THE GENERAL GEOPHYSICS AND GEOLOGY OF THE STRAIT OF SICILY

by

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Available geophysical and geological data combined with newly compiled bathymetric, bottom sample, underwater photograph and recently published geophysical data [Ref. 1] have been analysed to describe the geophysical and geology of the Strait of Sicily.

This area has many unique geological and geophysical features. It separates Sicily from Africa and divides the Mediterranean into two basins.

BATHYMETRY AND PHYSIOGRAPHIC REGIONS

The bottom configuration of the Strait of Sicily is complicated in the central part, but very simple on the shelves along the Sicilian and African coast [Fig. 1]. The sea floor of the shelf is very flat except for a few very shallow banks. As seen, the zone is very well indicated by the 100 fathom (180 m) contour. In the middle of the strait there is a deep region where depths are mostly greater than 900 fm (1650 m). Then there is a complicated zone between the deep region and the shallow shelves, which extends to both the entrances of the Strait. In this area the depths vary between 100 to 500 fm (180 m to 900 m). Some of the characteristic bathymetric profiles of the area are shown in Figs. 2 and 3. These profiles and the other available bathymetric profiles were used to construct a chart showing the physiographic regions of the area [Fig. 4].

The physiographic structure of the area as shown in the figure can be divided into four basic regions:

a. broad continental shelves with banks
b. continental borderlands
c. continental slopes
d. a series of NW-SE oriented depressions (rifts).

Shallow continental borderlands extend towards the entrances of the Strait and descend to the Tyrrhenian basin at the north and to the Sicilian Basin at the east by means of steep continental slopes.

SEDIMENT DISTRIBUTION

Figure 5 shows the distribution of bottom sediments in the Strait of Sicily. The locations where samples have been taken are shown, with symbols indicating the type of sediment. Boundaries between sediment types have been drawn to show general areas in which major types of sediments are found, but in fact these boundaries are generally transitional regions. The accuracy with which these boundaries are defined depends of course on the density of sampling. The data from which this chart has been prepared come from the Atlas of the U.S. Fleet Numerical Weather Central [Ref. 2], published data from various institutions, and recently-obtained unpublished SACLANTCEN data.

The upper sediments in the Strait of Sicily are:

1. Rock and Gravel
These are unconsolidated sediments with a median grain size greater than 2 mm and fine-grained sediments that have been indurated. These can be of any origin, such as chalk, shale, or gravel.

2. Sand and silt (except for calcareous ooze)

These are unconsolidated sediments, regardless of origin, and with a median grain size between 2 mm and 4 μm.

3. Clay-Mud

Unconsolidated sediments with median grain size less than 4 μm. In the original references both clay and mud are used to describe everything finer than silt.

4. Calcareous ooze

Unindurated sediments containing more than 30% and having median grain size less than 2 mm.

5. Transitional zones of these four sediment types

Sand and silt spread over the western Sicilian and Tunisian continental shelves and extend towards the north-western flanks of the northern continental borderland. Generally, except in the southern part of the Tunisian shelf, this sand and silt is mixed with mud; over the northern borderland it is mixed with calcareous oozes. Rock and gravel patches occur over near-shore regions and over the banks. Mud and clay cover the rest of the northern continental borderland, some parts of the plateau, and the eastern parts of the southern Sicily shelf. The middle part of the strait and the northern part of the northern borderland are covered with calcareous oozes.

So far only four cores have been taken in this area. As shown in Fig. 5, cores 1 and 2 are taken from the western Sicily bank and 3 and 4 from the Tunisian Shelf (south of the Island of Lampedusa). Photographs of core sections and some of the measured physical properties of these cores are shown in Figs. 6 and 7.

The underwater photographs taken over the western shelf showed two different kinds of bottom material. In one photograph the bottom is seen to be covered with mud, in the other with sand and silt together with corals. The photographs taken over the Tunisian shelf (S of Lampedusa) show the bottom covered with sand-silt, shells and a large amount of flora, [Figs. 8-9].

GEOPHYSICAL MEASUREMENTS

The magnetic and gravity fields of the Strait of Sicily have been described by Allan and Morelli [Ref. 1].

Figure 10 shows the total magnetic field map obtained for this area. Anomalies in the magnetic field occur over boundaries of bodies of rocks of different magnetism. As seen, the magnetic field in the area is remarkably uniform, except for a few local anomalies. Generally local bipole anomalies are related to the centre of volcanic regions, such as the one near Pantelleria Island. The direction of the polarity on this anomaly is normal, i.e., as here, most bipolar anomalies have maxima to the south and minima to the north.

Figures 11 and 12 show the free-air and Bouguer anomaly maps of the area, respectively. For a long time it has been known that there is a relationship between gravity anomalies and bathymetry; free air anomalies being directly related to the bathymetry and Bouguer anomalies being principally related to regional elevations (Isostasy).

The negative anomaly zones of the free-air gravity anomaly map [Fig. 11] generally results from tectonic activity; these are hatched on the map to indicate the correlation between the NW-SE oriented rift system. The small, positive anomalies are also more or less oriented in the same direction as the middle rift system. This indicates a small mass excess there. As shown, the area contains seamounts and old volcanoes that may produce three local free-air anomalies.

As seen from Fig. 12, Bouguer anomalies are generally not very extensive. The rift system has an anomaly of more than +90 mgal on the continuation of the rift system at the south of Pantelleria and east of the Linosa islands.

Figure 13 shows two magnetic and free-air gravity anomaly profiles together with the corresponding bathymetric profiles. Two continuous seismic reflection profiles were made in the area during the Marine Geophysical Survey [Ref. 3]. These are shown in Fig. 14. The sediment thickness decreases from the Tyrrhenian basin towards the northern continental borderland. Over the borderland, sediments have filled the deeper parts of the basement to a depth of about 600 m. The sediment accumulation on the other parts are of the order of 100 m to 200 m. The second profile also shows the same characteristic and both of them reveal evidence of basement faulting.

CONCLUSIONS

As seen from the various geophysical and geological data, the area has two distinctive geological features of volcanic and tectonic activities. As reported by Segre and Barbieri et al [Ref. 4], volcanic activities in the Strait have not been restricted to the two volcanic islands of Pantelleria and Linosa. All the others, however, have been submarine, except for Giulia Ferdinandeo Bank where volcanic activities have been recorded since 1632; three times — in 1701, June 1831 and August 1863 — a volcanic island emerged but had a short life. Other submarine volcanic and seismic activities are recorded in the area, especially on the southern side of the Sicilian shelf within a 10 km to 20 km wide-band parallel to the southern coast approximately 50 km off-shore.

Figure 15 shows the plots of the centre of the band of positive and negative free-air and Bouguer anomalies, over the strait, together with the major magnetic anomalies of the zone. As seen, the area of both anomalies are NW-SE oriented, as is the rift system, and the magnetic anomalies are situated near to the axis of positive anomalies. The rift zone is represented by the axis of the positive Bouguer and negative free-air anomalies. Structurally, a rift is always a complex graben [Fig. 16a], as can be seen from the bathymetric chart; its total displacement here is about 1500 m to 2000 m and naturally varies along the rift system.

The volcanic activities mostly define the zones of tensional fractures along which magma has migrated to the sea floor. The fact that rifts are confined to regions of both continental and oceanic crust, and the basaltic volcanism associated with rifts, indicate that their formation is connected with the upper mantle rather than with the crust.

As reported by Barbieri et al [Ref. 4] the volcanic islands of the strait of Sicily contain basaltic rocks. Caputo et al [Ref. 5] analysed the seismicity of the Mediterranean and by taking into account the plate tectonic theory, they concluded that the African plate is wedged under the Euro-Asiatic plate in the Ustica-Lipari region. Figure 16b illustrates this aspect of plate tectonics, showing the breaking of a continent by the formation of a rift in the Strait of Sicily zone.

REFERENCES

1. T.D. Allan, C. Morelli, A Geophysical Study of the Mediterranean Sea; Bollettino di Geophysica Teorica ed Applicata, Vl. XIII, N. 50 1971.

2. Texas Instruments Inc. U.S. Naval Oceanographic Office Marine Geophysical Survey Program, 1965-67, North Atlantic Ocean, Norwegian Sea, Dallas, Texas, 1967-69 (U.S. Naval Oceanographic Office, SP-95), Area 6, Vol. 5.

3. J.Z. Frazer, G. Arrhenius, J.S. Hanor, D.L. Hawkins, "Surface Sediment Distribution - Mediterranean Sea", prepared by Scripps Institution of Oceanography for U.S. Fleet Numerical Weather Central, 1970.

4. F.Barbieri, S. Borsi, G. Ferrara, and F. Innocenti, "Strontium Isotopic Composition of Some Recent Basic Volcanites of Southern Tyrrhenian Sea and Sicily Channel", Contrib. Petrol. Berlin, 23, 1969.

5. M. Caputo, G. F. Panza, and D. Postipischl, "Deep Structure of the Mediterranean Basin", J.G.R. Vl. 75, N. 26, 1970, p. 4919.

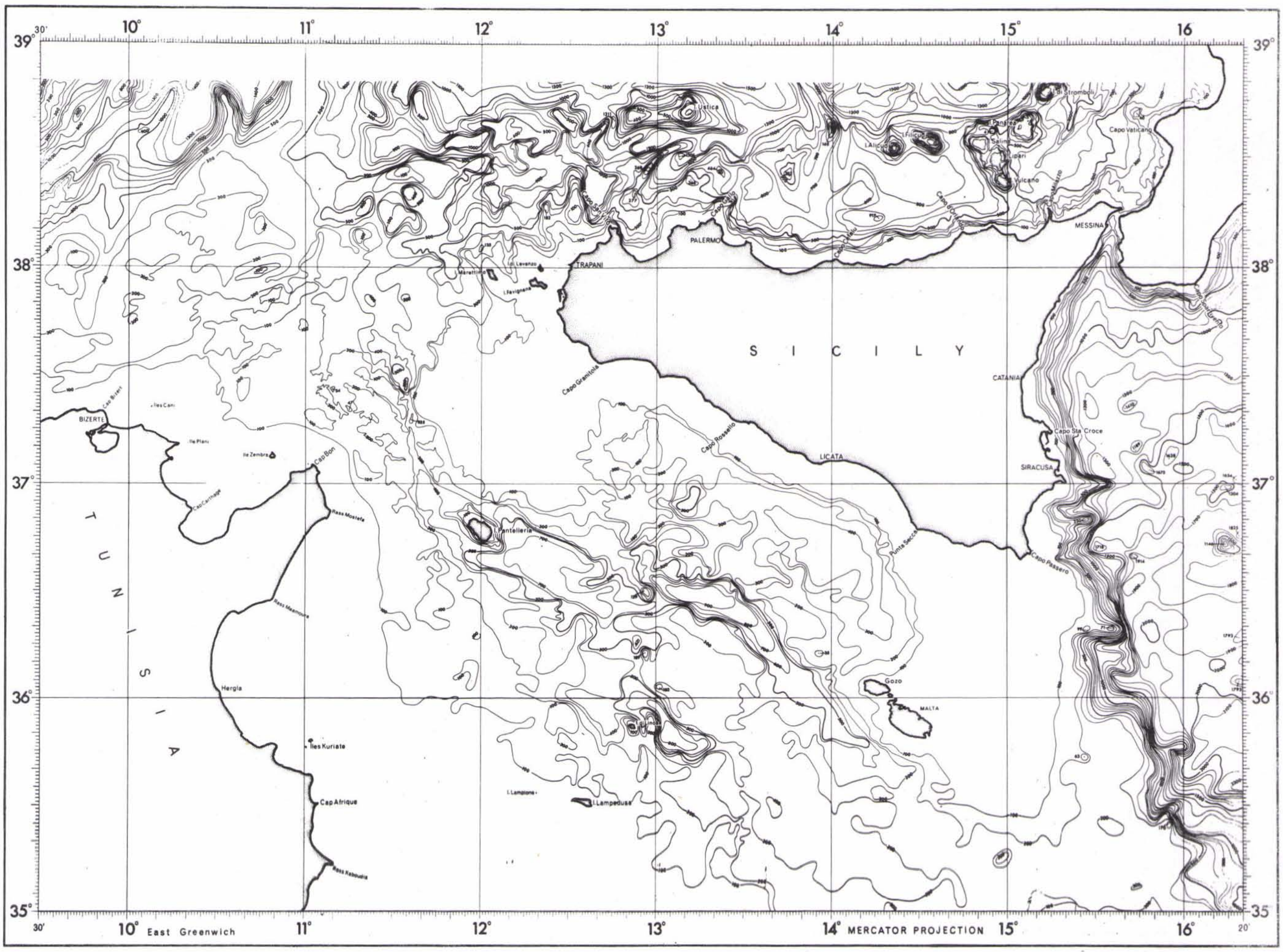


FIG. 1

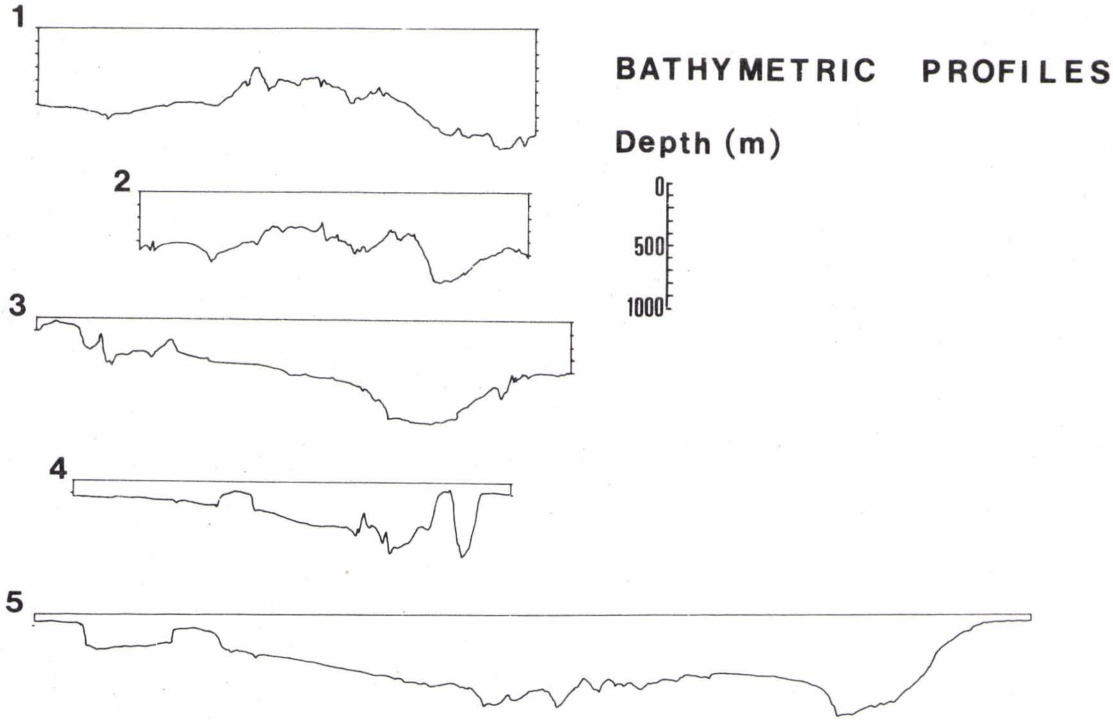

1
2
3
4
5
BATHYMETRIC PROFILES
Depth (m)
0
500
1000

FIG. 2

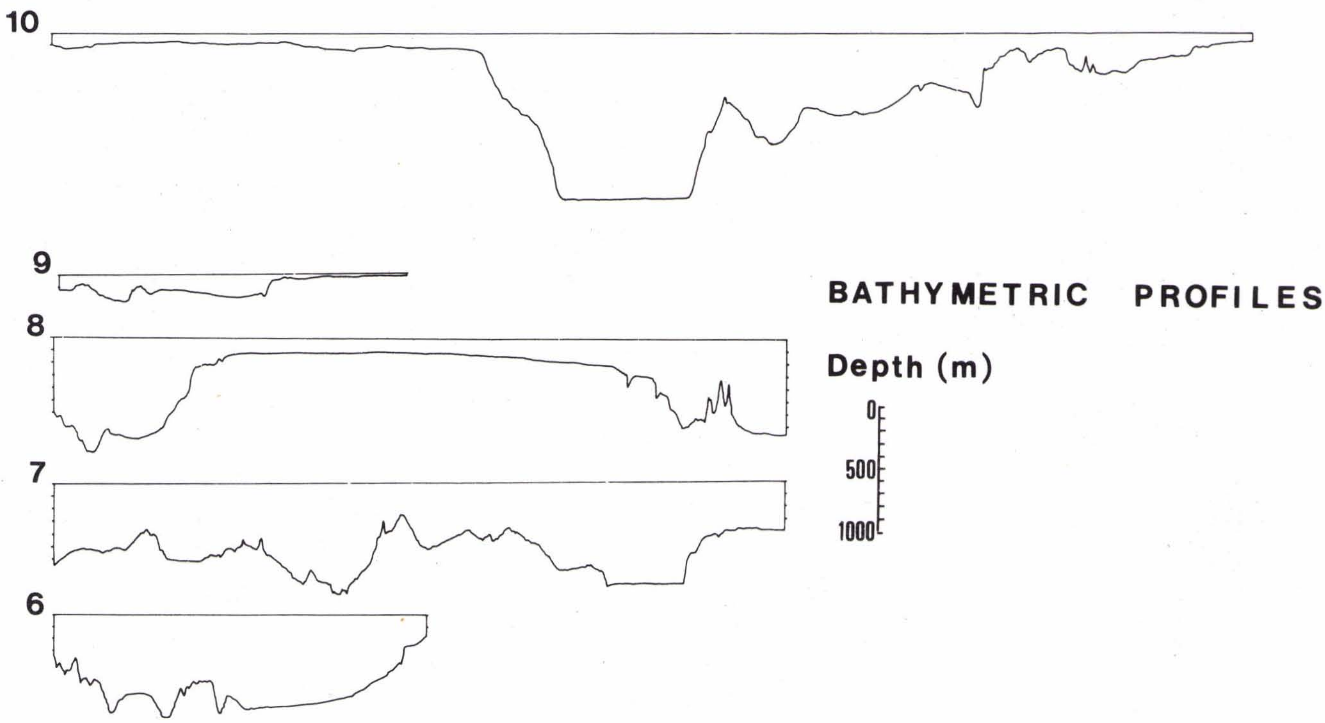

10
9
8
7
6
BATHYMETRIC PROFILES
Depth (m)
0
500
1000

FIG. 3

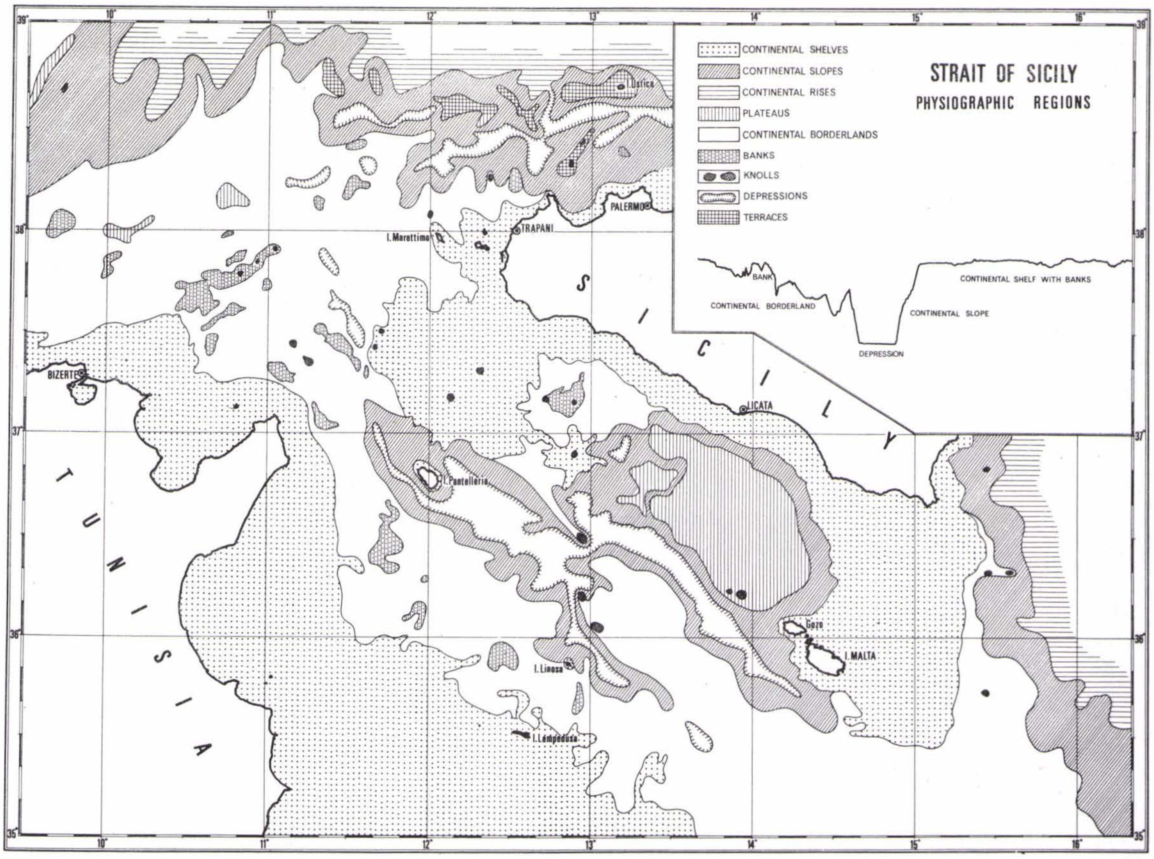

STRAIT OF SICILY
PHYSIOGRAPHIC REGIONS
CONTINENTAL SHELVES
CONTINENTAL SLOPES
CONTINENTAL RISES
PLATEAUS
CONTINENTAL BORDERLANDS
BANKS
KNOLLS
DEPRESSIONS
TERRACES
BANK
CONTINENTAL BORDERLAND
DEPRESSION
CONTINENTAL SLOPE
CONTINENTAL SHELF WITH BANKS
I. Ustica
PALERMO
TRAPANI
I. Marettimo
BIZERTE
LICATA
I. Pantelleria
Gozo
I. MALTA
I. Linosa
I. Lampedusa
SICILY
TUNISIA

FIG. 4

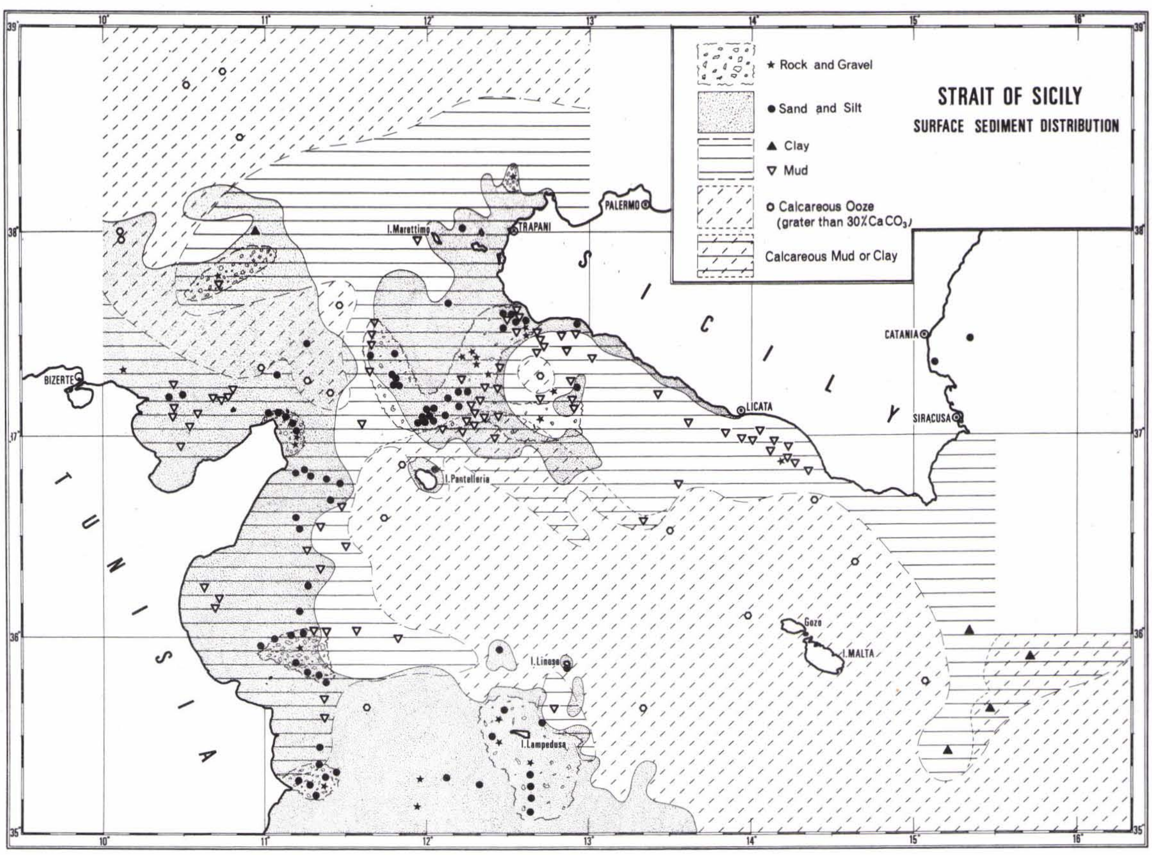

STRAIT OF SICILY
SURFACE SEDIMENT DISTRIBUTION
Rock and Gravel
Sand and Silt
Clay
Mud
Calcareous Ooze
(grater than 30% $CaCO_3$)
Calcareous Mud or Clay
PALERMO
TRAPANI
I. Marettimo
BIZERTE
CATANIA
LICATA
SIRACUSA
I. Pantelleria
Gozo
I. MALTA
I. Linosa
I. Lampedusa
SICILY
TUNISIA

FIG. 5

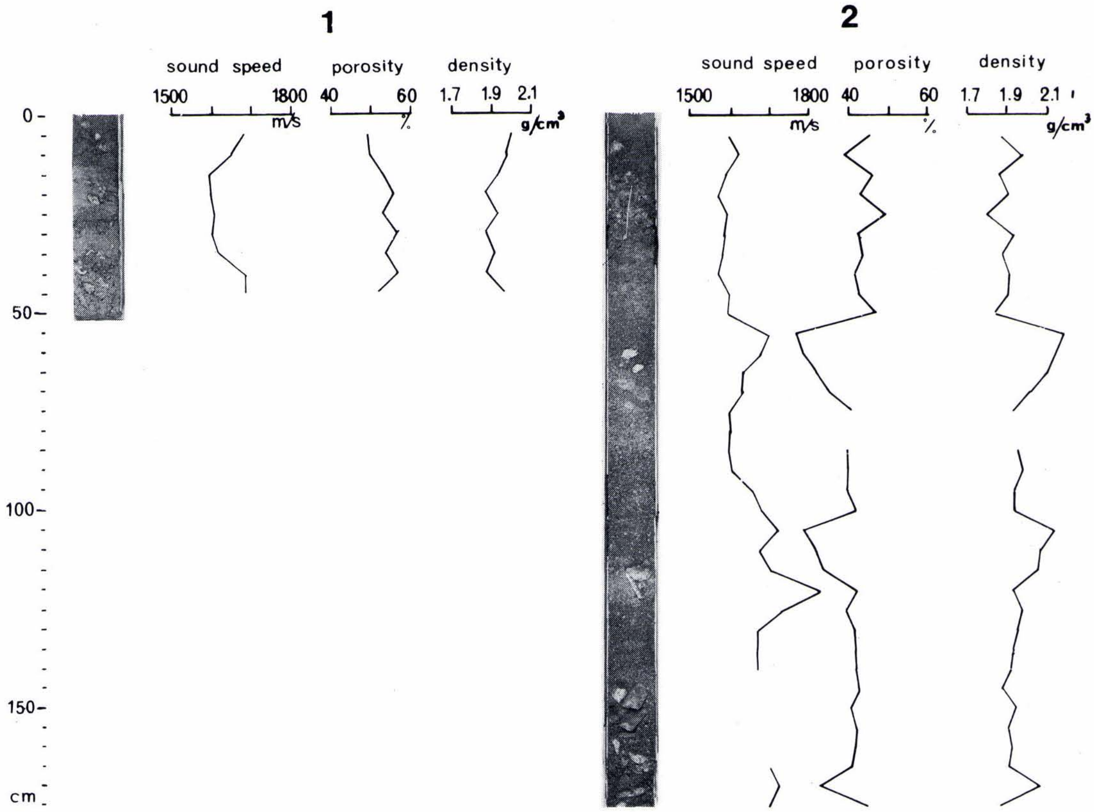

1
sound speed
porosity
density
1500
1800
m/s
40
60
%
1.7
1.9
2.1
g/cm³
2
sound speed
porosity
density
1500
1800
m/s
40
60
%
1.7
1.9
2.1
g/cm³
0
50
100
150
cm

FIG. 6

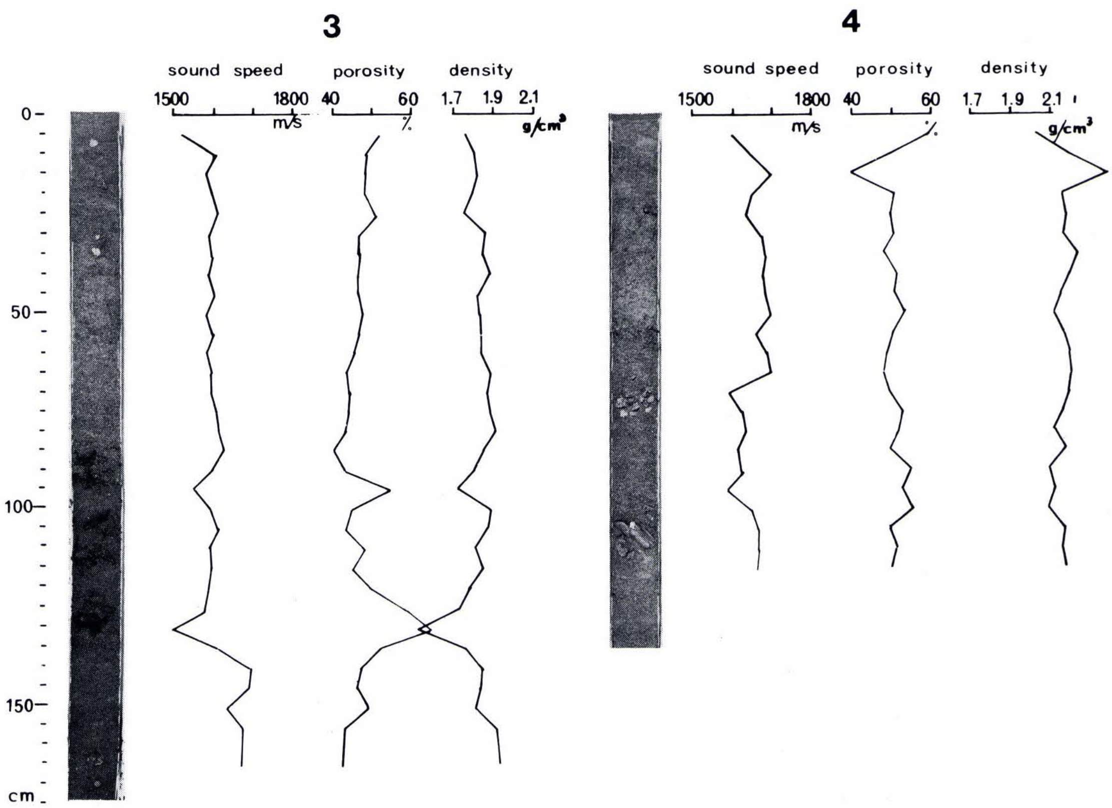

3
sound speed
porosity
density
1500
1800
m/s
40
60
%
1.7
1.9
2.1
g/cm³
4
sound speed
porosity
density
1500
1800
m/s
40
60
%
1.7
1.9
2.1
g/cm³
0
50
100
150
cm

FIG. 7

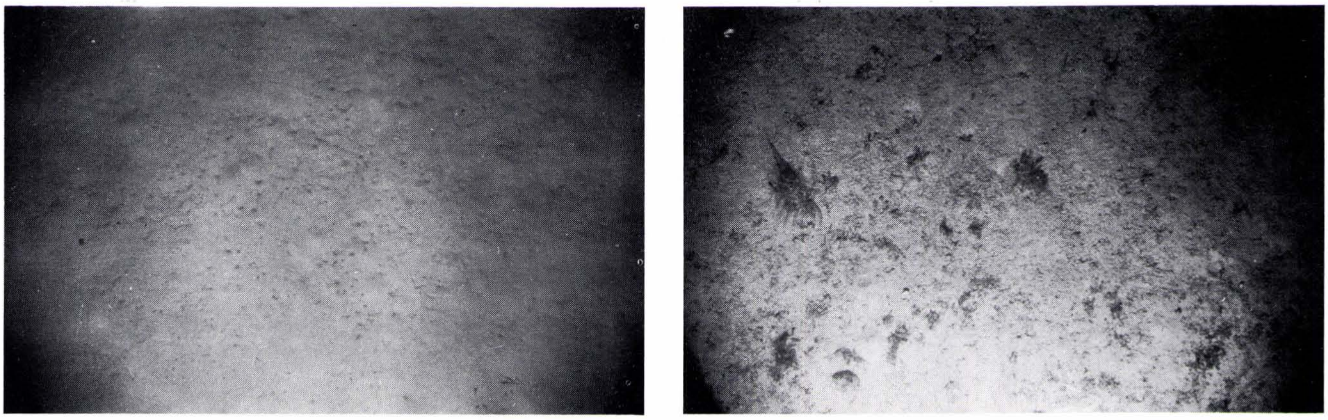


FIG. 8

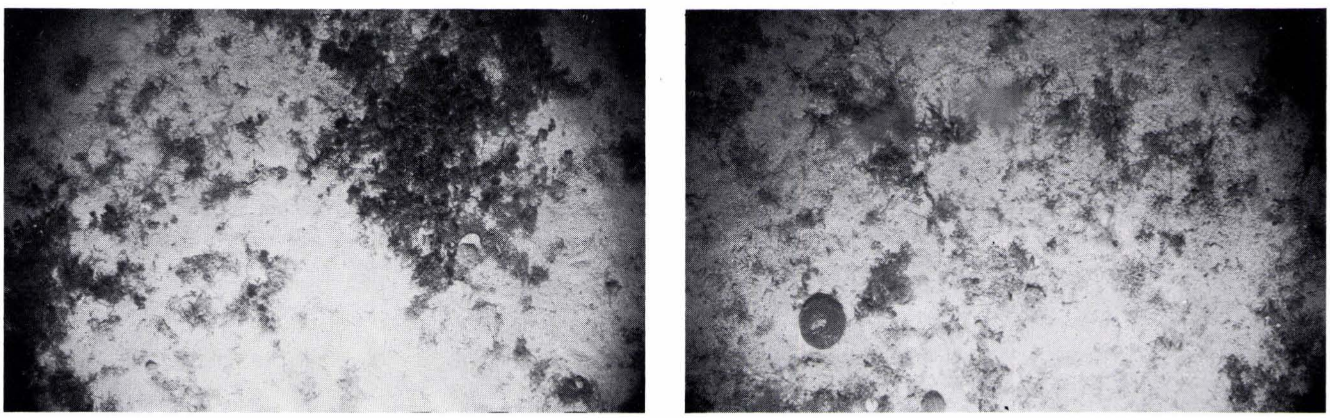


FIG. 9

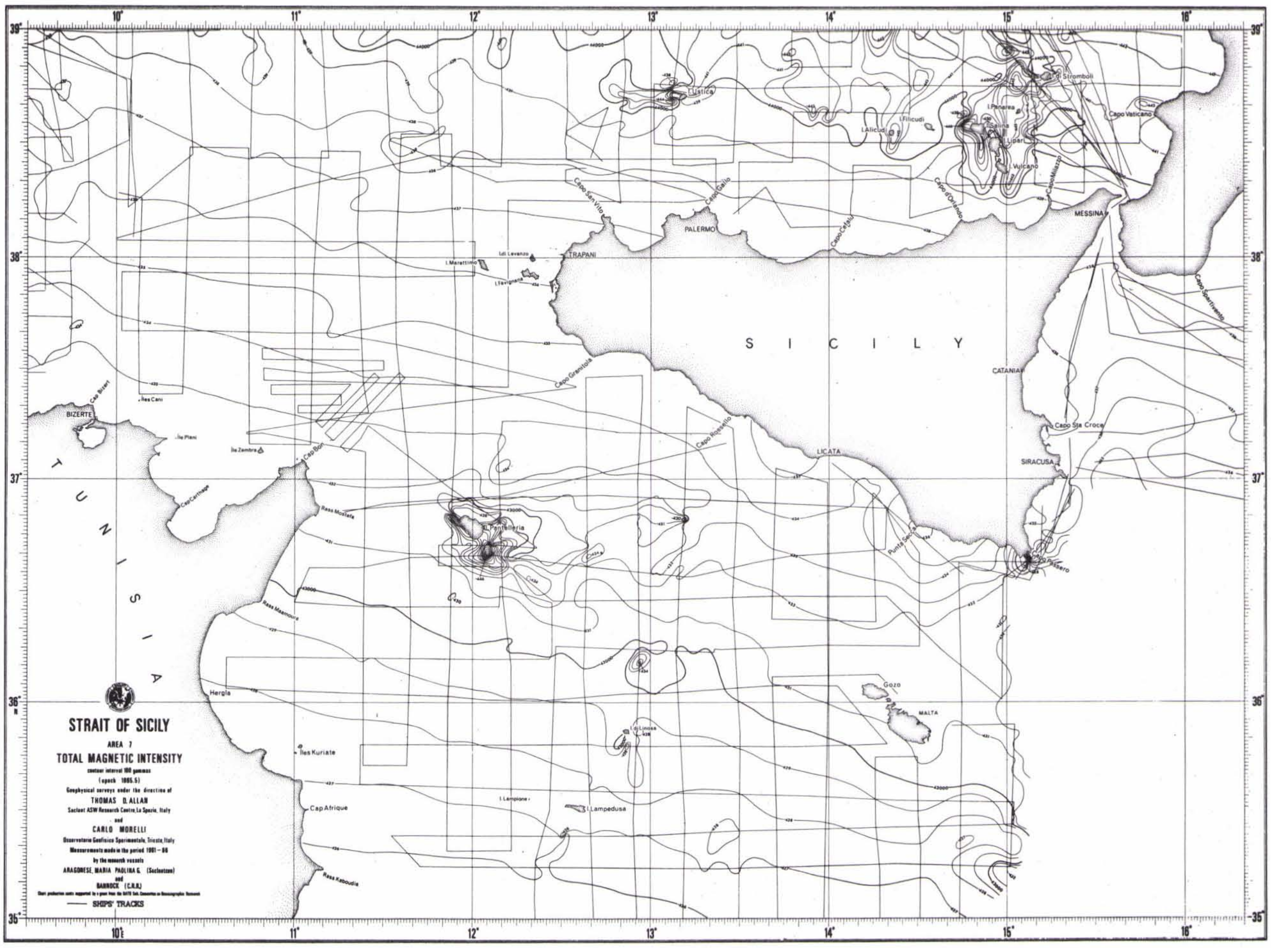

STRAIT OF SICILY
AREA 7
TOTAL MAGNETIC INTENSITY
contour interval 100 gammas
(epoch 1965.5)
Geophysical surveys under the direction of
THOMAS D. ALLAN
Saclant ASW Research Centre, La Spezia, Italy
and
CARLO MORELLI
Osservatorio Geofisico Sperimentale, Trieste, Italy
Measurements made in the period 1961 – 66
by the research vessels
ARAGONESE, MARIA PAOLINA G. (Saclantcen)
and
BANNOCK (C.N.R.)
SHIPS' TRACKS
SICILY
TUNISIA
PALERMO
TRAPANI
MESSINA
CATANIA
SIRACUSA
LICATA
BIZERTE
MALTA
Gozo
I. Pantelleria
I. Lampedusa
Hergla
Cap Afrique

FIG. 10

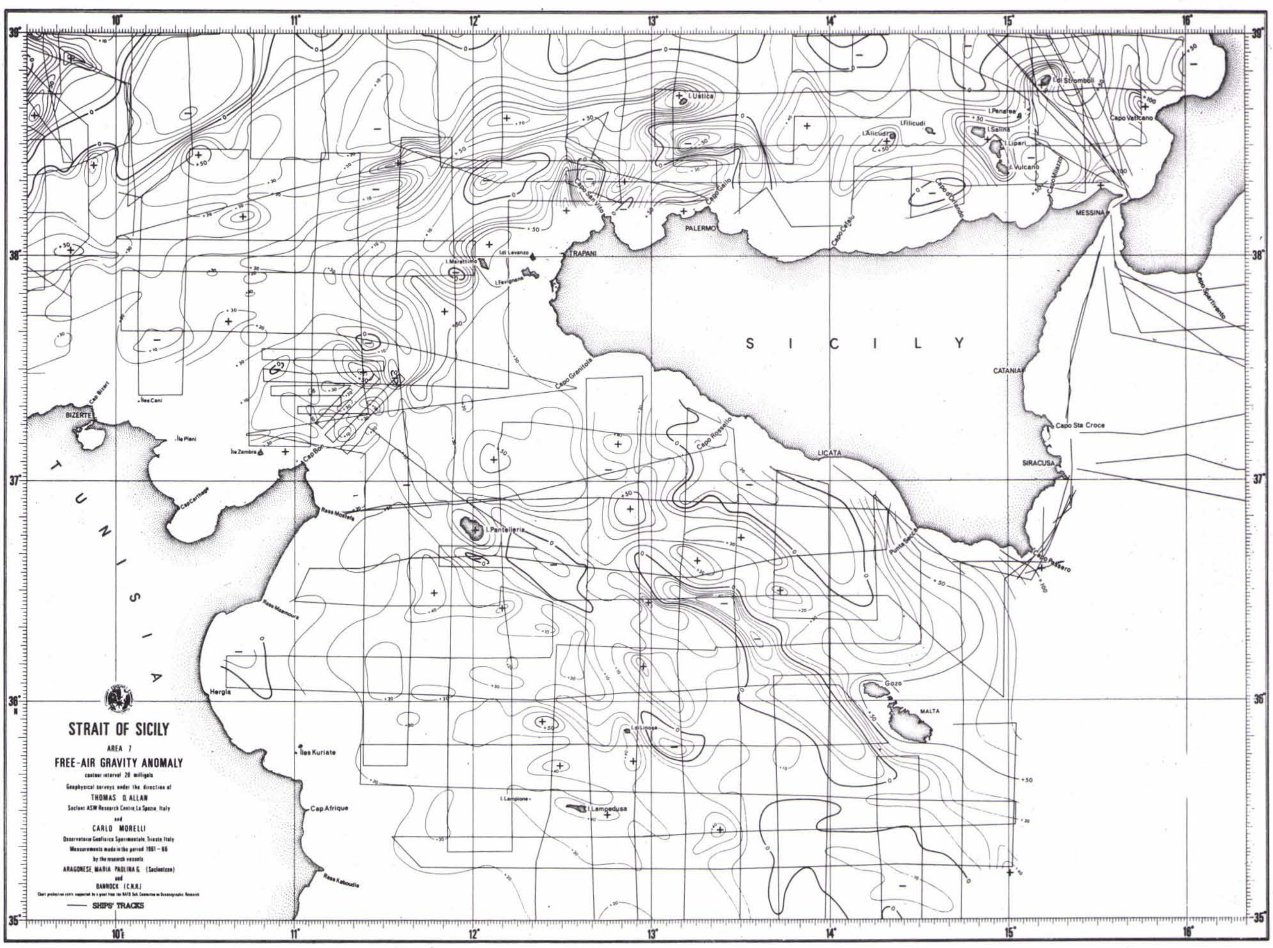
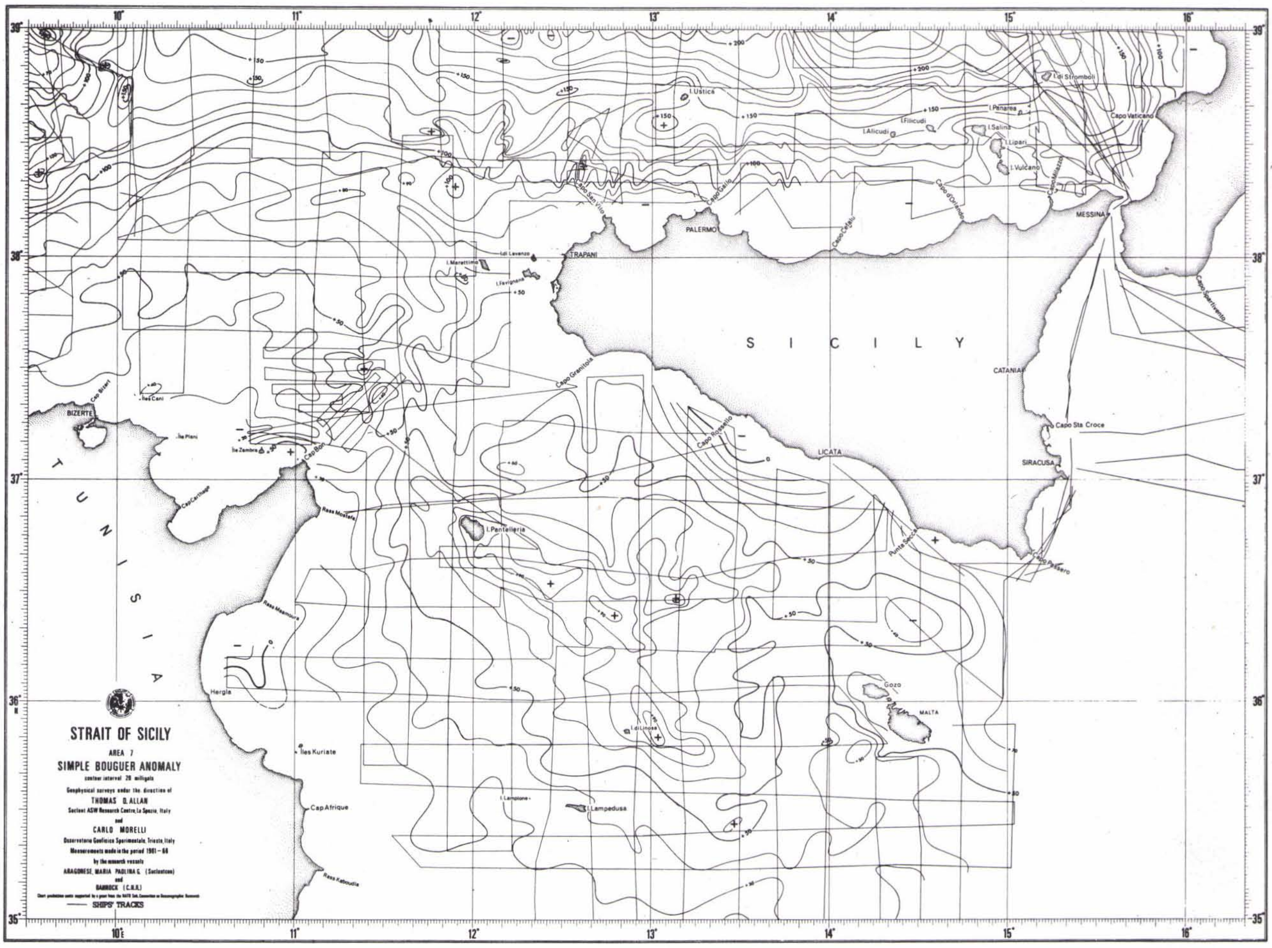

STRAIT OF SICILY
AREA 7
FREE-AIR GRAVITY ANOMALY
contour interval 20 milligals
Geophysical surveys under the direction of
THOMAS D. ALLAN
Saclant ASW Research Centre, La Spezia, Italy
and
CARLO MORELLI
Osservatorio Geofisico Sperimentale, Trieste, Italy
Measurements made in the period 1961 – 66
by the research vessels
ARAGONESE, MARIA PAOLINA G. (Saclantcen)
and
BANNOCK (C.N.R.)
SHIPS' TRACKS
SICILY
TUNISIA
PALERMO
TRAPANI
MESSINA
CATANIA
SIRACUSA
LICATA
BIZERTE
MALTA
Gozo
I. Pantelleria
I. Lampedusa
Hergla
Cap Afrique

FIG. 11



STRAIT OF SICILY
AREA 7
SIMPLE BOUGUER ANOMALY
contour interval 20 milligals
Geophysical surveys under the direction of
THOMAS D. ALLAN
Saclant ASW Research Centre, La Spezia, Italy
and
CARLO MORELLI
Osservatorio Geofisico Sperimentale, Trieste, Italy
Measurements made in the period 1961 – 68
SHIPS' TRACKS
SICILY
TUNISIA
PALERMO
TRAPANI
MESSINA
CATANIA
SIRACUSA
LICATA
BIZERTE
I. Ustica
I. Pantelleria
I. Lampedusa
Gozo
MALTA
Capo Sta Croce
Capo Vaticano
Hergla
Iles Kuriate
Cap Afrique

FIG. 12

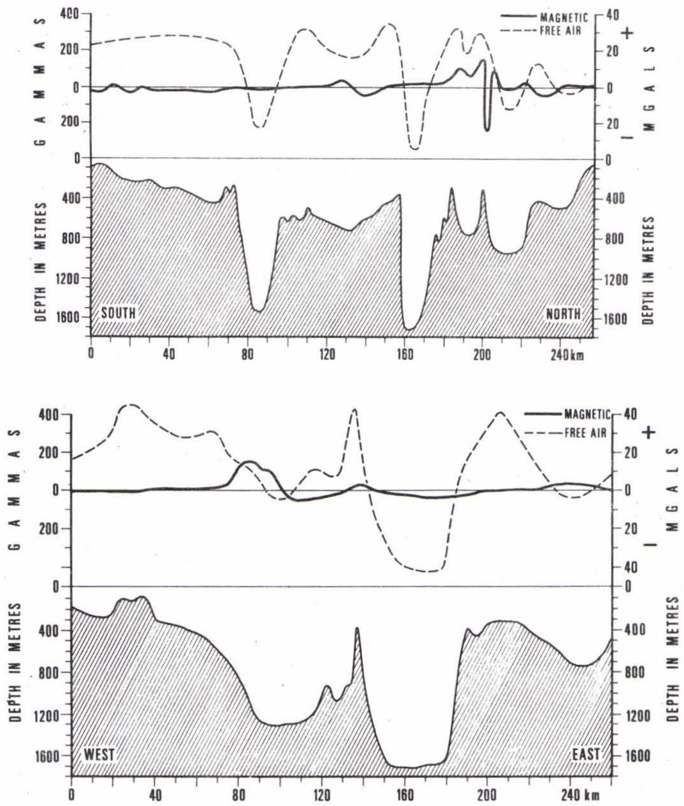

GAMMAS
MGALS
MAGNETIC
FREE AIR
DEPTH IN METRES
SOUTH
NORTH
0
40
80
120
160
200
240 km
WEST
EAST
240 km

FIG. 13

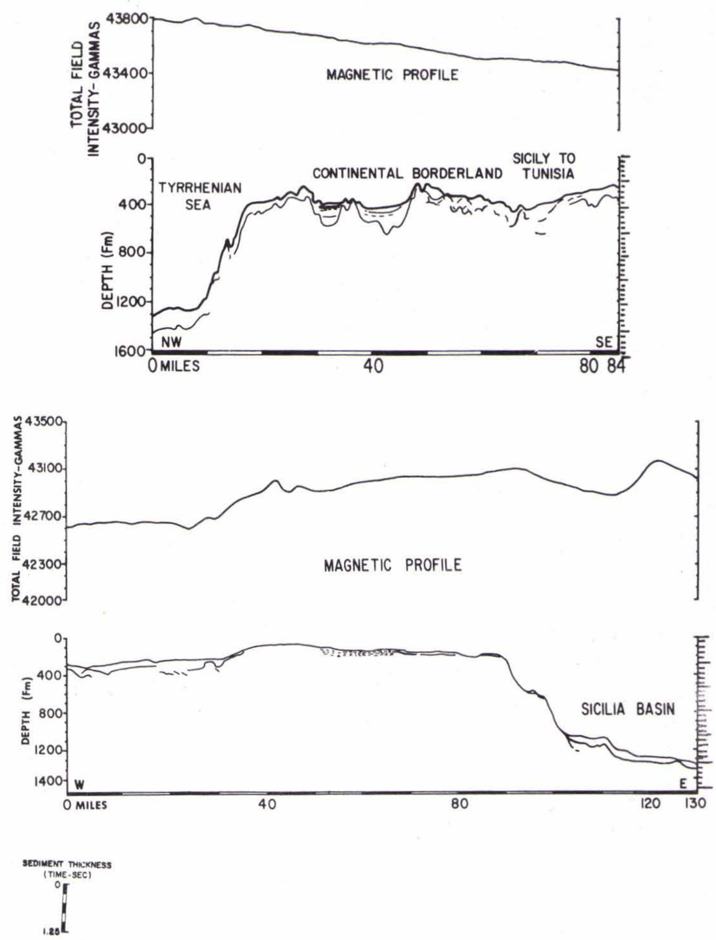
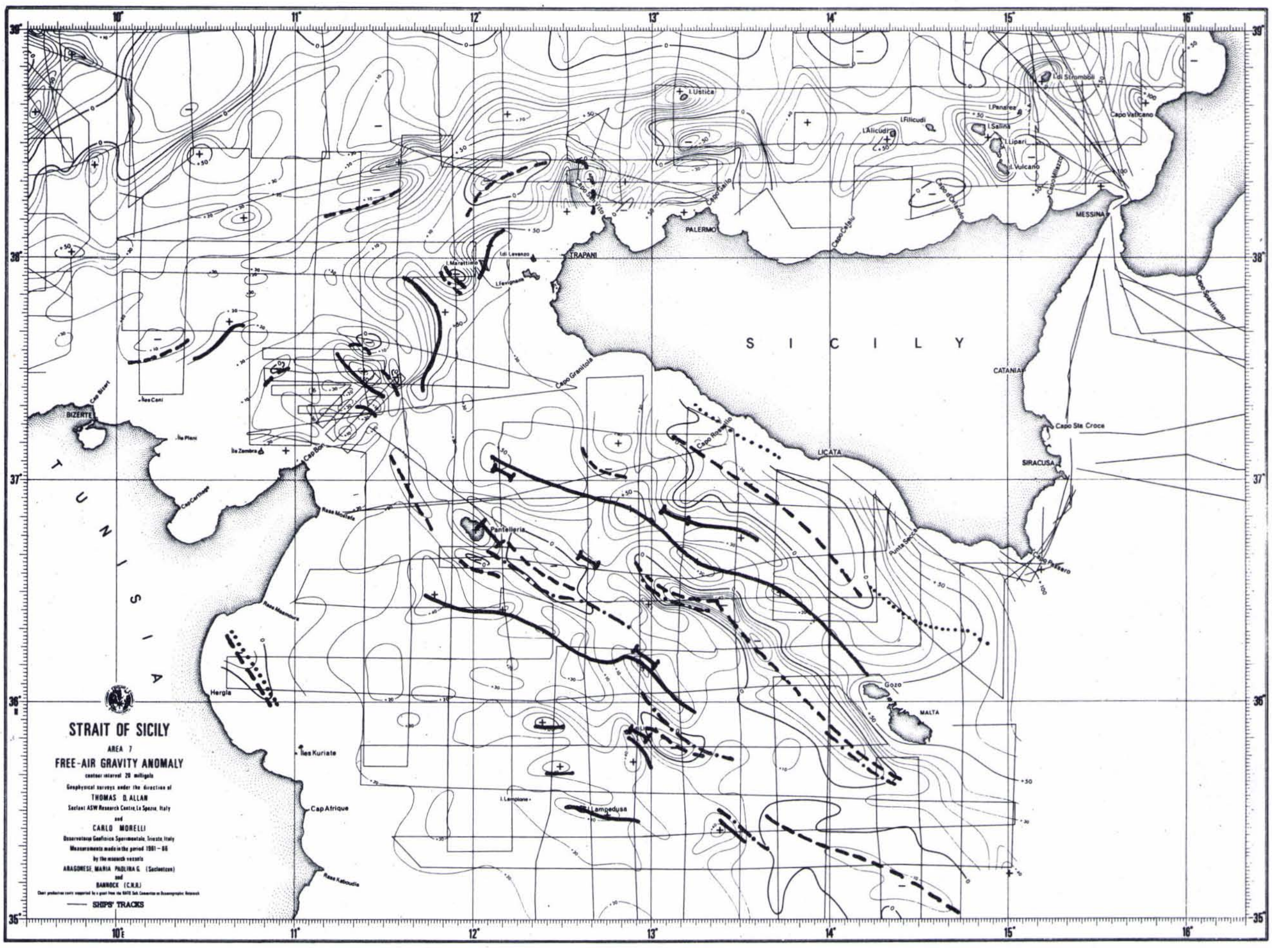

TOTAL FIELD INTENSITY-GAMMAS
MAGNETIC PROFILE
DEPTH (Fm)
TYRRHENIAN SEA
CONTINENTAL BORDERLAND
SICILY TO TUNISIA
NW
SE
0 MILES
40
80 84
MAGNETIC PROFILE
SICILIA BASIN
W
E
0 MILES
40
80
120
130
SEDIMENT THICKNESS (TIME-SEC)

FIG. 14



Axis of positive Free–air anomalies
" " negative " " "
" " positive Bouger "
" " negative " "
Magnetic anomalies

FIG. 15

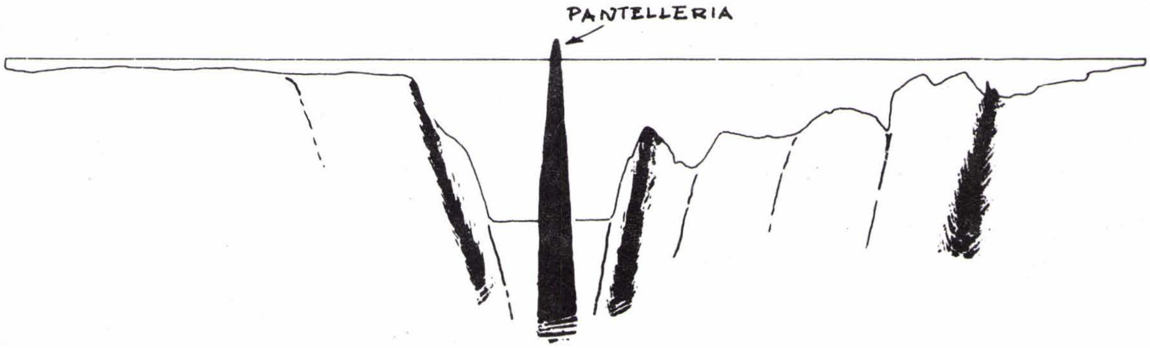


FIG. 16a

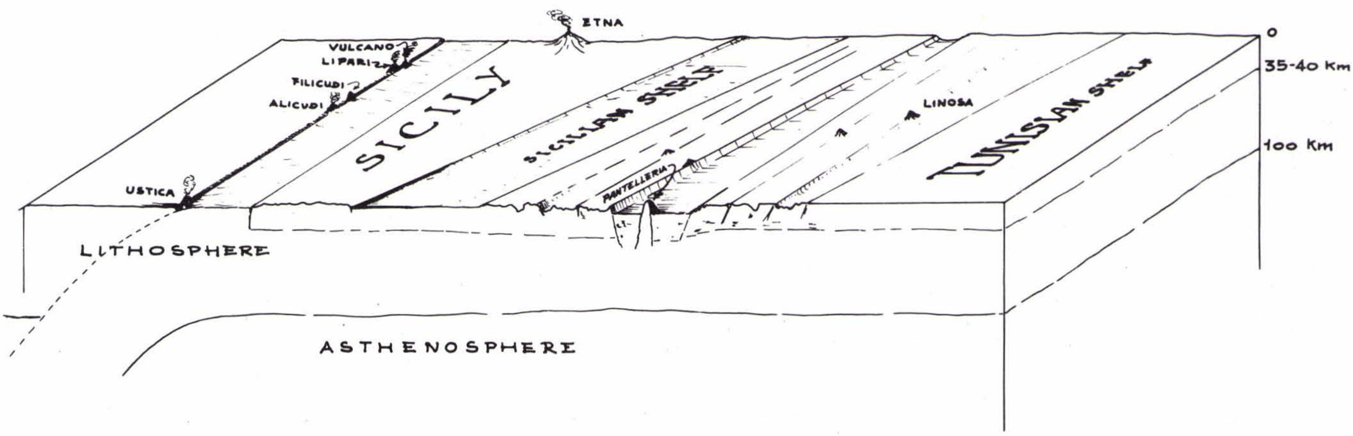


FIG. 16b