04 %, C 0.40 %.
Surrounding bottom : $CaCO_3$ 30.61-29.54 %, N 0.070-0.073 %, C 0.48-0.64 %.

Specimens of Lophohelia, Caryophyllia and Dorocidaris appear amongst the Coelenterata and Echinodermata.

Among the molluscs are the following :

Emarginula cancellata Philippi
? *Polinices catena* (Da Costa)
Nassarius prismaticus (Brocchi)
Fusinus rostratus (Olivi)
Pleurotoma sp.
Dentalium rubescens Deshayes
Dentalium vulgare Da Costa
Nucula sulcata Brown
Arca lactea Linnaeus
Modiolus phaseolinus (Phil.)
? *Ostrea edulis* L.
Beguina trapezia (L.)
Venus ovata Pennant
? *Syndosmya ovata* Wood
Hiatella arctica (L.)

GENERAL CONSIDERATIONS

On account of the isolation of the seaknoll, its form and its geographical position relative to Scoglio Pomo and Lissa — where there is evidence of old effusive phenomena which, because of their geolithical peculiarity, give a disturbed magnetic field — we are inclined to the opinion that in origin the knoll has a close connection with the aforesaid islands, and that it was subsequently buried under a thick strata of sediment. In fact, our cores of up to 7 m in length, taken with the Kullenberg corer at numerous points, never reached the nucleus (*).

While future research will be directed towards finding a correlation between the sub-surface echo and the mineralogical aspect of the core (despite the fact that the exact sound velocity of the sediments is not known) it can now be affirmed that the single trace on the north-west, west and south slopes derives from the serpulid biostrome which appears here as a thick and compact mass (**). It is possible that such a compact and well-defined biostrome has been conditioned by the ascending Adriatic current (presupposing its continued existence) which, on account of the Lissa continental shelf, tends to deviate to the north-west when approaching the knoll, thus creating favourable conditions of habitat and, at the same time, affecting the settling of sediments by its dispersing action. There

(*) Van STRAATEN also found some unconsolidated sediments: those from the surface (few cm) he attributes to the Holocene, the remainder to the Pleistocene. According to him, the sediments were formed in the Pleistocene due to the proximity of a large river.

(**) In this respect, in cores taken in the South Adriatic, van STRAATEN tried to find a correlation, as follows : "The first sub-bottom reflection to the ash layer, and the second one to the lower parts of turbidite. The third to the next lower turbidite ".

appears, however, to be a correspondance between the area of serpulid biostrome and the higher percentage of garnet, dark minerals and amphibole as opposed to the lower values found on the other slopes and surrounding sea bottom. The same applies to augite which is present in higher quantities all over the knoll than in the surrounding area.

This peculiar distribution of minerals can be explained by a surfacing of the sub-strata, for which we found indirect confirmation in the deeper echogram trace (No. 3) that emerges on the surface along the slopes mentioned in the preceding paragraph.

Another explanation might be selective sedimentation (insofar as the aforementioned magnetic minerals are concerned) occasioned by the magnetic anomalies due to the presence of igneous rocks. These rocks are found on Scoglio Pomo and Lissa, but if they are also present in the seaknoll they would have to form a sufficient mass with specific orientation in relation to the covering strata of sediments to cause such selective topographical phenomena.

The ravine running down the south-west slope reminds us of submarine canyons (profile, orientation, sharply cut walls, and scarcity of sediment except towards the lower end). While remaining uncertain as to what originally caused the ravine — for this must be considered as either primitive form or else determined by erosion — we assume that in more recent ages its form was maintained by currents of turbidity. On account of the knoll's isolation these currents can be imputed solely to the sliding of unconsolidated sediments from the summit due to seismic phenomena, for as is well known there are numerous epicentres on the east and west Adriatic shores, especially along and off the Dalmatian coast (MONTESSUS) with occasional repercussions of characteristic waves (seismic waves) (RUDOLPH).

Of more doubtful interpretation are the small V-shaped depressions that run along this part of the Mesoadriatic shelf. The tapering pointed ends, and the fact that the trenches run counter to the major line of declivity, suggest that this morphological aspect is due to the sliding of unconsolidated sedimentary masses rather than to (*a*) turbidity currents, both old and recent, or (*b*) fluvial erosion; notwithstanding that there may have been such a lowering in the Adriatic sea level, because this geologic aspect would have been altered, if not cancelled out, by succeeding transgressions. It is not possible to say if these features are similar to those described by Van STRAATEN between 800 and 1 000 m along the south Adriatic Italian continental slope because the incisions, which seem both in profile and in depth very similar to those we have described, have not been followed up in development and orientation in relation to the continental slope. Van STRAATEN considers these incisions as being probably due to submarine erosion occurring before the Holocene " ... most likely by turbidity currents".

On the other hand, the nature of the mineralogical content of dredged sediments from the knoll differs markedly from that of sediments coming from the surrounding sea bottom. The latter, on account of their excellent selection, the predominance of clay, and of the non-biomodal granulometric curve, show a similarity to those of the deep sea basin. In constrast, sediments dredged from the knoll itself show lime with little clay and moderate classification, thus having an affinity with those found on the borders of the continental shelf where river and shoreline influences are common.

If, as reported by van STRAATEN, the lowering in the Adriatic sea level may have reached 120-130 m at its deepest point, and if erosion waves have affected the shelf to a depth "not exceeding 20 m" (although this figure is far too high, even when the longest fetch in the Adriatic is taken into account) and also bearing in mind subsidences due to compaction of the muddy sediments, then the top of the knoll may perhaps have been close to the sea surface during that moment of the Pleistocene. This would explain the granulometric similarity between sediments from the top of the knoll and those from the continental shelf.

ACKNOWLEDGEMENTS

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My thanks go also to Dr. L.M.J.U. van STRAATEN for his helpful advice.

Note on the illustrations

In figures 1, 2, 3, 4, 5, 9, 10 and 11 the paper speed was 8 mm/minute.

In figures 6, 7 and 8 the paper speed was 24 mm/minute.

Each vertical space on the echogram is equivalent to 5 fathoms.

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