

THE GEOPHYSICAL SITUATION IN ITALIAN WATERS (1966.0)

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1. — PREFACE

No study of the substratum for purely scientific aims (basic research : geology, geophysics, tectonics, etc.) or for applied research (mine prospecting) can ignore geophysical data. This is true on land and even more so at sea where direct observation of the surface of the marine sub-bottom is only possible to some several tens of metres in depth, and even in this case is not of much value on account of the mud that normally recovers everything.

The understanding of subsoil problems must therefore be based above all on geophysics.

All geophysical methods up to the last few years have run up against great difficulties when applied to the sea, for reasons which will be mentioned here at the beginning of each report on these methods. For the not very recent past the results are consequently either non-existent (terrestrial magnetism, geothermics, seismology and seismics), or they do not come up to present-day standards of accuracy (gravimetry). This simplifies research for obtaining significant data.

Another reason is that geophysics at sea necessitates such a combination of means, personnel and experience that normally there are but few organizations operating in the marine geophysical field (in Italy at present there is only the Trieste Experimental Geophysical Observatory), and the interesting data are already centralized and easily available.

In view of the close inter-dependence of certain data (gravimetric and magnetic data, for example) in the various basins of the Mediterranean or the paucity of others (geothermic and seismic data) we have here given a detailed account of them for Italian waters and all the adjoining Mediterranean basins.

The sectors in which data exist are enumerated below.

2. — GRAVITY AT SEA

Gravity measurements at sea are made difficult because the primary condition for a correct gravity measurement is lacking, i.e. a fixed platform. The ship's motions give rise to accelerations which are up to 10^5 times higher than the desired accuracy for gravity measurement ($1 \text{ mgal} = 10^{-3} \text{ cm.s}^{-2}$) and which up to the last few years it was not known how to take into account.

This is why until about 1959-1960 gravity measurements were all carried out either from a submarine or from a bathysphere resting on the bottom.

2.1. Measurements from a submarine.

Geophysics at sea started in practice in 1923 when F.A. VENING MEINESZ developed his pendulum device for measurement from a submarine. In 1931, with an instrument of this type lent by the Dutch Geodesy Commission, Professor CASSINIS carried out a first cruise of 102 stations in Italian waters with the submarine *Vettor Pisani*, followed in 1935 by a second cruise of 57 stations with the submarine *Des Geneys* using another Vening Meinesz pendulum instrument acquired in the meantime by the Institute of Geodesy of Padua University. By reason of instrumental defects and unreliable knowledge of the true motion of the submarine during measurements the inaccuracy of these measurements is of the order of $\pm 10 \text{ mgal}$. However, in view of the fact that, especially in the Tyrrhenian and Ionian Sea areas, the Bouguer anomalies are of about some hundreds of milligals (due to the presence of an oceanic type crust) for many years these measurements have been of great value for a first knowledge of the gravity field in Italian waters, excepting the Adriatic Sea.

Similarly, the other gravity measurements from a submarine quoted in the bibliography given below, particularly WORZEL's measurements, have been useful for the first knowledge of the g-values in the Mediterranean, even although for the same reasons as those already given the inaccuracy is always of about ± 5 to $\pm 10 \text{ mgal}$.

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2.2. Measurements from a bathysphere on the bottom.

A decisive step towards knowledge of gravity at sea up to the depth of the continental shelf (depth of about 200 m) *with the same accuracy* (± 0.01 mgal) *as measurements on land* (and consequently also useful for mine prospecting) was taken by placing modern gravimeters in special bathyspheres on the bottom, and by carrying out all the measurements on board a ship by means of remote control.

Table 1. — Summary of Gravity Measurements at Sea 1953-1960

Year	Ship	Gravimeter used	Scale factors	SEA STATIONS					Total
				Adriatic	Ionian	Sardinian	Sicilian	Tyrrhenian	
1953	M/v <i>Seismo</i>	G 32	0.09540	331	—	—	—	—	331
1954	M/v <i>Seismo</i>	G 27	0.10087	—	—	—	—	—	—
	Drag. <i>Abete</i>	G 32	0.09392	586	—	—	—	—	586
		G 27	0.10087	—	—	—	—	—	—
		G 32	0.09392	157	—	—	—	—	157
1955	M/v <i>Seismo</i>	G 27	0.10090	114	—	—	—	—	114
	Cann. <i>Alano</i>	G 32	0.09392	32	—	—	—	—	32
1956	M/b <i>Vercelli</i>	G 27	0.10090	—	151	—	37	314	502
1957	M/b <i>Vercelli</i>	G 27	0.10058	188	112	—	—	—	300
	Drag. <i>Mango</i>	G 17	0.09941	244	—	—	—	—	244
1958	M/b <i>Vercelli</i>	G 27	0.10079	23	—	—	—	—	23
1959	M/b <i>Vercelli</i>	G 27	0.10090	164	—	—	414	194	772
1960	M/b <i>Vercelli</i>	G 27	0.10059	—	—	318	—	74	392
TOTALS				1839	263	318	451	582	3453

These measurements, started in the Mediterranean in 1953, have been extended, under the auspices of the Commissione Geodetica Italiana and financially aided by the Consiglio Nazionale delle Ricerche, to the epicontinental terrace of all the waters surrounding Italy (see figure 1). Statistical data given in table 1.

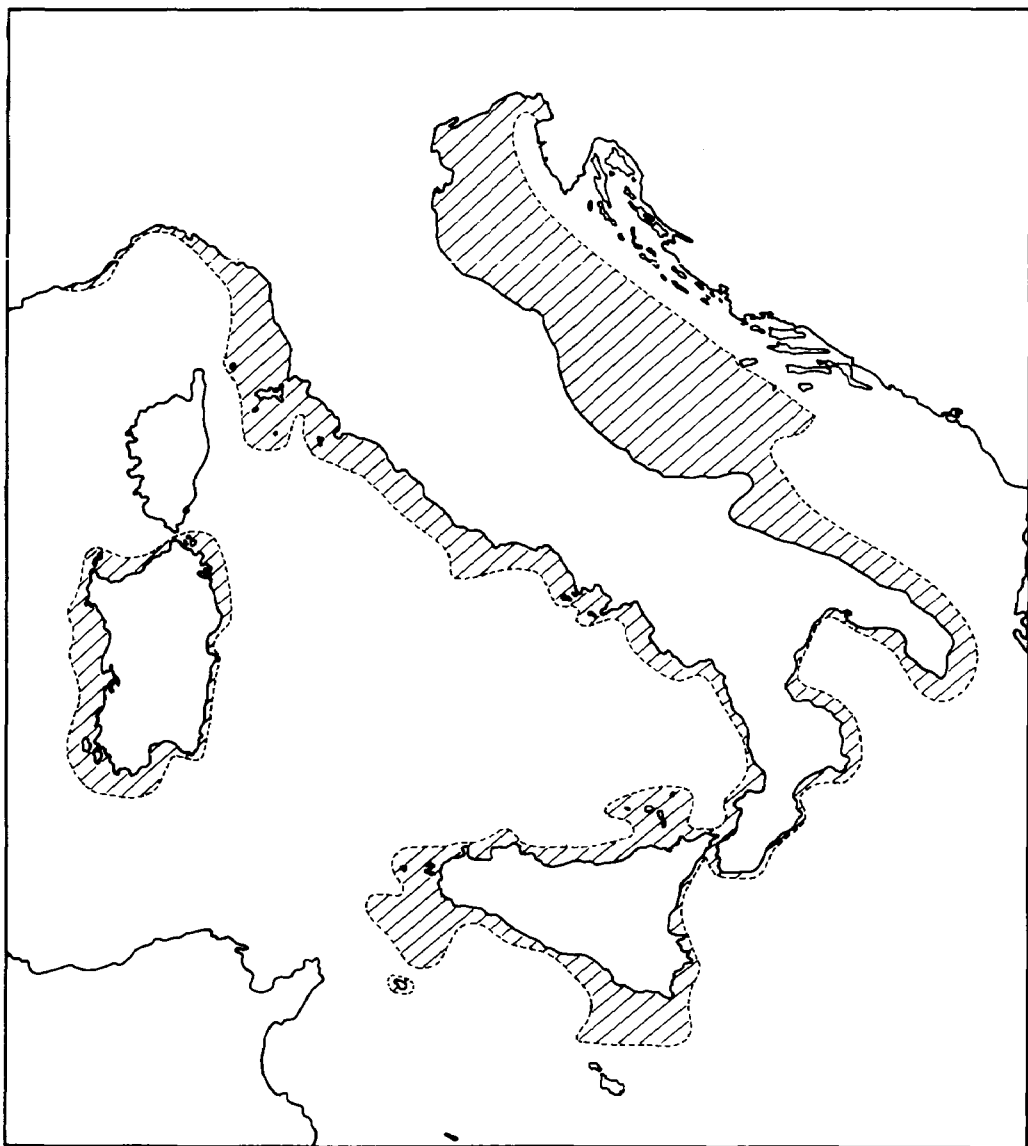


FIG. 1. — Area covered with bottom measurements with remotely controlled gravity-meters.

The positions were normally determined by means of radar trilateration, directly by radar reflectors placed along the coast up to a distance of about 20 miles and indirectly by a series of special reflecting radar buoys out at

sea. The accuracy varies from ± 50 m to ± 300 m, according to the distance from the coast.

The mean density of stations varies between 1 station per 4 km² (in the coastal network between the Po delta and Ancona) to about 1 station per 50 km² or 100 km² in other areas. Such is the density of the first order stations of the Italian gravimetric network on land.

The literature, in chronological order, is as follows :

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2.3. Measurements from surface vessels.

A decisive contribution to gravity measurements in deep water was brought about after many years of trial and experience when it became possible to use gravimeters on surface vessels. Between the years 1950 and 1960 measurements took two different paths : one, the European, with Graf-Askania gravimeters mounted on stable platforms, the other in the U.S.A. with La Coste & Romberg gravimeters hung on gimbals. Today these two types of instrument give accuracies of about one milligal which is very satisfactory, but the way has been long and hard.

The first experiments at sea with the Graf-Askania gravimeter were carried out between Trieste and Venice (GRAF, 1957) in order to use already existing data from remote-controlled gravimeters as comparison (see 2.2).

The first Italian measurements with the same type of gravimeter were carried out on the *Staffeta* in 1959 in the southern Adriatic. The results were not satisfactory owing to the excessive sensibility to temperature

variations, humidity and vibration; to the lack of absolute stability of the electric current supply, both in intensity and frequency; and to insufficient intrinsic dampening. Thus the mean error was ± 6.5 mgal.

After these causes of error were eliminated the instrument underwent further development, both theoretic and experimental (even on a special apparatus simulating ship motions, constructed at the request of the OGS by the Istituto di Meccanica applicata of Trieste University). In 1961 a calibration survey carried out on board the vessel *Aragonese* (3 000 tons), belonging to the Saclant ASW Research Centre, La Spezia, over a region sufficiently covered by remote-controlled gravimeter stations on the bottom made it possible to verify that the accuracy obtainable today is of the order of ± 3 mgal, and consequently sufficient for regional surveys for which these measurements are normally intended.

Since 1961 a systematic survey project of all Italian waters and of the Mediterranean is in consequence being carried out, supported by a financial grant from the Consiglio Nazionale delle Ricerche. The areas so far surveyed are shown in figures 2a, 2b and 2c, and the statistical data in table 2.

Table 2. — Geophysical cruise progress in the Mediterranean at 31-12-1965

No.	Cruise	Year	Ship	Region	Position fixing	Distance covered
I	Cossak	1961	<i>Aragonese</i>	Northern Tyrrhenian Sea.	Radar	3 356
II	Corsair	1961	«	West Sardinia and Corsica, East Corsica.	Radar	5 060
III	Concrete	1961	«	Southern Aegean Sea and Crete, Red Sea.	Radar	12 660
IV	Codicil	1962	«	Ligurian Sea, Sicilian Channel.	Loran C	6 744
V	Corinth	1962	«	Aegean Sea, South of Crete, Eastern Mediterranean.	Radar	7 710
VI	Concord	1963	«	Central Aegean Sea.	Radar	2 214
VII	Coran	1963	«	Ligurian Sea.	Radar + Rana	4 239
VIII	Cornet	1963	«	Central Tyrrhenian Sea.	Loran C	3 788
IX	Cocktail	1963	«	Southern Tyrrhenian Sea.	Loran C	3 559
X	Coalesce	1964	<i>M. Paolina</i>	Southern Tyrrhenian Sea, Northern Aegean Sea.	Loran C + Radar	5 375
XI	Baby	1964	<i>Bannock</i>	Balearic Isles, Southern Adriatic.	Radar	6 420
XII	Cobweb	1965	<i>M. Paolina</i>	Gulf of Lions.	Loran C	3 093
XIII	Bachelor	1965	<i>Bannock</i>	Western Mediterranean.	Loran C	20 180
XIV	Cobra	1965	<i>M. Paolina</i>	Alboran Sea, Gibraltar.	Radar	2 500
XV	Barrister	1965	<i>Bannock</i>	Adriatic & Ionian Seas, Gulf of Gabès.	Loran C	12 000
					TOTAL	98 900

Since the ship should be of at least 1 000 tons, measurements were immediately taken on the 3 000-ton vessels *Aragonese* and *Maria Paolina* of the Saclant ASW Research Centre, La Spezia, on the occasion of cruises

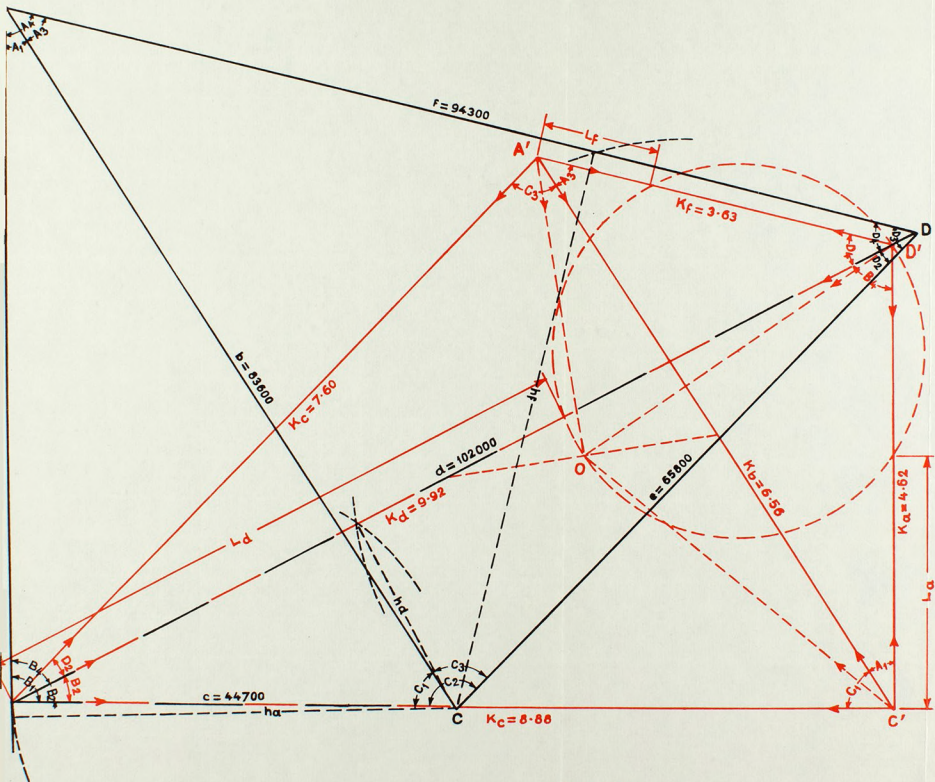
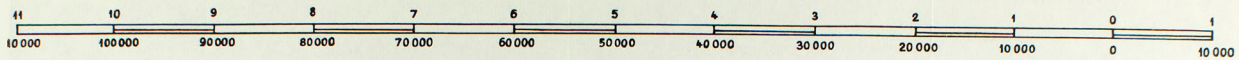


FIG. A and B₁

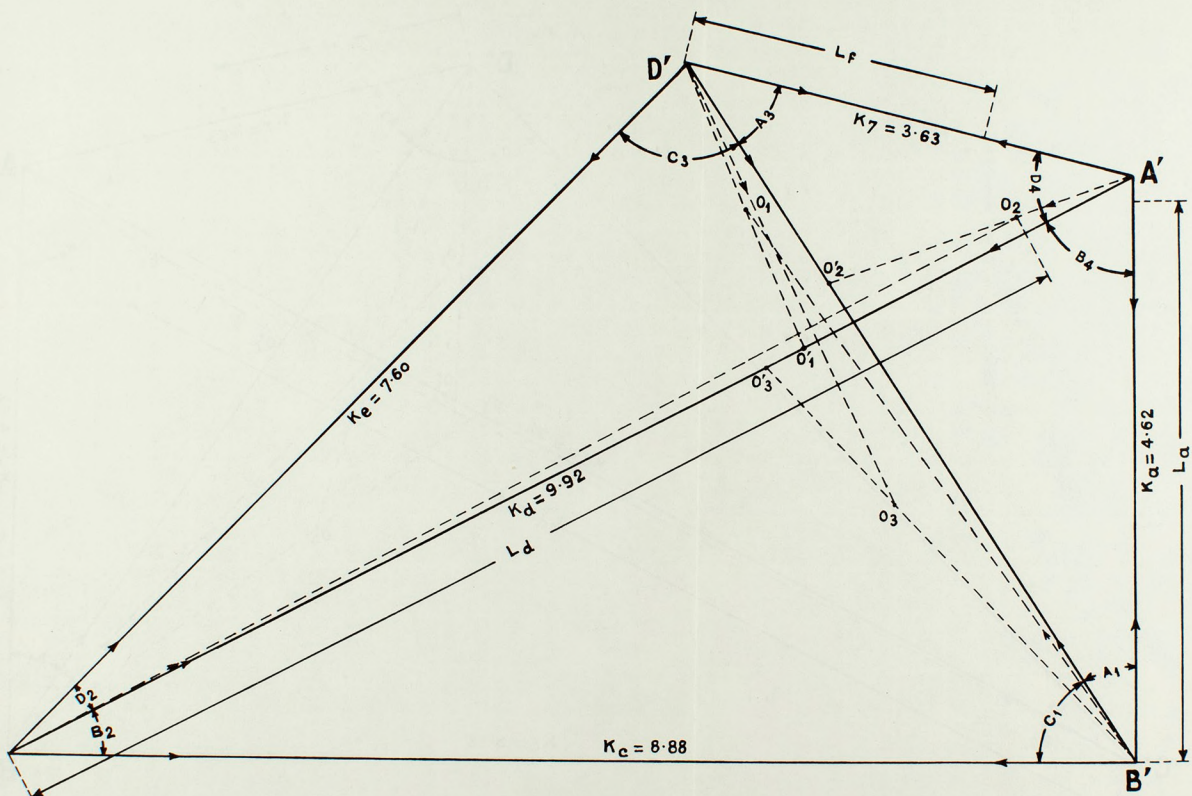


FIG. B₂

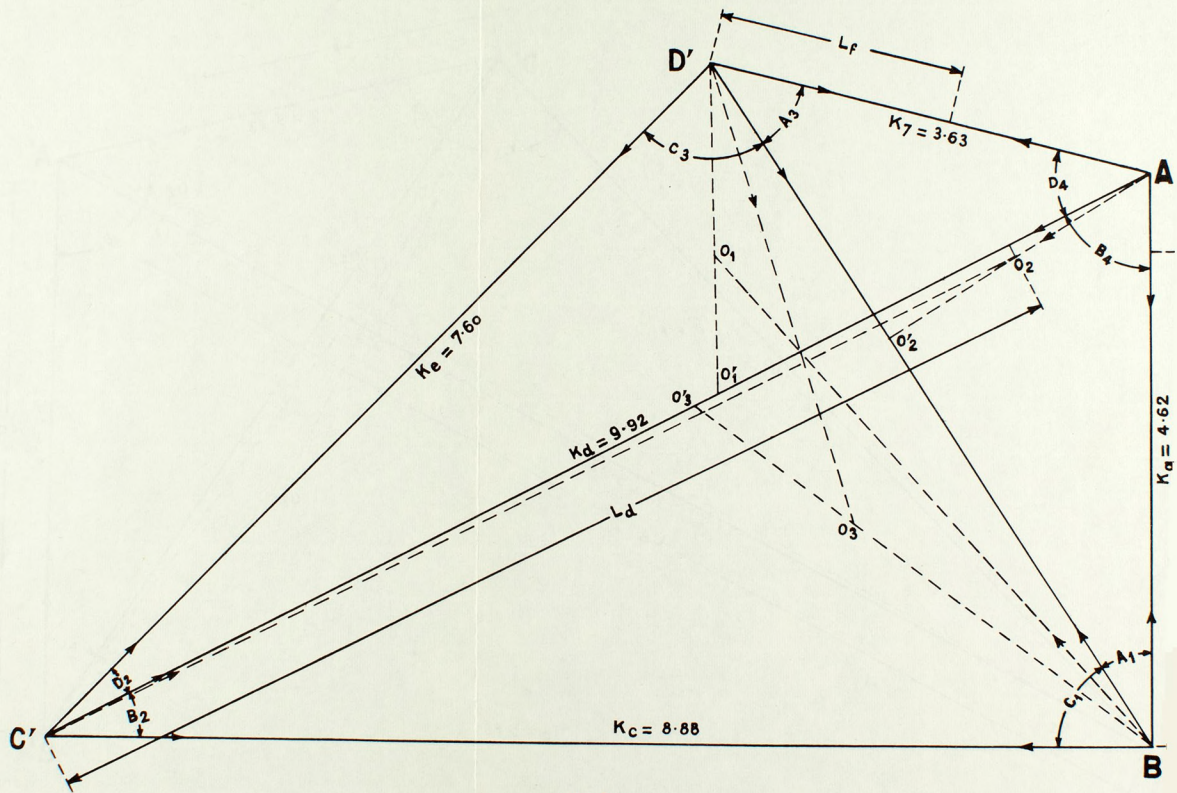


FIG. B₃

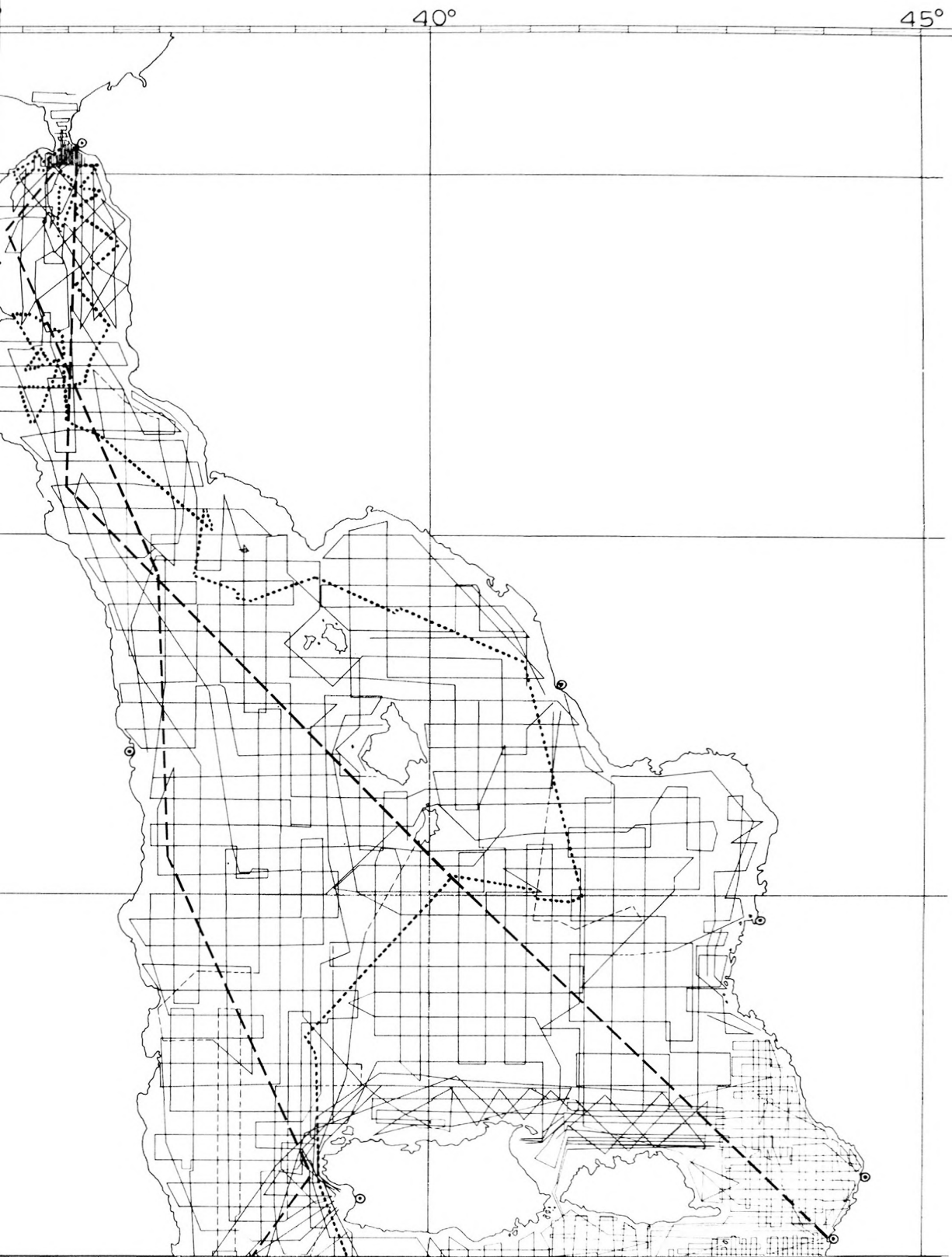


Fig. 2a. — Gravimetry, Earth Magnetism and Bathymetry 1966.0.

- | | | |
|-------|-----------------------|-------------------------------|
| — | { Gravity | O.G.S., Trieste |
| — | { Earth magnetism ... | Saclant + O.G.S. |
| - - - | { Gravity | Dept. Geod. Geoph., Cambridge |
| - - - | { Earth magnetism ... | Dept. Geod. Geoph., Cambridge |
| | Earth magnetism ... | Lamont Geol. Obs., N.Y. |

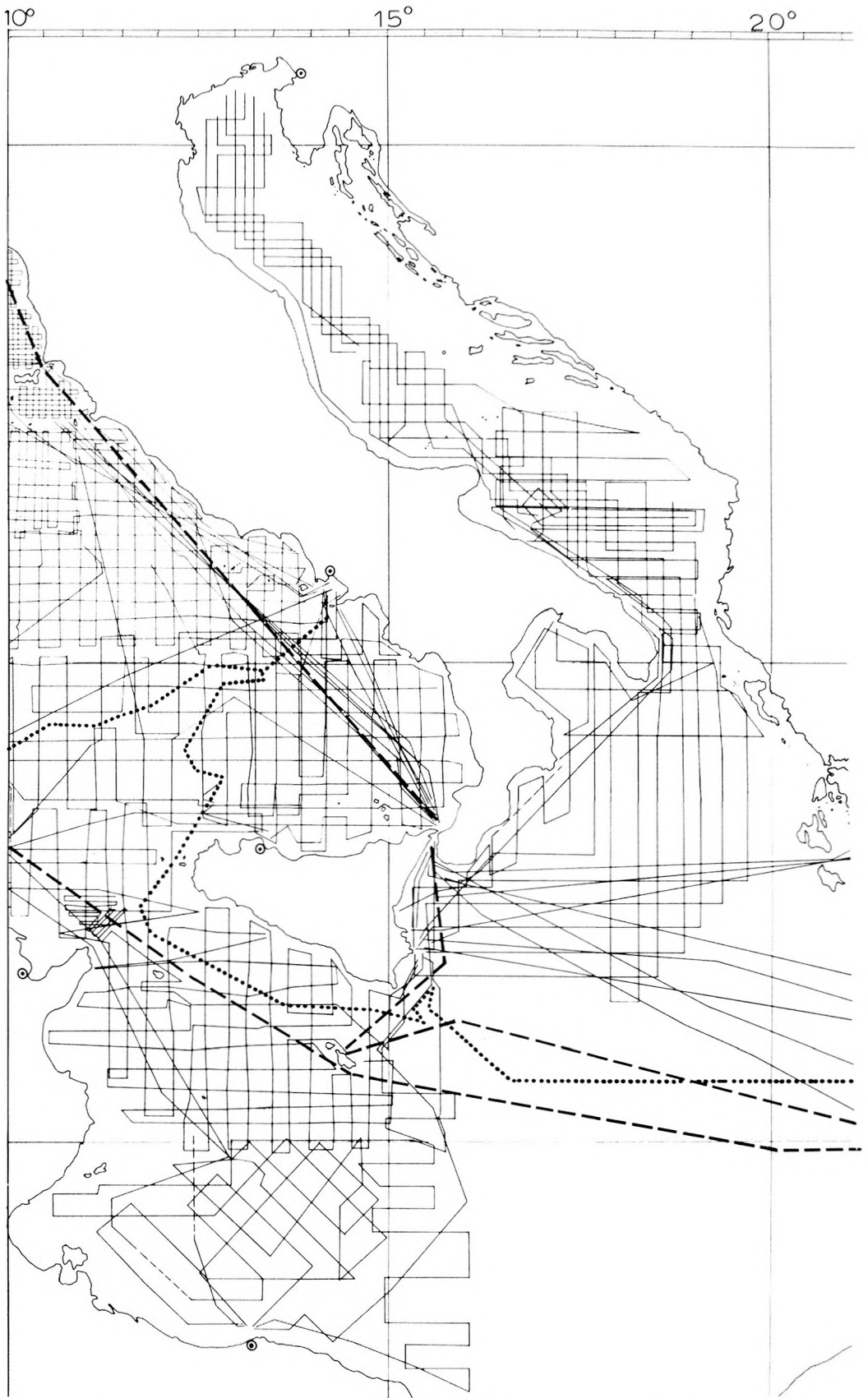


Fig. 2b. — Gravimetry, Earth Magnetism and Bathymetry 1966.0.

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|-------|---|---------------------|-------------------------------|
| ————— | { | Gravity | O.G.S., Trieste |
| | { | Earth magnetism ... | Saclant + O.G.S |
| ----- | { | Gravity | Dept. Geod. Geoph., Cambridge |
| | { | Earth magnetism ... | |
| | | Earth magnetism ... | Lamont Geol. Obs., N.Y. |

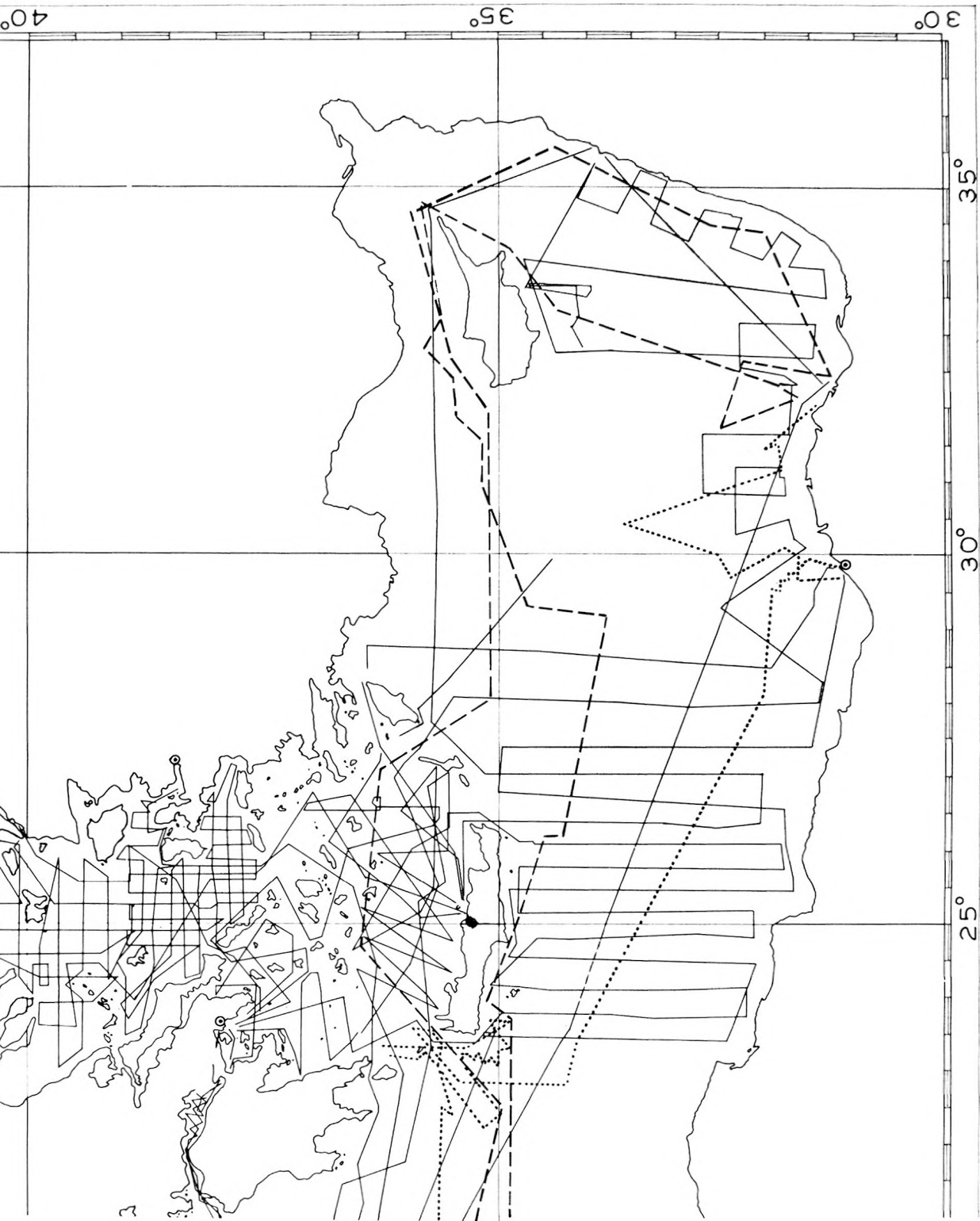


FIG. 2c. — Gravimetry, Earth Magnetism and Bathymetry 1966.0.

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|-------|---|---------------------|-------------------------------|
| ————— | { | Gravimetry | O.G.S., Trieste |
| | { | Earth magnetism ... | Saclant + O.G.S. |
| ----- | { | Gravimetry | Dept. Geod. Geoph., Cambridge |
| | { | Earth magnetism ... | |
| | | Earth magnetism ... | Lamont Geol. Obs., N.Y. |

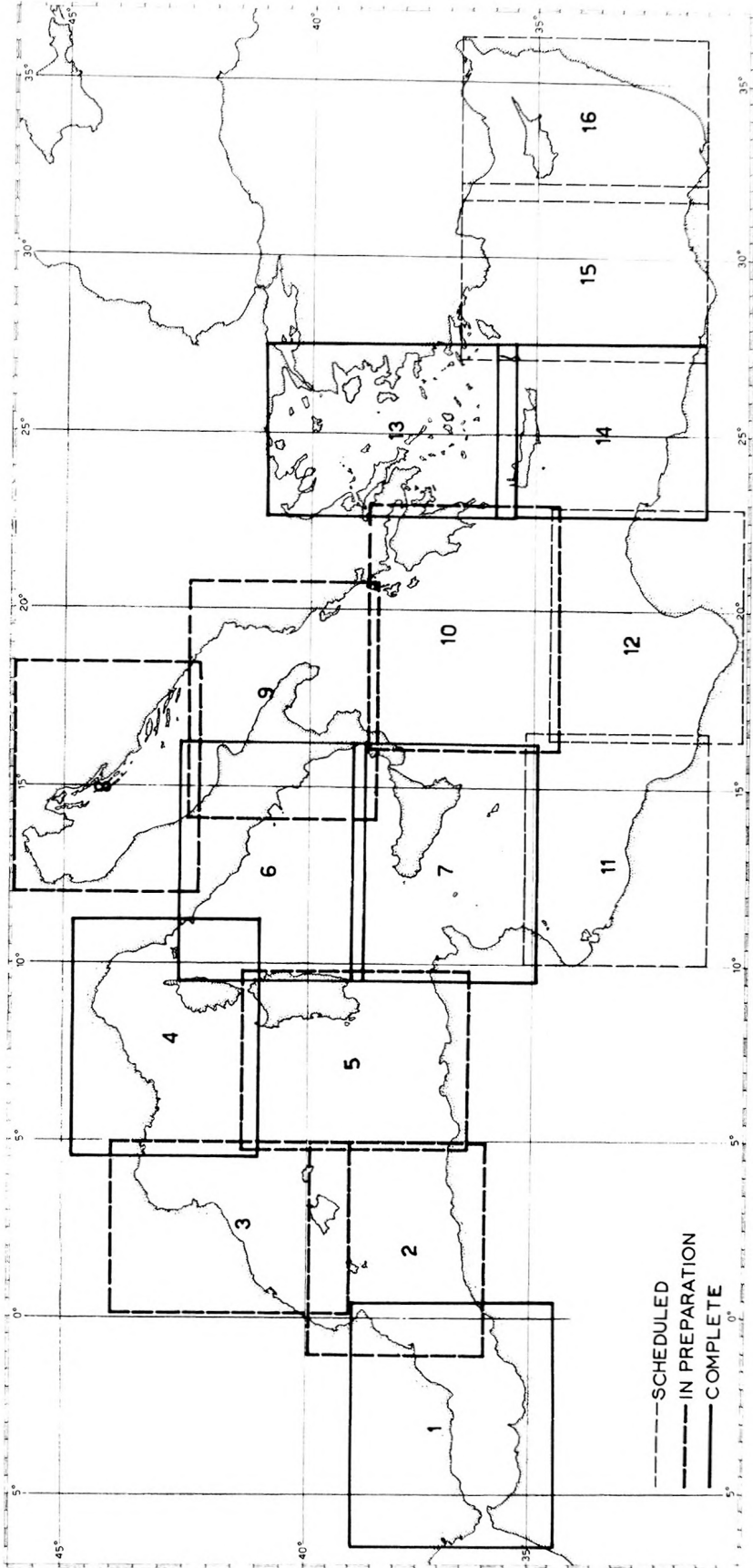


FIG. 3. — Chart of the 1/500 000 sheets in preparation for the presentation of the gravimetric, magnetic, morphologic and stratigraphic results in the Mediterranean Sea.

intended for magnetometric measurements. Since 1964 cruises have also been made with *Bannock* (1 570 tons), belonging to the Consiglio Nazionale delle Ricerche.

Since these ships are also equipped with special echo-sounding instruments with a high resolving power (PDR and PGR) a continuous bathymetric profile with an accuracy as high as ± 1 m was made during these same cruises, and when non-consolidated sediments were found a stratigraphic profile was also recorded up to a depth of about several tens of metres. Figures 2a, 2b and 2c also give the gravimetric profiles obtained in the Mediterranean by the Department of Geodesy and Geophysics of Cambridge University, England.

The literature, which today deals principally with methods and reductions, is given in the bibliography below. The results will be published at a scale of 1/500 000 according to the Index Chart shown in figure 3. Each sheet will include charts of the following :

- | | |
|-------------------|------------------------|
| a) profiles | e) Bouguer anomalies |
| b) bathymetry | f) isostatic anomalies |
| c) morphology | g) magnetic field |
| d) Faye anomalies | h) residual anomalies |

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3. — TERRESTRIAL MAGNETISM

As we have said, the *Aragonese* and *Maria Paolina* Saclant ASW cruises were principally concerned in surveying the total intensity of the terres-

trial magnetic field. The magnetometer was of the nuclear precession type described by HILL (1959) and manufactured by Bruce Peebles, Ltd. It has a sensitivity of $\pm 0.5 \gamma$, but the accuracy of the measurements is lessened by the uncertainty in the diurnal variation.

The same instrument has up to now been used during the geophysical cruise of the *Bannock* (see table 2) so that, for terrestrial magnetism also, progress up to the present is shown in figures 2a, 2b and 2c.

The profiles carried out by the Department of Geodesy and Geophysics of Cambridge University, England, and the Lamont Geological Observatory, New York, are also shown on these same figures.

In mid-1966 the *Bannock* will be provided with a new Varian V-4937 proton magnetometer which will allow the data to be digitalized and thus made ready for electronic reduction.

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4. — GEOTHERMICS AT SEA

The study of heat flow is taking on more and more importance for basic research, in view of its close correlation with seismic and tectonic flow and with the study of the upper mantle, etc. Moreover this flow is also important to applied research, particularly for endogenetic forces.

Measurements on land are far simpler than those at sea, but they have against them great difficulties of interpretation, above all because of the many causes of disturbances which on land are difficult to eliminate. At sea when it is possible to operate at depths over 200-300 m, for which the existence of a stationary layer may be assumed, interpretation is easier and more certain. For this reason the majority of thermal flow measurements have up to now been carried out on the sea bottom.

An up-to-date catalogue of published results is given by LEE, UYEDA, 1965. However for the Mediterranean the results for only four stations are given (see figure 4). The results for the other stations (Woods Hole and UCLA) shown in figure 4 have not yet been published.

Since 1965 the *Bannock* has also been equipped with a thermoprobe and the first measurements (see figure 4) are being prepared for publication (LAVENIA, 1966) as well as a critical appraisal of methods and the causes of errors.

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5. — SEISMOLOGY AT SEA

In seismology at sea we also make a distinction between that part of this science solely devoted to basic research (structural or tectonic research) and that devoted to mining research (specifically for the case of hydrocarbons).

In the case of seismology for prospecting purposes, however, the data are not normally published. We have therefore shown in figure 4, for purposes of information, only those zones covered by seismologic reflection, in the Adriatic (by the Ente Nazionale Idrocarburi, as well as by a group of private companies) and in the Ionian Sea (by the Montecatini Company).

The purpose of deep-sea seismology is the study of structures :

a) *by reflection*, making a stratigraphical sediment survey possible right down to the roof of crystalline bedrock (for special requirements it is even possible to follow the internal discontinuities of the earth's crust by reflection).

b) *by refraction*, showing up the principal discontinuities in elasticity, their depth and shape, and the elastic nature of stratifications. This is therefore the most efficient means for studying the Earth's interior.

In seismological work at sea, there are important difficulties in organization, procedures and techniques. A critical appraisal of the preparation of the Italian programme by FINETTI was published in 1965. The profiles obtained in the Mediterranean are shown in figure 4.

A study of a general character by HERSEY was published in 1965.

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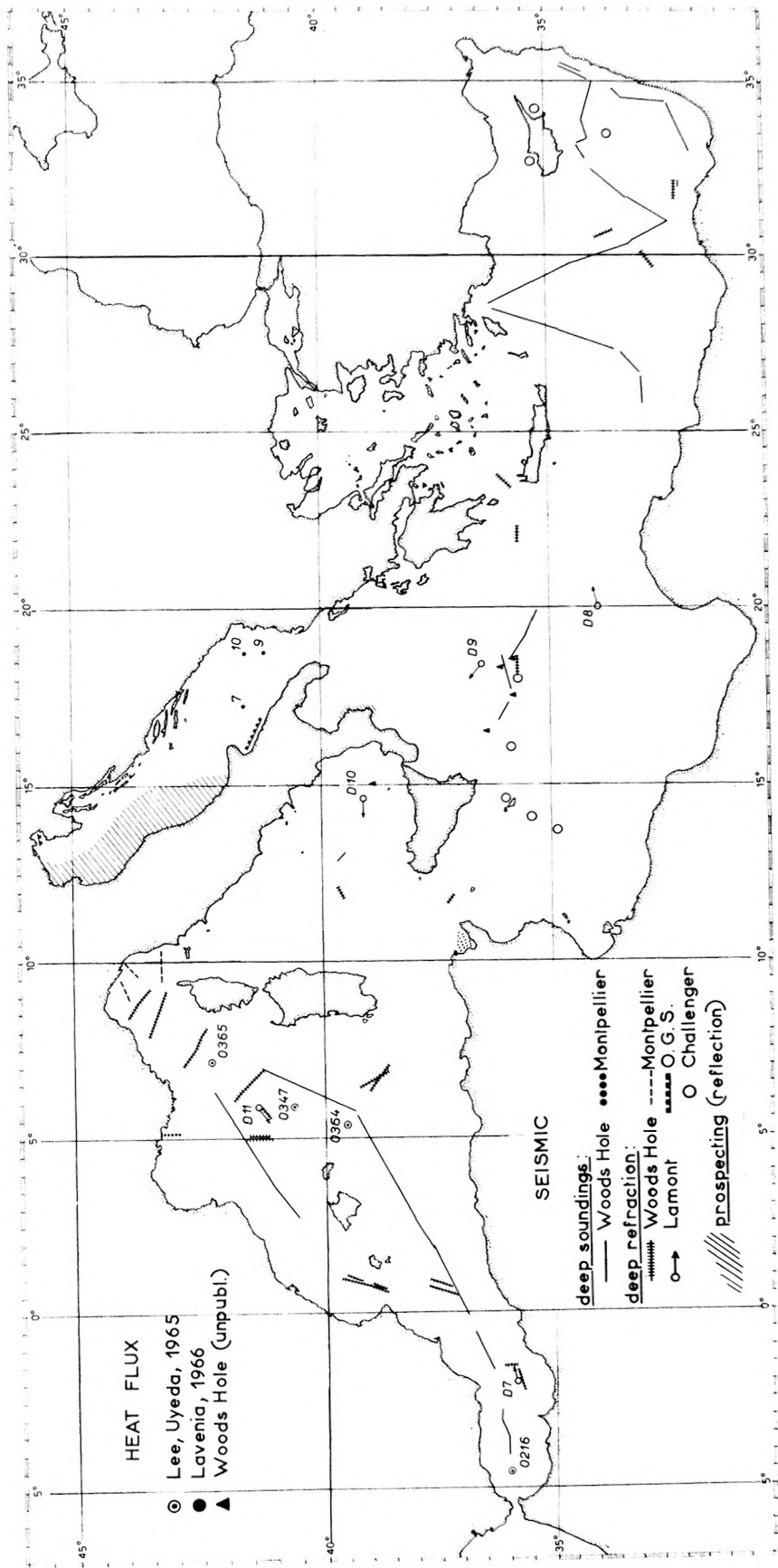


FIG. 4. — Actual situation of marine seismic and heat flux stations.

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