PROPOSALS FOR A MORE THROUGH EVALUATION OF THE SEISMIC RISK IN ITALY

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S U M M A R Y

The evaluation of the seismic risk must be faced by amplifyng our knowledge through the help of following disciplines: Seismology, Geology, Geophysics, Volcanology, Geotechnic, Science and Technique of the Constructions. In Italy, an eminently seismic region, the problem of the risk is very actual; as an indicative scope, a statistics enquiry of the seismic events registrered during the last twenty years has been undertaken. After a rapid glance at the earthquakes genesis (volcanology & tectonic) on the base of the fundamental lines of geology in Italy, a preliminary division in 23 geoseismic zones has been arranged.

We propose, as work of an extreme practical utility, the compilation of the "Geoseismic Map of Italy", which could be the technical basic instrument for the instructive integrations of the future new law".

1) INTRODUCTION: The great world and national seismic events lead us to consider more and more the seismic risk which interests our country and in particular the constructive work of public utility which, further to progress assume characteristics more and more arduous.

Until now, in Italy, the caution for seismic risks were based only on statistic and seismologic evaluations and on studies deriving from science and technique of the Constructions. Thus, according to our opinion, the problem is only partially faced, failing the explanatory part of the phenomenon which frames it in the determining causes and delimits it in sites and mean through which it spreads, developping its effects.

Such problem necessarily implicates, for both, scientific-technical and applicated part, other disciplines such as geology, geophysics, geotechnic, volcanology etc. In such a manner one has a careful discernment of the areas, an anticipated selection of the same based on sicentific evaluations with further reduction of the risk and useles caution excesses, financially heavy and bearer of unecessary limitations.

This problem is very present in our country insofar that a program has been planned for industrial plants and manufacturers in the under-developped regions which partly coincide with the most seismic zones in Italy.

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2) GEOSEISMIC ACTIVITY: Italy is a very seismic region. Its geographical position and complicated geology render greatly different its seismic characteristics from region to region. In order to give an ample view of intensity, frequency and diffusion of this phenomenon in Italy, we deemed advisable to take off final seismic bulletins issued by the National Geophysical Institute of Rome, and partially to elaborate the data of the last 20 years (1952-1971).

Although being in possession of results taken from very interesting literatures, catalogues and statistics of different periods issued by Mercalli, Baratta, Cavasino, Caloi, De Panfilis, Giorgetti-Iaccarino, Caputo-Postpischl, etc. we preferred to take the last twenty years for these data, with Mercalli intensity more and equal to the 2nd degree, due to the improved observation instruments, the national and international advanced techniques and organizations can give a more real picture of it.

The intensity of the events expressed in Mercalli degrees is the one of the relative epicenters and, owing to the scope of the report, not all data of geophysical interest have been considered (See table A, B, and Fig. 1).

The last twenty years have registered in the whole n° 4,443 earthquakes with an average of about 220 per year; some authors indicate the annual average of earthquakes in Italy around n° 400; in the present work neither the events illustrated in bulletins as "traces" nor those with an at least regionally non definable epicenter have been considered.

The regions which during the last twenty years have been subject to more than 500 earthquakes (Tab. A), are in decreasing order; Campania, Abruzzi, Sicily and Umbria. These four regions constitute a group completely detached from the average, represented by regions which have had from 370 to 70 earthquakes; these are: Latium, Eolie Isles, Emilia, Tuscany, Calabria, Friuli, Marches, Liguria and Piedmont. It follows a group of five regions in which seismic activity resulted very low (less than 70): Pulia, Lombardy, Venetian Region, Trentino and Basilicata; Sardinia on the other hand can be considered almost aseismic zone.

The earthquake distribution during the past twenty years is different. For instance the regions with greatest seismic activity, Latium, Abruzzo, Sicily and Umbria, have the earthquakes, in average, uniformly distributed during these years, while Campania, although having the most elevated number of earthquakes, shows the greatest discontinuity in the time.

The percentages of earthquakes number, suitable interpolated, are represented in the diagram (Fig. 1) which shows an exponential curve according to the equation:

$$y = 434,6^{-0,92\,x} \quad \text{and} \quad \log_{10} y = 2,63 - 0,4\,x$$

The diagram clearly shows that, the 88,5% is formed by events inferior or equal to the 4th degree Mercalli scale. From said intensity value, the percentages decrease very rapidly until reaching 1% for intensity 6 degree and 7 degree, and values inferior to 0.5% for higher intensity.

That the earthquakes which are defined "instrumental" have not been calculated, as well as all earthquakes which data did not allow a sure location of the epicenter. Now, as it is shown by the diagram (Fig. 1) the percentage of the earthquakes equal and lower to the 4th degree Mercalli scale can be elevated around 95% and over.

Therefore, according to our opinion, for the qualification of seismicity of a zone it is necessary and more practical to know the "light" or "sensitive" (3°); "very light" (2°) and "instrumental" (1°) earthquakes which collectively in general identify themselves with "microseismic". Therefore we deem essential, for the seismological enquiry, to dispose of modern and sensitive instruments and an observation network adequated distributed and in proper meshes.

3) NATURE OF THE SEISMIC EVENTS AND INFLUENCE OF THE GEODYNAMIC FACTORS: From the genetic point of view out, earthquakes can be divided in following categories: plutonic, volcanic and tectonic. The earthquakes connected to the magmatic activity, (plutonic and volcanic) as the results reached in the geophysical geochemical volcanologic geologic field show, that are strictly connected also to the volcanologic processes. In particular the genesis of magmas has to be considered, which presently shows two essential stocks: granite and basalt magmas. The first are generated in the crust level and the latter in the upper mantle.

It has not to be forgotten that some magmatic groups, such as the andesitic ones, generate at the level of Benioff's surfaces delineated by distribution of earthquakes deeper and deeper along the subduction surface. Therefore in Italy, where we find magmatic provinces of different origin, we must pay attention to refounding zones and relative production of magma.

To provinces of certain anatectic genesis (dissolving in the crust of sediments with formations of granite magmas) other are opposed so that it is possible to prospect a subcrustal origin. Therefore, in zones close to the volcanism and paleo-volcanism of Etna it is possible that deep earthquakes exist connected also with particular "wedge-shaped" direction of the surface "type Benioff". These earthquakes would allow to enbody the Eolie Isles magmatism in those of the arc-insular type, and may be in connection with the migration of the African plate below Sicily.

In other volcanic zones, such as Central Italy northern to the tectonic Ancona-Anzio line (or Ancona-Posta) it is clear that earthquakes will be of a less deep origin insofar that these sectors (Tolfa-Ceriti; Monte Amiata-Cimini; Rocca Strada; Elba) are referred to anatectic magmas and therefore of crustal genesis. To conclude, in these zones it is possible that the effects of non-deep focus earthquakes and therefore with energy localized on superficial sectors with modest extension where the relative diastrophism can cause, due to the magmatic event, destruction phenomena with a more elevated intensity.

The "tectonic" earthquakes are the effects of the stresses and the tension to which the rock masses of the earth crust are subject in relation to the orogenetic movements or to the settlement of masses placed in unstable equilibrium by the above movements. The reason of seismicity of a zone must be interpreted according to the regional structures which include not only the faults but every phenomena: fold, nappes, overthrust, etc. Only in regional terms it is suitable to consider the relations between seismicity and tectonic without wanting to reconstruct faults more or less hypothetic on the basis of seismologic data.

As shown in Fig. 2 the tectonic trends which can be found in surfaces, can be framed as orientation with the major axes of isoseists surveyed further to the most important earthquakes of the Tuscan-Romagnan Apennine. The accurated study of the isoseists, based on carefully selected data has always pointed out the relation between regional tectonic and the seismic events. Obviously, the relation between epicenters and local surface structures is not always determining and the relative tectonics suitably studied, must always be judged in the regional increase with deepness and displace following the same trends. In Italy there are still many active tensions in both, sediments covering and sialic crust over Conrad's discontinuity. Said residual forces reveal in principle in coincidence of particular tectonic structures among which the most frequent are:

- a) Faults and superficial or buried fault systems forming active displacements or maintaining residual tensions.

- b) Overthrust due to flowing and sliding or rock masses connected to systems of faults in prevalence reversed and folds more or less broken, which generally take place at the edges of tectonic depressions.

- c) Settlement of subsident masses: prevalence of vertical forces along the principal axes of the subsiding basin.

- d) Secondary displacements and consequent to a paleotectonic: trends of the second phase are normal at the former tectonic, with developments of passed and transformed faults generated by forces which break the relatively stable equilibrium reached after the old tectonic.

- e) Contacts between petrophysically heterogenic masses (tectonic contacts): in particular among gravity sliding or allochthonous covers and autochthonous or semi-autochthonous masses. The different physical and mechanical features of the rock-masses give rise to particular tectonic phenomena deriving principally by forces of gravity an shear.

- f) Nappes of plastic covers differently transferred with consequent deep landslides, slidings, differentiated settling etc., especially in sectors with many and large litoid inclusions (olistolites). The epicenters, generally do not find correlation with the scarce and sometimes false structures shown in surfaces.
The allochthonous mass, due to its own petrophysic features, functions also as absorbing mass of seismic energy.

- g) Overthrusting of extended rigid masses on the allochthonous with consequent reversed fault systems with very inclined planes and with phenomena similar to those described in paragraph b).

- h) Falls, crustal underthrusting and shortenings with consequent colapsing of superficial and subsuperficial formations (graben and different tectonic depressions). The stresses agents are in prevalence gravitational and show complications and changes connected to the causes of the phenomenon.

- i) Settlement of large rigid formations (klippen) etc., aiming to regain the stable equilibrium.

The consideration regarding the tectonic structures stated above and their influence on the geodynamic factors in the seismic events of tectonic nature, must be helped by observations on the attitude, on the petrophysic characteristics of the geolitologic masses concerned (such as, the elastic dynamic module is of all function of the rock den

sity and velocity of waves propagation) and on the lithofacies and their hydrologic situations (such as sands in connection with water reservoirs due to vibrations, can be subject to a sudden variation of the fluid contents, breaking their equilibrium and transforming in "mobile sands"; this fact, said "soil liquefation" may cause sinking of constructions and slipping of rocks standing above.).

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In order to face the problem of the seismotectonic interpretation, especially in our country where geology is various and complicated, it would be useful to undertake a division of zones with tectogenetic characteristics similar, or at least comparable among them. Besides a limited extension of many geologic zones suggests that at a first degree division, follow divisions and, may be, subdivisions of inferior degree (regions, compartments, zones, sectors etc.).

Due to the vastness and complication of the argument, this is not the place to describe possible seismo-geologic regions, however, on the basis of the recent literature we give a schematic preliminary subdivision (see sketch map - Fig. 3).

a) Helvetic-Delfinese zone: Crystalline groups and Mesozoic-Tertiary covers.
b) Piemontese Zone: Crystalline Pretriassic and Precarboniferous nucleous sometimes with ophiolites.
c) Southern Alps Basement: Plutonites, Permian porphiry and Triassic sediments.
d) Australpine Zone: Igneous rocks with Mesozoic sedimentary cover.
e) Bellunese-Giulio Area: Pelagic Mesozoic sediments and flysch.
f) Brianza Zone: Mesozoic-Tertiary sequence and Permo-Carboniferous sediments.
g) Liguride Group: Very large nappes including many litofacies.
h) New autochthonous Apennine Flysch of Monferrato: Monferrato and Ligurian-Emilian Apennine edge Flysch.
i) Po-Venetian Plane: Pelitic neogenetic-quaternary (post-orogene) sediments.
l) Tuscan-Romagnan Apennine: Carbonic Mesozoic substratum with allochthonous cover.
m) Umbrian-Marchisan-Abruzzese Apennine: Marl-calcareous formations of the Mesozoic.
n) Apennine Hinterland: Area with post orogene sediments and allochthonous covers.

o) Zone of Latium-Campania and Sicilian volcanism: Pyroclastic and extrusive rocks.
p) Romagnan-Marchisan-Abruzzese Foreland: Post-orogene, principally pelitic sediments.
q) Garganic-Pugliese-Iblean Foreland: Marine principally carbonic sediments.
r) Bradanic Through: Sediments essentially pelitic (post-orogene).
s) Calabrian-Sicilian Schisto-Crystalline Group: Igneous and metamorphic formations very altered.
t) Nappes of North-Western Sicily: Carbonic, Mesozoic-Eocenic Masses.
u) South-Western Sicily and Nisseno basin: Post-orogenic sediments and allochthonous covers.
v) Eolie Isle Archipelago: Old and recent Volcanism.
x) Sardinian-Corsican Crystalline Group: Igneous rocks eminently intrusive.
y) Campidano Graben: Sedimentary formations eminently carbonatic.
z) Sardinia Western Zone: Volcanic rocks.

Sea Zone - Continental platform and slope: The large coast development expose Italy to the possibility of "Tsunamis". The strong and rapid movements of the sea-bottom may reflect back on the sea waters giving rise to this phenomenon.

The study of "Tsunamis" should be faced also by hydrodynamic observations connected to the morphology of the sea-bottom especially in correspondence of the Continental platform and slope.

4) PRESENT PROTECTIVE SITUATION ON THE TECHNICAL-JURIDICAL PLAN: The first valid measures to face the construction problem in seismic areas go back to 1908 further to the earthquake of Messina (fixing of the foundations of constructions in rocks in site, limitation of the height of works and finally the adoption of regulating plans to establish distances and detachments to be respected). Those essential principles constituted the rules of the first Italian Seismic Law n. 2105 dated 11/22/1937. Further amplifying and improvements gave rise to the compilation of a law n. 1684 dated 11/25/1962, still in force, which is based only on statical criterium. The regulation is applicated to the ordinary building art, and, only if not differently disposed by other laws, interests special constructions. The seismic locations, according to intensity, are classified in 1st and 2nd category, and are delimited, according to the boundaries of Communes listed in the law.

Fig. 4 is the planimetric construction of the Communes stated in the Law and in different following Decrees.

At Parliament, a project of Law submitted by the present Ministry of Public Works concerning "Measures for constructions with particu-

lar prescriptions for seismic zones" is in course of approval. This law has considerable innovations for both, introduction of the dynamic computation of the structures, on the basis of the velocity spectra of the rocks to the different seismic accelerations, and for the reclassification and more detailed selection of the zones, but above all, for the suppleness of the rules, which allows to be integrated with further Decrees of Law in accordance with the research progress.

5) GEOSEISMIC MAP: The elaboration of all data ineherent to the geoseismic problem and deriving from the collaboration of seismologists, geotectonists, geophysicians, volcanologists, geotechnicians and specialists in Science and Tecnique of constructions, find its realization in the "Geoseismic Map of Italy".

With a rapid and accessible consultation this work will afford the tecnician the possibility to evaluate the seismologic situation in the regional and local picture, in the whole national territory. Particularly useful will also be for the realization of constructions such as: roads, railways, hight tension lines, which, due to their great area development, interest more zones with different seismic characteristics and with various antiseismic rules.

For the compilation of the map (preferably in scale 1:200,000 ÷ 500,000) with specific illustrative notes, it would be advantageous to use the quantity of scientific and technical data which have been published during the last 20 years by industry and by the research corporations. Among this material, we recall:

- a) All geoseismic data of the events suitably pointed out by history, reports and instrumental registrations. There are different files, catalogues, statistics and re-elaborations of this material which, nodoubt, forms the principal patrimony as regards the study concerned;
- b) The official geological Map of Italy, although has been drawn in scale 1:100,000, the Geological Service disposes of the whole documentation and original surveys effected in scale 25,000. The two thirds of the whole national territory has been surveyed during the last ten years, with the participation of all Italian Universities and the coordination of the Italian Geological Service (Ministry of Industry and Trade). This huge work has been performed on the basis of new stratigraphic discoveries and according to the new tectonic schemes deriving from more advanced studies.

  The whole territory in Calabria, further to a special Law of the "Cassa per il Mezzogiorno", has been geologically surveyed during the period 1959-1963 and published in scale 1:25,000;

- c) All the numerous geophysical studies performed by the different companies having obtained the grant and the concession for hydrocarbons researches. Great part of the territory has been explored with a gravimetrical, reflexion and refraction seismic system. Prospectings give indicative data as regards the structural adjustments buried sometimes at a depth of 6,000 meters and over. The "off-shore" hydrocarbons research has caused the realization by AGIP (1964-1968) of the reflexion seismic with a multiple covering and "aquapulse" power of the whole eastern sea band of the peninsula, part of the western band and isle to the bathymetric curve 200, for a total of about 80,000 sq. Km. At present along the Tyrrhenian and ionian coasts prospectings are in course for the thickening of the previous ones and to extend recognition to the whole sea bottom with bathymetry lower than 1,000 meters.

  Reflexions, although concerning the carbonatic series, (first 3-4,000 mt. thickness of the sea-bottom) indirectly illuminate as regards the structural adjustment set below, thus facilitating the interpretation of tectonic of the coast part and that of the limitroph Continent.

  The gravimetric prospection covers, though with different links, the whole national territory. Recently the "Italian Geodetic Commission" decided to collect and suitably connect the different prospections, elaborating a "National Gravimetric Map" in scale 1:250,000;
- d) The stratigraphic and researches wells very useful, above all, for the interpretation of geology and geophysics. Leaving out the many thousands cultivation and development drillings for hydrocarbons research, the wells drilled in whole Italy, until July 1972 amount, according to official data, are to n. 647 with a depth of 1,200 ÷ 2,400 mt., and n. 417 with a depth of more than 2,400 mt. Among these last ones many have passed the 4,000 mt. and of all the drillings the Ministry of Industry and Trade is the trustee of the stratigraphic logs and special prospections performed in the wells;
- e) The recent studies and those in course concerning sea and coast geology; in fact with the most advanced technologies and under the most different scientific aspects oceanographic campaigns are effected, aiming to the survey of the whole national continental slope;
- f) The altimeters data collected by the Ministry of Public Works, by the State Railways, by the Military Geographical Institute, by the Register of Land Survey, and by the National Committee of Research, which can be useful to signal subsidences, vertical movements and present tectonic movements: while for horizontal movements of the

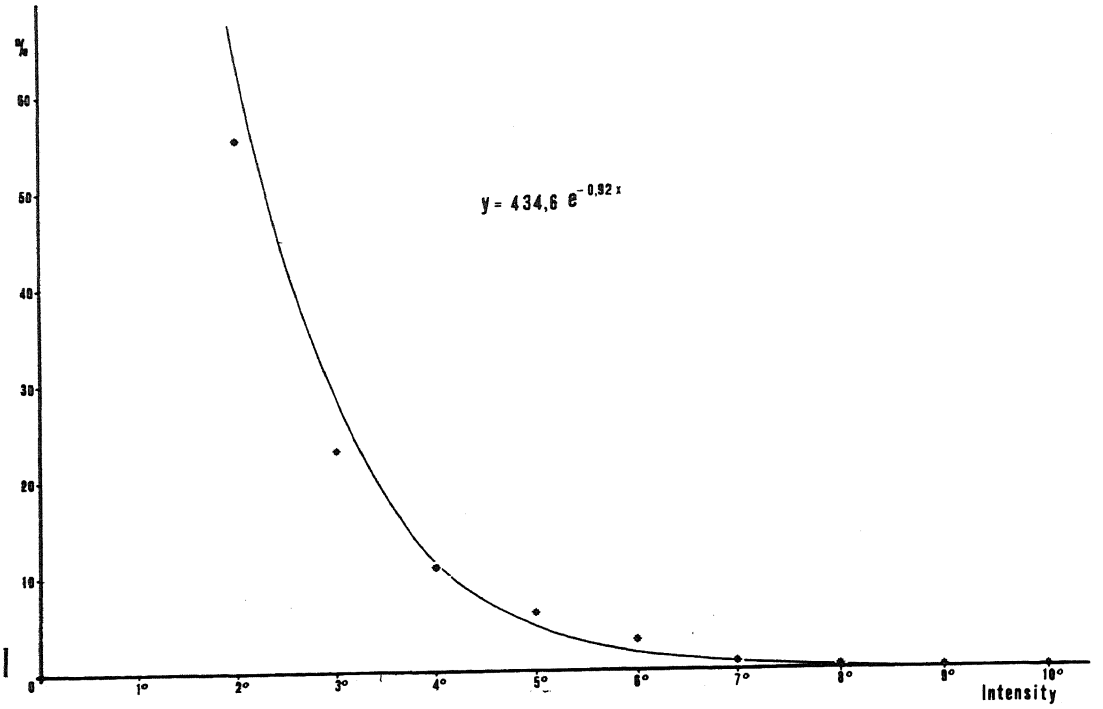

fig. I

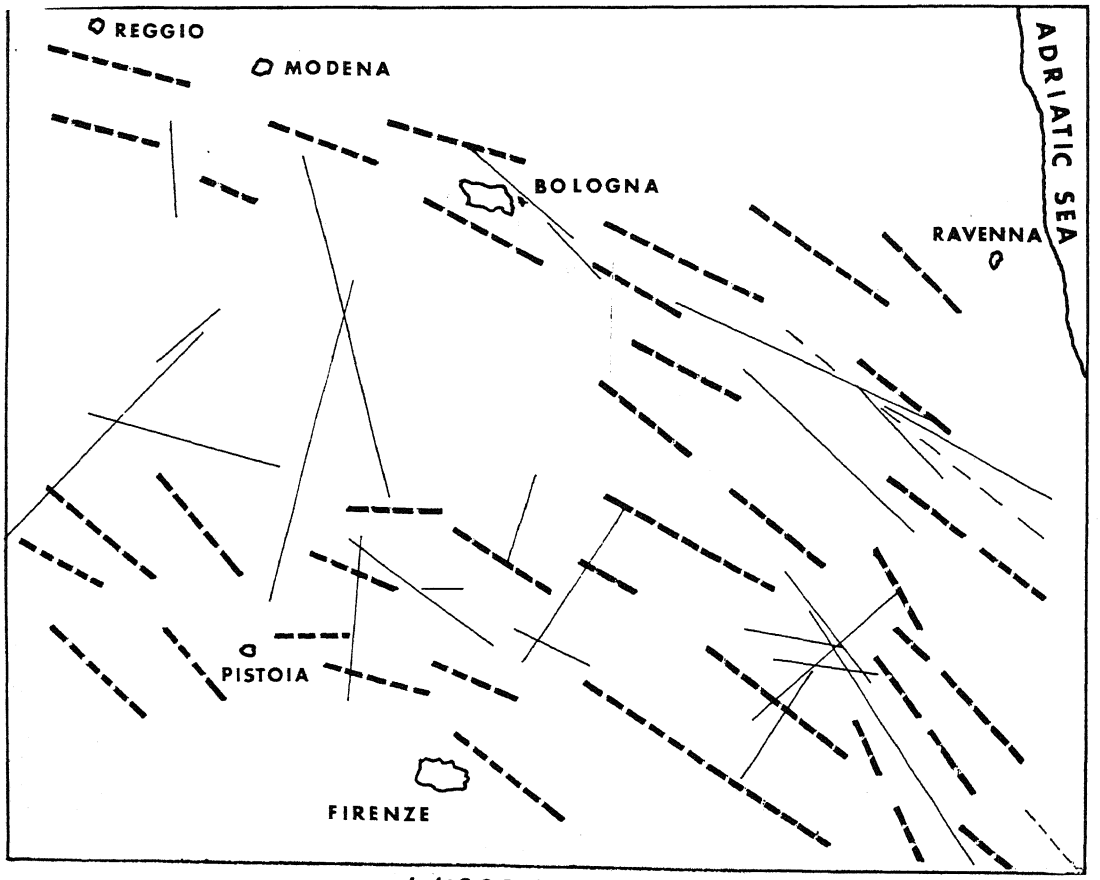

fig. 2

scale = 1:1'000'000

——— major axes of main isoseismals

– – – – main tectonic trends

FIG.3

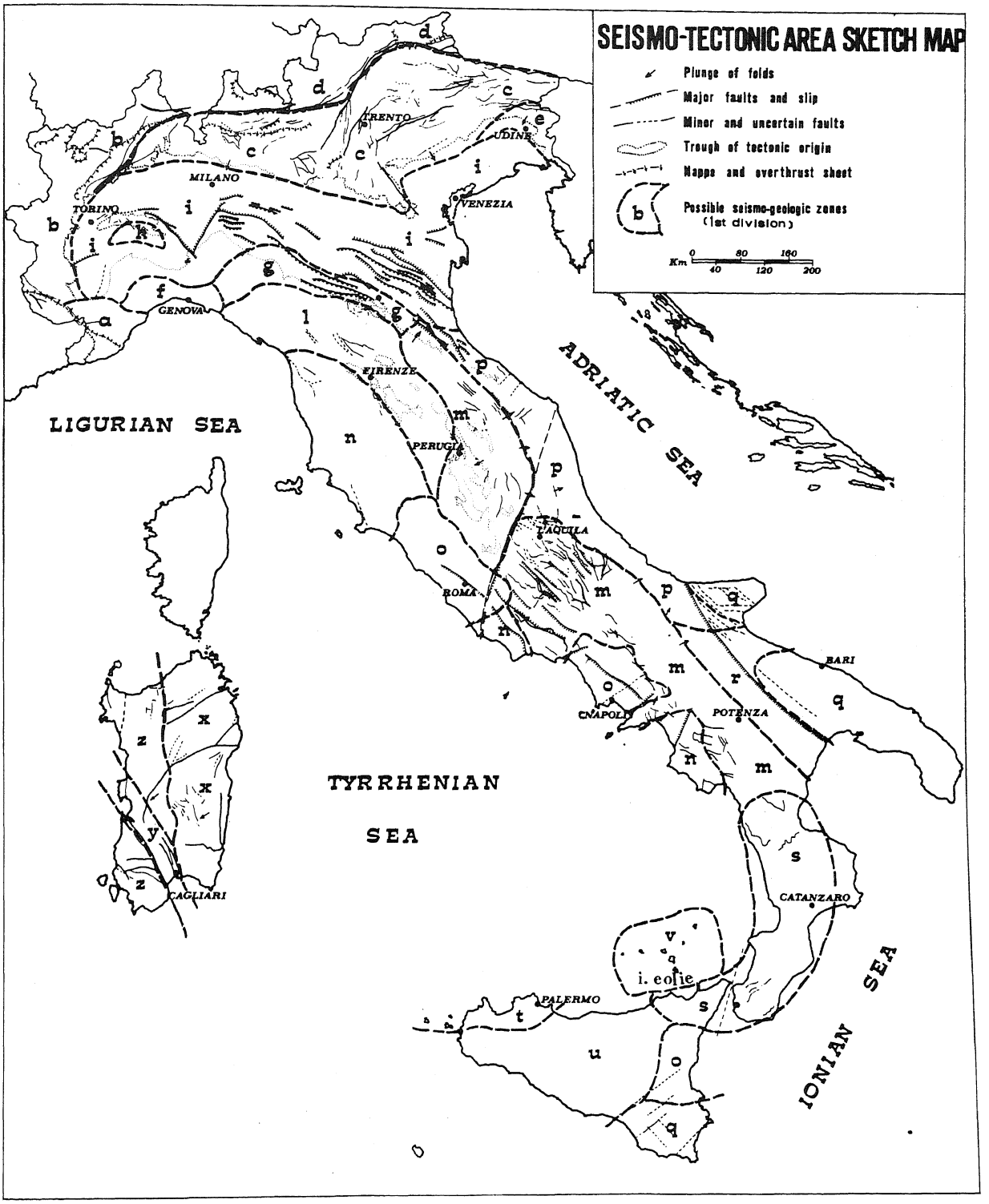
SEISMO-TECTONIC AREA SKETCH MAP
Plunge of folds
Major faults and slip
Minor and uncertain faults
Trough of tectonic origin
Nappe and overthrust sheet
Possible seismo-geologic zones (1st division)
Km 0 80 160 40 120 200
LIGURIAN SEA
TYRRHENIAN SEA
ADRIATIC SEA
IONIAN SEA
TORINO
MILANO
TRENTO
UDINE
VENEZIA
GENOVA
FIRENZE
PERUGIA
L'AQUILA
ROMA
NAPOLI
POTENZA
BARI
CATANZARO
PALERMO
CAGLIARI
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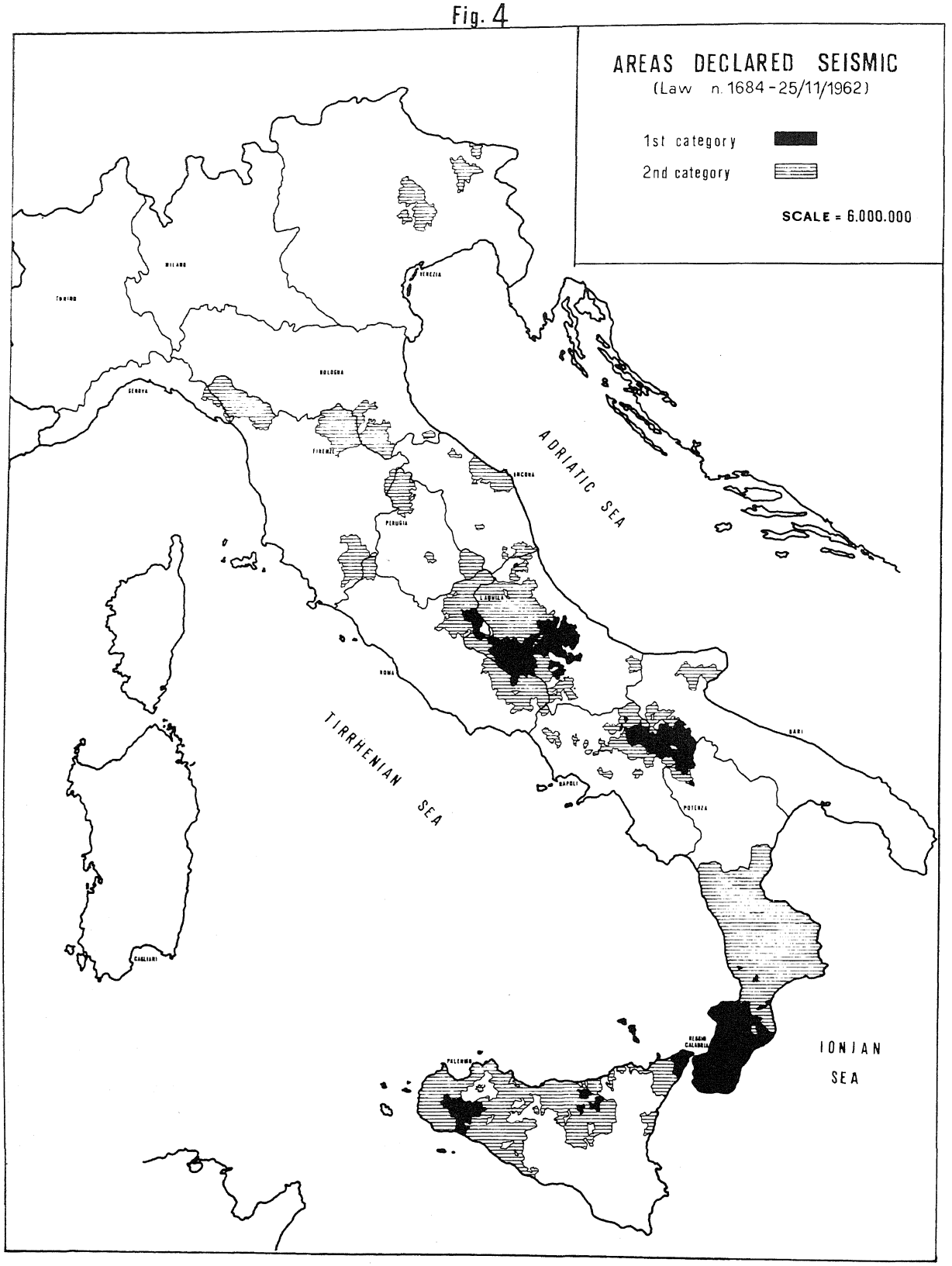
Fig. 4


AREAS DECLARED SEISMIC
(Law n. 1684 - 25/11/1962)
1st category
2nd category
SCALE = 6.000.000
MILANO
TORINO
VENEZIA
BOLOGNA
GENOVA
FIRENZE
ANCONA
PERUGIA
L'AQUILA
ROMA
BARI
NAPOLI
POTENZA
CAGLIARI
PALERMO
REGGIO CALABRIA
ADRIATIC SEA
TIRRHENIAN SEA
IONIAN SEA