Preliminary crustal model from seismological observations at the Messina Straits network *

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ABSTRACT

Starting from a general tectonic description of the Strait of Messina, what follows is an explanation of the criteria adopted in choosing sites for seismic stations of the Straits network.

The main lithological and mechanical characteristics of the terrains where the stations are been located, together with the equipment used, are mentioned, are looked at in relation to the positions of the main centres of seismic activity both actual and in recent past, and to the microseismic energy threshold.

A number of observations regarding the seismic crisis in the Gulf of Patti (1978) are analized, with the aim of suggesting a crustal model compatible with the area of the Messina Straits.

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The travel times observed in the epicentral distance-interval, $0.1 \leq \Delta^{\circ} \leq 2.0$, are tentatively placed into groups according to their hypocentral depth. From a first evaluation of the hypocentral coordinates (by the I.N.G.) it was possible to divide the data into two groups (for $h'=10$ Km and $h''=20$ Km, respectively). Using the slopes of the various linear regression obtained from the data contained in the two groups, it was possible to elaborate a crustal model (MSM), by progressively correlating those elements that can be deduced from the two groups of the data, i.e. the longitudinal wave velocity and the intercept times of the respective travel-time curves. In particular the differences of the intercept times of observed phases are compared with similar intercept times compatible with the proposed model.

The resulting MSM in four layers can be characterized as follows:

$h_1 = 2$ Km, $v_1 = 3.0$ Km $\cdot$ sec^{-1}; $h_2 = 4$ Km, $v_2 = 4.5$ Km $\cdot$ sec^{-1};

$h_3 = 16$ Km, $v_3 = 5.8$ Km $\cdot$ sec^{-1}; $h_4 = 13.5$ Km, $v_4 = 6.4$ Km $\cdot$ sec^{-1};

$v_5 = 7.8$ Km $\cdot$ sec^{-1}.

Such a model is compatible with the crustal sections obtained by seismic deep refraction in areas along the margins of the Straits as well as with the trend of Bouguer's iso-anomalies in the propagation zone of the seismic rays.

RIASSUNTO

Muovendo da una descrizione generale della tettonica dello Stretto di Messina, sono esposti i criteri adottati nella scelta dei siti delle stazioni sismiche costituenti la Rete dello Stretto.

Le principali caratteristiche litologiche e meccaniche dei terreni di fondazione delle stazioni, unitamente alle dotazioni strumentali, sono riportate e messe in relazione all'ubicazione dei maggiori centri sismici attuali e recenti e al livello di soglia di energia dell'attività microsismica.

Un congruo numero di osservazioni relative alla crisi sismica del Golfo di Patti (1978), è poi analizzato al fine di elaborare un modello di crosta compatibile con l'area dello Stretto di Messina. I tempi di tragitto osservati nell'intervallo di distanze epicentrali $0.1 \leq \Delta^{\circ} \leq 2.0$, sono preliminarmente discriminati in base alla profondità ipocentrale. Da una prima valutazione delle coordinate ipocentrali (effettuate dall'I.N.G.) è possibile suddividere l'intera popolazione dei dati in due gruppi, rispettivamente di profondità focale 10 e 20 Km. Dalle inclinazioni dei vari allineamenti ottenuti con i dati dei due gruppi, è possibile elaborare un modello crostale (MSM), correlando progressivamente gli elementi deducibili dai due raggruppamenti relativamente alle velocità delle onde longitudinali ed ai tempi intercetti delle rispettive dromocrome. In particolare sono confrontate le differenze dei tempi intercetti delle fasi osservate con quelle corrispondenti, deducibili dal modello proposto.

Un modello di crosta a quattro strati è così caratterizzato:

$h_1 = 2$ Km, $v_1 = 3.0$ Km $\cdot$ sec^{-1}; $h_2 = 4$ Km, $v_2 = 4.5$ Km $\cdot$ sec^{-1};

$h_3 = 16$ Km, $v_3 = 5.8$ Km $\cdot$ sec^{-1}; $h_4 = 13.5$ Km, $v_4 = 6.4$ Km $\cdot$ sec^{-1};

$v_5 = 7.8$ Km $\cdot$ sec^{-1}.

Tale modello risulta compatibile sia con le sezioni crostali ottenute mediante sismica a rifrazione profonda in aree ai margini dello Stretto, sia con l'andamento delle isoanomale di Bouguer nella zona di propagazione dei raggi sismici.

INTRODUCTION

The area centred on the Straits of Messina has been affected by most of the worst seismic catastrophes wich occurred in Italy in the last two centuries.

For this reason the necessity of creating a suitable infrastructure for seismological observation has been felt since the last century; but it was only after the disastrous earthquake that destroyed Messina and Reggio Calabria on December 28, 1908 that steps were taken to fill the gap.

In 1976 the C.N.R., granting financial support to the seismic-network of the Straits of Messina, through the Italian Geodynamic Project, made possible the realization of this modern network.

GEOLOGICAL AND STRUCTURAL FRAMEWORK

The Straits of Messina are the most important tectonic feature cutting across the southern branch of the Calabro-Peloritan mountain range, along the SE edge of the Tyrrhenian Sea.

This range is mostly made up of the Calabried Complex, which consists of intrusive igneous rocks, of Hercynian metamorphites, as well as by Mesozoic and Tertiary sedimentary covers.

During the Appennine orogenesis the Calabride Complex, consisting of several nappes, was emplaced by an overthrust moving SE. Later, during the Lower and Middle Miocene, the metamorphic and igneous rocks, were greatly altered by weathering. For this reason such terrains, especially in Calabria, are intensely cataclastic and superficially arenitic.

Recent studies in marine geology and neotectonics (Selli, 1978; Barbano et al., 1979) confirm the presence in the Straits of an already suspected Graben structure. According to the most recent studies the post-orogenic tectonic evolution in the area of the Straits can be summarized thus:

— after the phase of sub-aerial degradation, during the Tortonian, a transgression took place with the formation of sandstone and conglomerates of lacustrine to coastal environments. This transgression was accompanied by a preliminary post-orogenic phase in which subsiding basins are noticeable, e.g. the Fiume Mesima, which also involving the area of the Straits of Messina (Barbano et al., 1978).

— a compressive tectonic phase followed in the Lower and Middle Pliocene, probably due to the continuing southeastward movement of the range accompanied by transcurrent movements at the edges (Barbano et al., 1978; Selli, 1978).

— between the Upper Pliocene and the Pre-glacial Pleistocene a distensive tectonic phase directly involved the genesis of the Straits. In an early stage, the Straits, between the faults of Portella Arena and Gallico (Fig. 1, a and b), had the shape of a Graben created by a major distension σ_3, WNW-ESE (Selli, 1978).

— in the Upper Pleistocene a tensional tectonic phase began, which seems to be still going on. This phase caused normal faulting and lineaments (E-W, N-S, NW-SE) and reactivated earlier faults. According to some Author (Selli, 1978) this phase was caracterized by a NW-SE main distension, which generate a conjugate system E-W, N-S. This phase has been responsible for strong uplift, more noticeable on the Calabrian side, with the formation of various orders of terraces. The complete separation of the two shores of the Straits is thought to belong to this phase, which, with the opening of the Graben (ENE-WSW), gave the Straits their northern access, and their present shape.

It is important to note that, according to geophysical research and stratigraphic soundings in the area of the Straits, the greatest thickness of the post-orogenic sedimentary cover on the crystalline formations is generally less than 1 kilometer.

Seismic Station Site Selection

The trend of the recent and current seismic activity in the area conform to the tectonic picture given above. There are two levels of seismic activity. The first one refers to larger events (e.g. the earthquake of December 28, 1908, $M = 7.1$) while the second one, very active, refers to microseismic activity. Both types have their origins in the internal structures of the Grabens of the Straits (Baratta, 1910; Bottari, 1971; Bottari and Lo Giudice, 1975; Bottari et al., 1975). In particular, the most energetic activity, is located in the northern Graben and along the Calabrian shore of the southern one (Fig. 1), while the microseismic activity is higher along the Sicilian shore (Bottari, 1971) of the southern Graben.

Seismological observations and mechanical considerations regarding the geological and structural patterns of the area lead to the suggestion that seismogenetic structures are most probably found in the crystalline terrains. The sites of the seismic stations were choosen accordingly using the following criteria:

— optimum distribution of the sensors in order to locate hypocentres and to study the focal mechanism of seismic events in the Straits;

— area covered by the network to be commensurate with the energy threshold of the microseismic activity to be examined;

— possibility of placing the sensors in contact with the crystalline formations where the seismic phenomena are claimed to occur.

It was not always possible to fullfil these criteria because: of the marine location of the major epicentrale clusters, the

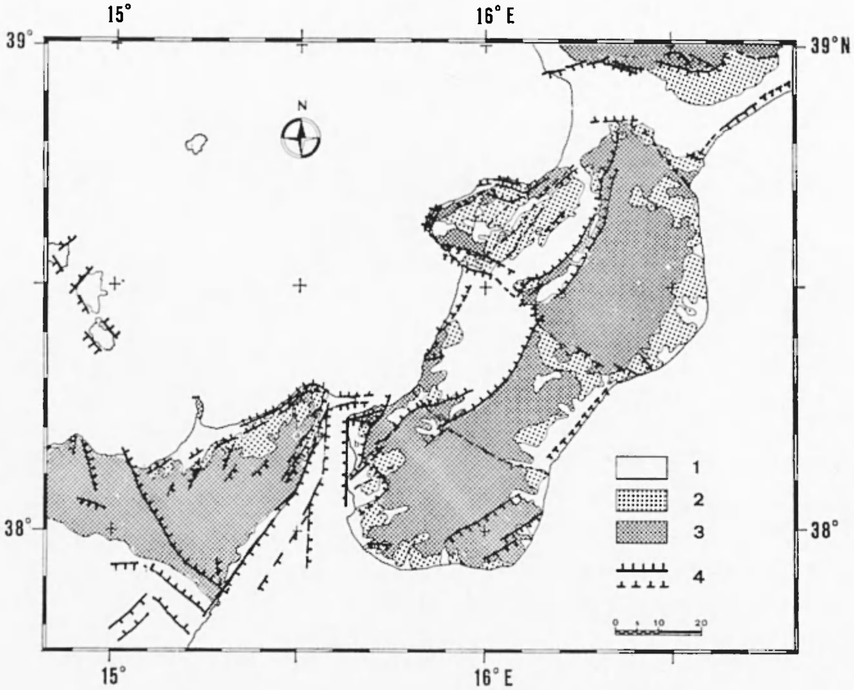

Fig. 1 - The geological map shown in the figure has been obtained through a synthesis of data of various Authors (Ortolani, 1975; Amodio-Morelli et all., 1976; Barbano et all. 1978; Ghisetti and Vezzani, 1978; Selli, 1978).

1) *Middle Pliocene-Recent Formations*: quaternary volcanites, recent and terraced clastic deposits of the Upper Pleistocene; calcarenites, sands, clays and conglomerates.

2) *Tortonian - Infrapliocenic Sediments*: clays and whitish marls with foraminifera (« Trubi »), evaporites, diatomites (« Tripoli »); clays, sandstones and conglomerates transgressive on alloctonous units.

3) *Alloctonous Units*: ercinic metamorphites and their mesozoic and tertiary sedimentary covers.

4) Main Regional Faults.

complex topography of the area and the scattered occurrence of crystalline outcrops along the coast.

The configuration of the network shown in Fig. 2 is, in our opinion, the best solution compatible with the environmental and technical contraints. The network, in fact, has the peripheral stations well sited on the metamorphic formation (PL1, CC1, DM1, SC1, GB1) and the internal ones located either on the Mesozoic sedimentary covers (VN1) or on the postorogenic sedimentary formations, in close contact with the crystalline complex and with better mechanical characteristics (GZ1, MT1, and OR3).

On the Sicilian side of the Straits:

GZ1 Ganzirri)	38° 15' 53" *N*,	15° 36' 31" *E*,	85 m (a.s.l.)
MES (Messina)	38° 11' 54"	15° 33' 18"	45

For these two stations already existing installation were used. The first rests on the Lower Pleistocene marine sandy conglomerates; the second, housed in the Geophysical Institute of the Messina University rests on recent alluvial sands and poorly cemented gravels.

SC1 (Scaletta) 38° 03' 08" N, 15° 27' 51" E, 185 m (a.s.l.) is sited on the most coastal tongue of the crystalline basement, consisting of limestone embedded in a large formation of biotite paragneiss.

VN1 (Mt. Veneretta) 37° 52' 10" N, 15° 15' 51" E, 610 m (a.s.l.) is situated at the extreme edge of the Peloritani Range, on Mesozoic limestone covering the crystalline terrains, at the limit of the latters' overthrust. More exactly, it is sited on top of alternating layers of marly limestone and ammonite bearing marls overlying Upper Lias dolomite and dolomitic limestone. The whole marly-limestone dolomitic sequence, reaching a local thickness of 350 meters, transgressively rests on the epi-metamorphites.

Two other station are planned to be set up in Sicily, on the upper slopes of the Peloritani Range. The firts one near Dinnamare (DN1), will be sited on biotite paragneiss in which an extensive amphibolite body is embedded; the second one will be installed at the extreme northern edge of the range, near Mt. Ciccia (CC1), in area where augengneiss are outcroping.

The stations presently operating in Calabria are:

OR3 (Ortì) 38° 09' 14" N, 15° 41' 22" E, 490 m (a.s.l.) is sited on Tortonian massive conglomerates with interbedded micabearing sands and sandstone transgressively resting on the metamorphic terrains. They show the best mechanical characteristics among the post-orogenic sediments and they appear to be quite resistent to erosion. A local thickness of 10 - 15 m, and a dip of 23 - 33° is inferred for the Tortonian sediments, directly resting on biotite paragneiss.

MT1 (Martino) 38° 01' 05" N, 15° 42' 08" E, 560 m (a.s.l.) rests on poorly stratified mica-bearing sands with interbedded clayey silts. These Tortonian units are heteropic and younger than the sediments described for the station OR3 (Ortì). They show moderate resistance to erosion and reasonably good mechanical characteristics. At the site of the station they rest on limestone and sandstone silty clays of Middle to Lower Miocene age. The total thickness of the Miocene sediments, covering the biotite schists of the crystalline basement is ranging there between 20 and 40 m.

The other stations are planed to be set up in Calabria on crystalline terrains. The first one will be installed near Palmi (PL1) in a zone which is mainly characterized by granitic and quarzo-dioritic rocks. The second one, in the area of Gambarie, which is characterized by frequent outcrops of phyllite, biotite gneiss, and augengneiss.

STATION EQUIPMENT

The network presently consists of six peripheral stations connected by UHF radio to the central station sited in the Geophysical Institute of Messina University.

The peculiar configuration of the Straits, together with the conditions imposed by a suitable choise of sites, sometimes created problems for the realization of telemetric comunication.

In Fig. 2 and Table 1 some of the basic features of the sites and their equipment have been set out.

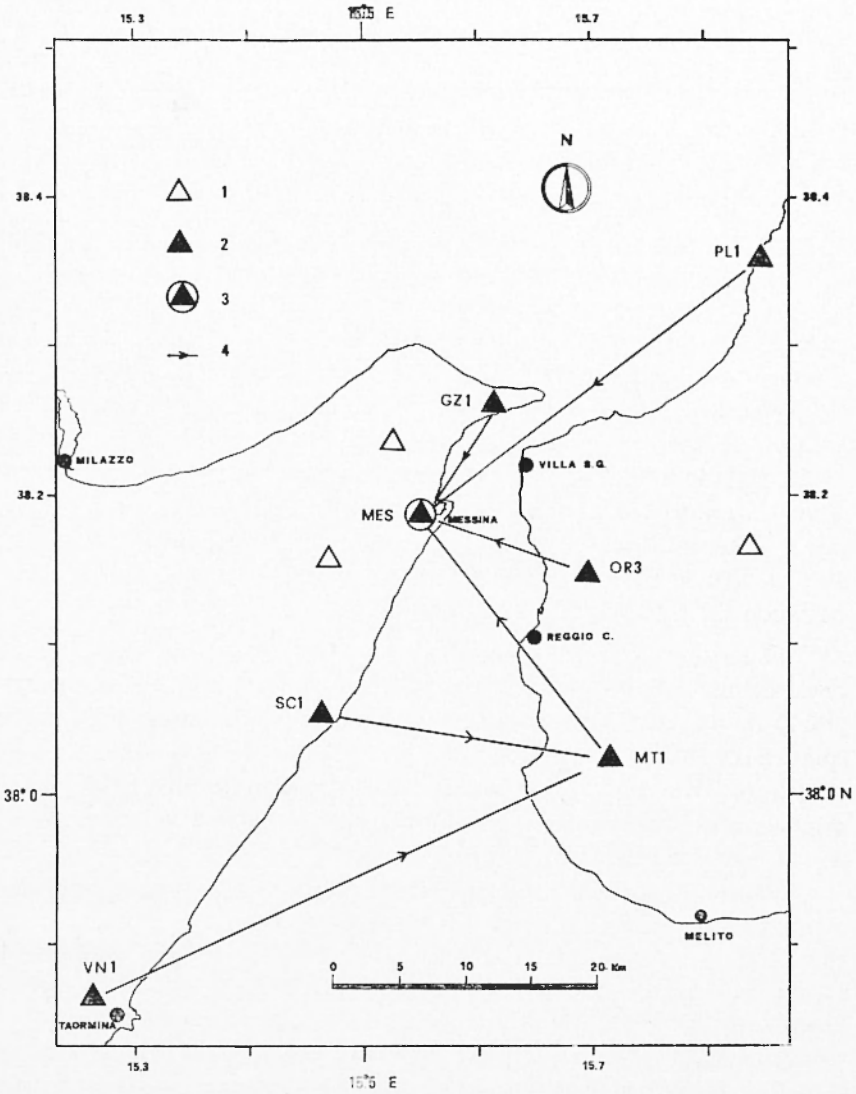

Fig. 2 - Picture of the Messina Strait Seismic Network (M S N): 1) Planned stations; 2) Operating stations; 3) Central station; 4) Radio links.

TABLE 1

Station Code	Seismometer Type	Component	System
GZ1	Geotech S13	Z	Lennartz, M.F., Multiplex
	Geotech S13	N-S	
	Geotech S13	E-W	
MES	MK III A	Z	Racal, M.F., single channel
SCI	MK III A	Z	Racal, M.F., single channel
VN1	MK III A	Z	Racal, M.F., single channel
PL1	MK III A	Z	Racal, M.F., single channel
OR3	MK III A	Z	Racal, M.F., single channel
MT1	Geotech S13	Z	Lennartz, M.F., Multiplex

In order to evaluate the magnitude of the less energetic shocks ($M \leq 2.5$) the duration-magnitude equation (Fig. 3):

$$D = 0.65\, M^{3.752}$$

has been characterized for the station at Ortì (OR3), using approximately fifty observations of events of known magnitude ranging between 1.8 and 4.3.

Seismic signals are recorded on a magnetic-tape (Geostore, Racal), and contemporarly monitored on paper ink-recorders, for an early analysis of the local shocks.

Lennartz equipments, in terms of actual shifting of the ground, vary from station to station — from a minimum of 15,000 to a maximum of 40,000 — according to the geological characteristics of the terrains, and distance from the sea and/or urban areas.

Retrieval of the recorded signals is effected by means of a Store-14 recorder-player manufactured by Racal, whose output, after any necessary filtering, is fed into a Siemens Oscillomink ink-jet recorder.

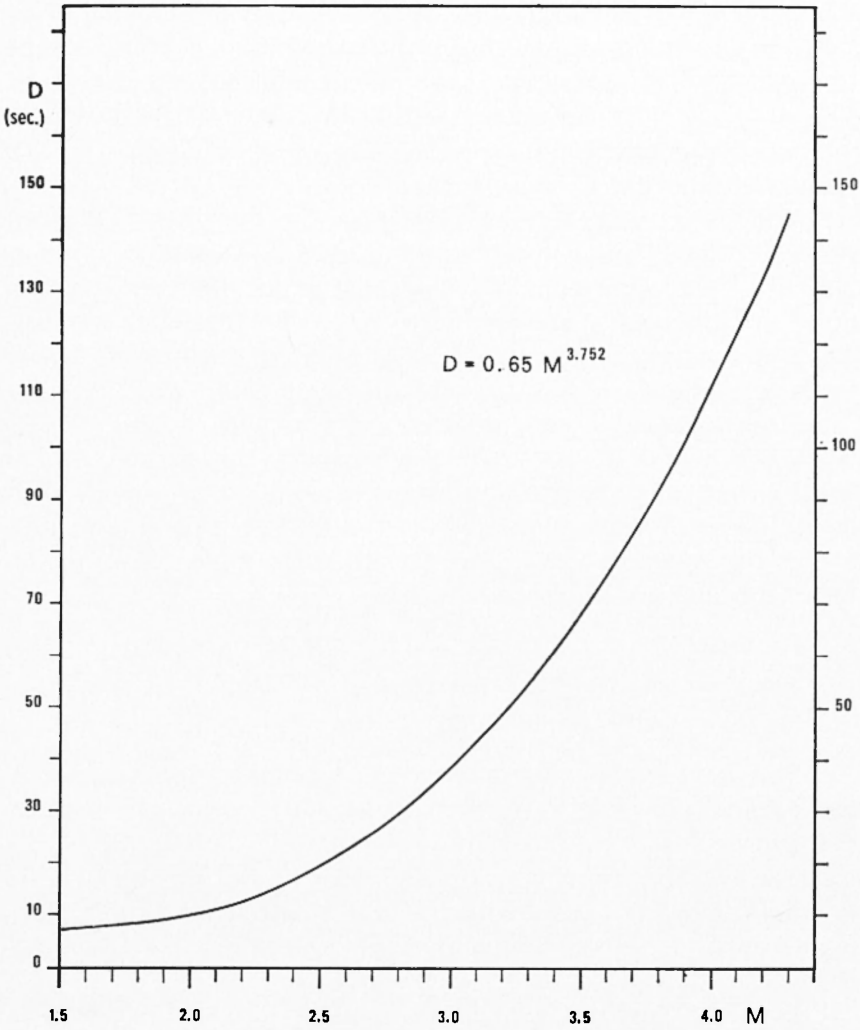

Figura 3

The continuity of the power supply at the central station is guaranteed by a Corel emergency static group which is capable of supplying with electricity even the complex and varied instruments of the Geophysical Institute of Messina's observation station.

The time-signal, generated by a radio-corrected (HBG) Philippe Patek clock, synchronizes the encoding clock inside the Geostore and produces the time marks on the ink recorders. The paper in these recorders runs at the speed of 60 mm/min. and they have an operating autonomy of ~ 26 hours with a space between the lines of 4 mm.

The power for the low-comsumption peripheral stations (Racal) comes from unrechargeable 1000 Ah batteries which have a life of approximately one year, while the stations with three components (Lennartz) are run off especially installed main electricity. In this last case a suitable recharging device feeds a group of stationary hermetically-sealed batteries.

Their particular orographical position does not allow stations SC1 and VN1 to trasmit directly to the central station (MES), and it is therefore necessary to send their signals first to an intermediary station in Calabria (MT1) where an interface allows transmission to Messina'station on the same carrier which the local station (MT1) uses.

TRAVEL TIMES ANALYSIS

The analysis of the data refers to observations made by the Straits network, integrated by records of other near-by stations.

The seismic event which took place in the Spring of 1978 in the Gulf of Patti resulted in several hundred readings includings records from neighbouring Aeolian Islands and Etna networks.

A further modest contribution to the overall picture was brougth by records of several seismic events originating in Calabria. The epicentral distances cover the interval $0.1 \leqq \Delta^{\circ} \leqq 2.0$ although the highest density of data refers to the interval $0.2 \leqq \Delta^{\circ} \leq 1.0$ approx.

Lacking orientative seismological elements, analysis was generally limited to the first returns when identifying the various phases present on the seismograms. Data can be considered accurate both because of the interval of epicentral distances considered, and because of the characteristics of the instruments in the short period stations. The records usually have very clear beginnings, generally of the « impetus » type, with only slight (± 0.2 sec) uncertainty in the readings.

The epicentral travel-time couples (Δ, T) that can be deduced from the epicentres determined by the National Geophysical Institute (I.N.G.) for events of magnitude $M \geq 3.0$, based on a 2-layered crustal model, which for brevity will be cited as MAA (h_1 = 25 Km, v_1 = 5.3 Km/sec; h_2 = 27 Km, v_2 = 6.6 Km/sec).

This model, although not compatible with the results of seismic research and deep seismic exploration in the area under examination (Cassinis et al., 1969; Bottari and Girlanda, 1974; Giese and Morelli, 1975; al.) does not appreciably alter the attributed epicentres due to favorable distribution of the stations around the focal area.

The data population has been divided into two groups, respectively for focal depths of 10 ± 5 Km (h') and 20± 5 Km (h'') as determined by the I.N.G.

The Δ, T couples for the two groups allow the identification in both cases of two distinct alignments (Figs. 4, 5). The second branch of these two lines can be interpreted as the travel-time of a refracted phase.

The crustal model MAA, although incompatible with the studied zone, contrains the origin time and therefore the travel-times, but not the slope of the diagram of the travel-times. It has been accordingly possible to characterize the velocities of the longitudinal waves along several refracting horizons. The first travel-time branch of the first group (h') is initially taken as relative to the originating Pg in an environment with a velocity of 5.8 Km/sec.

The second branch refers to a refracted phase along the horizon with a velocity of 6.49 Km/sec. In the second group a refracted phase with a velocity of 6.41 Km/sec, are evident. The remarkable clustering of data regarding the first phase (Fig. 5) of the group h'' is easily represented by means of a rectilinear travel-time curve valid for the interval $0.2 \leq \Delta^\circ \leq 1.0$.

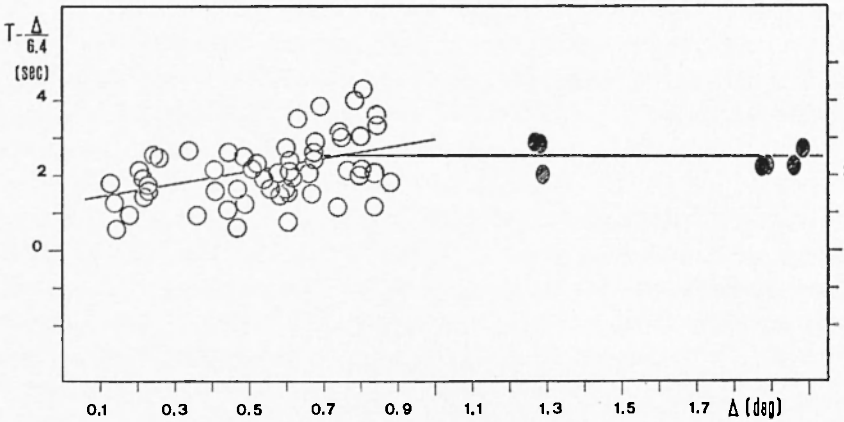

Fig. 4 -Reduced travel-time diagram for the hypocentral depth: $h = 10 \pm 5$ km.

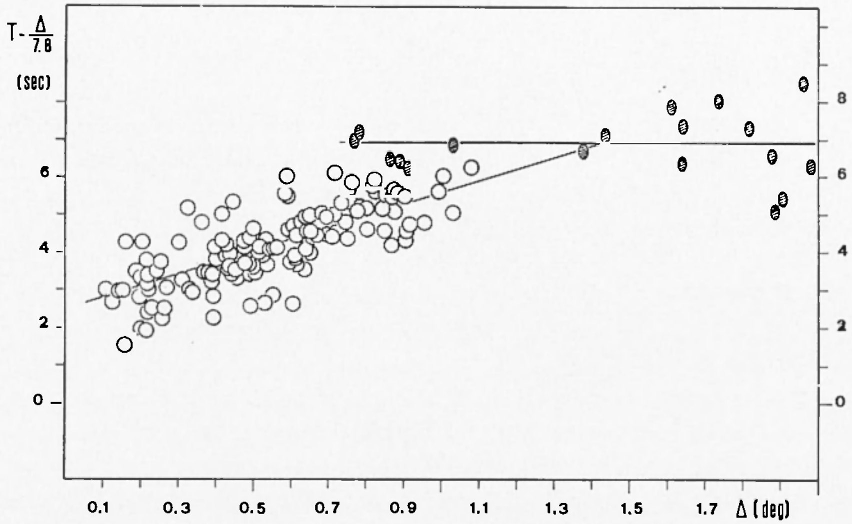

Fig. 5 - Reduced travel-time diagram for the hypocentral depth: $h = 20 \pm 5$.

Using the two groups of observed data and the epicentral distances- travel times equation, it appears possible to suggest a crustal model (MSM) having at least two seismologically characterized layers and a Moho velocity of 7.8 Km/sec, but incomplete as far as the characterization of its superficial part is concerned.

This gap is filled up by introducing into the model two layers ($h_, = 2$ Km and $h_2 = 4$ Km; $v_1 = 3.0$ Km/sec and $v_2 = 4.5$ Km/sec), compatible with the results of deep refraction seismic profiles carried out at the edges of the area (Cassinis et al., 1969; Scarascia and Colombi, 1971; Morelli et al., 1975).

The first target of this analysis is to evaluate the hypocentral depth for the group h', allowing the model MAA to be replaced by a three-layered model defined thus: $h_1 = 2$ Km, $h_2 = 4$ Km; $v_1 = 3.0$ Km/sec, $v_2 = 4.5$ Km/sec and $v_3 = 5.8$ Km/sec.

The difference between the intercept times of the direct phase ($T_i = 1.72$ sec) and the straight line:

$$T = (1.26 \pm 0.30) + (19.032 \pm 0.536)\,\Delta \qquad [1]$$

that most closely agrees with the data observed in the epicentral interval $0.13 \leq \Delta^\circ \leq 0.88$ has been calculated. This difference ($\Delta t_i = 0.46$ sec) is mostly approaced by that obtained ($\Delta t_i = 1.59 - 1.13 = 0.46$ sec), when in the model MSM the focus is placed at a depth of 6.2 Km. The second intercept time (1.13 sec) refers to the travel-time of the refracted waves:

$$T = 1.13 + 19.171\,\Delta, \qquad v = 5.8 \text{ Km} \cdot \text{sec}^{-1}. \qquad [2]$$

It is therefore assumed 6.2 Km as focal depth for the first data group in the model MSM.

It is observed that seismic source of the analized phase is located in the upper most portion of the 5.8 Km/sec layer, and that the observed travel times are matched by the straigth line of equation [1]. It is consequently assumed a velocity of 5.8 Km/sec for the longitudinal waves along the 6 Km depth wave-refractor.

In the preliminary hypothesis, assuming the existence of layers of uniform velocity, a depth h_3 can be evaluated from the difference between the second phase intercept times (group h') according to the equation:

$$T = (3.86 \pm 1.02) + (17.136 \pm 0.584)\,\Delta \qquad [3]$$

and the first phase of equation [1]. This difference, $\Delta T = 2.6$ sec, is confirmed in the model MSM as the difference between the intercept times of two refracted phases ($v_3 = 5.8$ and $v_4 = 6.49$ Km/sec) described by the equations:

$$T = 1.13 + 19.171\,\Delta$$

$$T = 3.73 + 17.134\,\Delta \qquad [4]$$

when $h_3 = 16.24$ Km, is the thickness of the third layer.

As already shown, the first phase of the second group closely fit a straight line (Fig. 5) according to the equation

$$T = (2.51 \pm 0.11) + (17.337 \pm 0.212)\,\Delta\ , \ v = 6.41 \text{ Km/sec} \qquad [5]$$

This is in contrast with the typical trend of the travel times of a direct phase originating in a layer either of uniform or normally increasing velocity, at a relevant depth ($h'' = 20 \pm 5$ Km).

This feature can be related to a mechanism involving the canalization of seismic energy which originate within a layer showing a velocity flexion. This hypothesis is supported by seismological soundings carried out in neighbouring areas to the

Straits of Messina (Cassinis et al., 1969; Scarascia and Colombi, 1971; Morelli et al., 1975; etc.). Such a canalization can be attributed to a medium having his lower limit at a depth of approximately 22 Km (6 + 16.25 Km, $v = 6.49$ Km/sec) and an upper boundary consisting of that horizon along which the refracted phase, by equation [5], is propagated at a velocity of 6.41 Km/sec.

The focal depth of the second group (h'') can be evaluated from the model MSM, considering the difference $\Delta T_i = 1.89$ sec for the two longitudinal waves which respectively originate at depths of $h'' = 20$ Km and $h' = 10$ Km, given $\Delta^o = 0$. This difference is verified in a layer showing a velocity of 5.8 Km/sec for a difference in the focal level of 10.94 Km. The focal depth for the second group can therefore be located in the model MSM at a depth of 17.14 Km (6.2 + 10.94 Km).

The difference between the two intercept times respectively obtained from the straight line of equation [5], where $T = 2.51$ sec, and from the straight line which most closely fit the second branch of group h'':

$$T = (5.7 \pm 0.29) + (14.226 \pm 0.270)\,\Delta\ ,\ v = 7.82 \text{ Km/sec} \qquad [6]$$

is $\Delta Ti = 3.46$ sec. This difference is verified in the model MSM for a focal depth of 17.14 Km when $h_4 = 13.5$ Km. In this case, the two phases refracted by horizons showing velocities of 6.41 Km/sec and 7.82 Km/sec, are respectively fitted by the equations

$$T = 2.79 + 17.348\,\Delta\ ,\ v = 6.41 \text{ Km/sec}$$

$$T = 6.23 + 14.220\,\Delta\ ,\ v = 7.82 \text{ Km/sec} \qquad [7]$$

The analyzed data are on the whole compatible with a four-layered crustal model, as schematically drawn in Fig. 6.

The values attributed to the velocity and thickness of the intermediate crustal layers, as well as the comprehensive thickness crust (35 ÷ 36 Km), can easily fit into the general framework resulting from deep seismic soundings. In particular, the two crustal sections corresponding to the area around Capo Calavà in Sicily, and to the edge of the Aeolian Archipelago (points B and A in Fig. 7) in the Southern Tyrrhenian Sea, seem to suggest a total crustal thickness of 30 ÷ 35 Km for the source zone of most of the seismic events considered. The same range of values for the depth of Mohorovicic's discontinuity is reported by Morelli et al. (1975) for the area of the Straits.

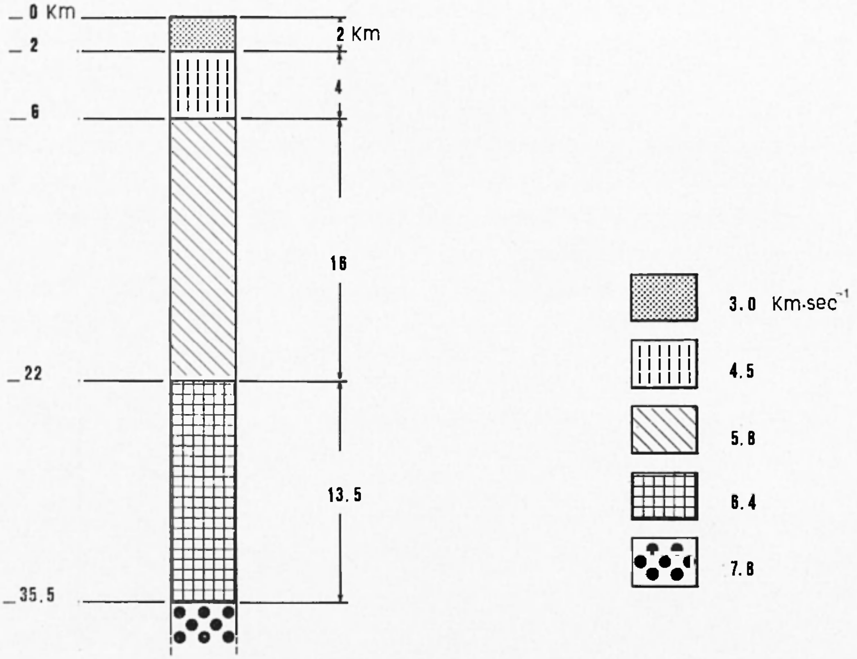

Fig. 6 - Crustal section model for the Messina Straits Area (M S M).

It is furthermore to be stressed that a nearly horizontal pattern of the Mohorovicic discontinuity can be assumed according to the trend of the Bouguer's iso-anomalies (Cassano et al., 1978) as shown in the area of propagation of seismic rays emerging at the statons of the Straits Network (Fig. 7).

Explosions in the Tyrrhenian and Ionian Seas, planned to be carried out on July 1979, are believed to be able and supply an useful quantitative check to the crustal model.

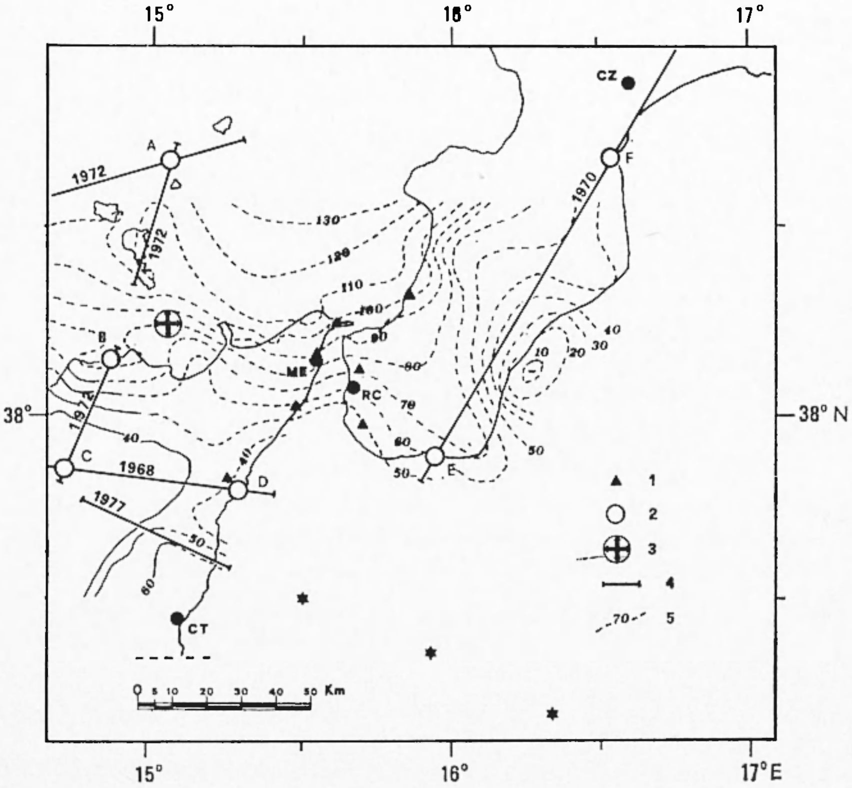

Fig. 7 - Gravimetric map of the Straits Messina area: 1) Seismic stations; 2) Cross points of seismic surveys profiles; 3) Focal zone of the seismic crisis in Gulf of Patti, 1978 (Barbano et al., 1979); 4) Traces of deep seismic surveys profiles (Giese and Morelli ,1975; Morelli et al., 1975); 5) Bouguer's iso-anomalies after Cassano et al. (1978). The asterisks indicate the shot points of the 1977 seismic survey (Sharp et al.).

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