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WORKSHOP
GLOBAL GEOPHYSICAL INFORMATICS WITH APPLICATIONS TO RESEARCH IN EARTHQUAKE PREDICTIONS AND REDUCTION OF SEISMIC RISK

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LINEAMENTS, SEISMICITY & MINERAL DEPOSITS

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LINEAMENTS, SEISMICITY AND MINERAL DEPOSITS

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In the problem of recognition of earthquake-prone areas the objects of recognition in many cases are the intersections of morphostructural lineaments.

This selection of objects of recognition is based on the hypothesis that locations of epicenters of strong enough earthquakes have to be close to intersections of lineaments.

For some seismic regions the validity of this hypothesis becomes clear after marking the locations of epicenters on the map of morphostructural zoning of the region. But there are regions for which the special jastification of this hypothesis is necessary.

The following algorithm can be suggested for this justification.

1. Testing of closeness of epicenters and intersections

Let $Q = \{ q_1, q_2, \ldots, q_n \}$ be the set of points identified with intersections of lineaments of the region under consideration and $E = \{ e_1, e_2, \ldots, e_m \}$ be the set of points identified with epicenters of strong earthquakes (with magnitude $M \geqslant M_0$, where M is the given threshold).

Let ρ_{ij} denote the distance between the epicenter e_i and the intersection q_j .

The distance from the epicenter e_i to the nearest intersection will be

$$\rho_i = \min_{1 \le j \le n} \rho_{ij} .$$

Let $N_Q(\rho)$ denote the number of epicenters for which $\rho_i \leqslant \rho$ in percent of their total number m .

The function $N_Q(\rho)$ characterizes closeness of epicenters to intersections. But epicenters may be close to intersections due to high density of lineaments and so due to great number of intersections in the region.

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$$\rho_i = \min_{1 \le j \le n} \rho_{ij} .$$

Let $N_Q(\rho)$ denote the number of epicenters for which $\rho_i \leqslant \rho$ in percent of their total number m .

For each intersection its new position is selected by random choice uniformly in the circle of radius R with the center in point q_j.

$$\xi(R) = \{ \xi_1 , \xi_2 , \ldots , \xi_m \}$$

is the random system of intersections.

To estimate wheather real closeness of epicenters to intersections is better or not than for some arbitarary system of intersections with the same density the following procedure is used.

For each intersection its new position is selected by random choice uniformly in the circle of radius R with the center in the point q_j. So a random system of intersections $\xi(R) = \{\xi_1, \xi_2, \dots, \xi_n\}$ is constructed. For this random system the function $N_\xi(\rho)$ can be defined. This function characterizes the closeness of epiceners to this random system of intersections.

$N_\xi(\rho)$ will be a random function. Let $MN_\xi(\rho)$ and $SN_\xi(\rho)$ denote the mean value and standard deviation of this function.

By comparision of the function $N_Q(\rho)$ with the function $MN_\xi(\rho)$ the estimation of the closeness of the epicenters to the intersections may be obtained.

Let $p(\rho)$ denote a probability of the event

$$N_\xi(\rho) - MN_\xi(\rho) \geq N_Q(\rho) - MN_\xi(\rho),$$

i.e.

$$p(\rho) = P\{ N_\xi(\rho) - MN_\xi(\rho) \geq N_Q(\rho) - MN_\xi(\rho) \}.$$

If some large enough range of values of ρ exists for which $p(\rho) < p_*$, where p is a small constant, then the closeness of epicenters to intersections takes place in the region.

2. Epicenters and intersections of South America

The procedure described above was used to estimate the closeness of epicenters of earthquakes with $M \geq 7.0$ to intersections of morphostructural lineaments of Andes (Fig. 1).

The radius R of circles in which random positions of intersections were distributed was selected to be equal 200 km.

Estimations of functions $MN_\xi(\rho)$ and $SN_\xi(\rho)$ were obtained by Monte-Carlo method with 100 tests (random systems of intersections).

$$MN_\xi(\rho) \approx 0.01 \cdot \sum_{i=1}^{100} N_\xi^{(i)}(\rho),$$

$$SN_\xi(\rho) \approx \left(0.01 \cdot \sum_{i=1}^{100} \left(N_\xi^{(i)}(\rho) - MN_\xi(\rho) \right)^2 \right)^{1/2}.$$

Functions $N_Q(\rho)$, $MN_\xi(\rho)$ and $SN_\xi(\rho)$ are shown in the Fig. 2 .

For $40\ km \leq \rho \leq 190\ km$, $N_Q(\rho) > MN_\xi(\rho)$.

For $50\ km \leq \rho \leq 140\ km$,

$$N_Q(\rho) - MN_\xi(\rho) \sim 3 \cdot SN_\xi(\rho),$$

and according to the formula

$$P\{ | N_\xi(\rho) - MN_\xi(\rho) | \geq n \cdot SN_\xi(\rho) \} < 1/n$$

$$P\{ | N_\xi(\rho) - MN_\xi(\rho) | \geq N_Q(\rho) - MN_\xi(\rho) \} < 1/9.$$

By this method the closeness of epicenters of earthquakes with $M \geq 5.5$ to the intersections of lineaments in the East of Central Asia was shown too.

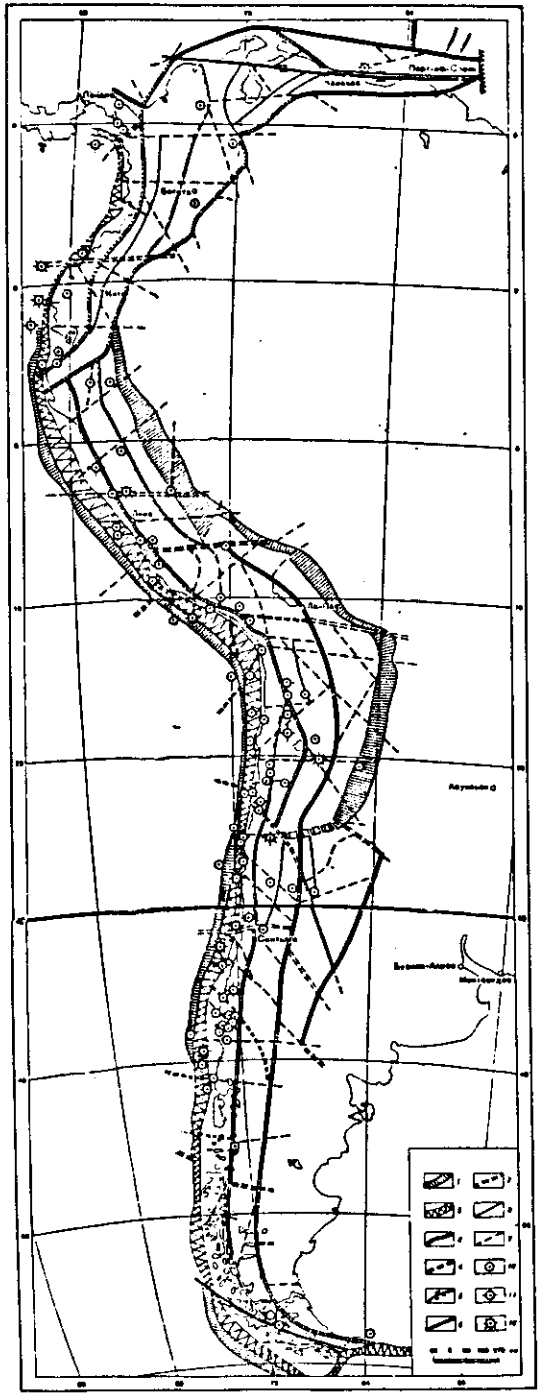

Fig. 1 The morphostructural sceme of Andes.

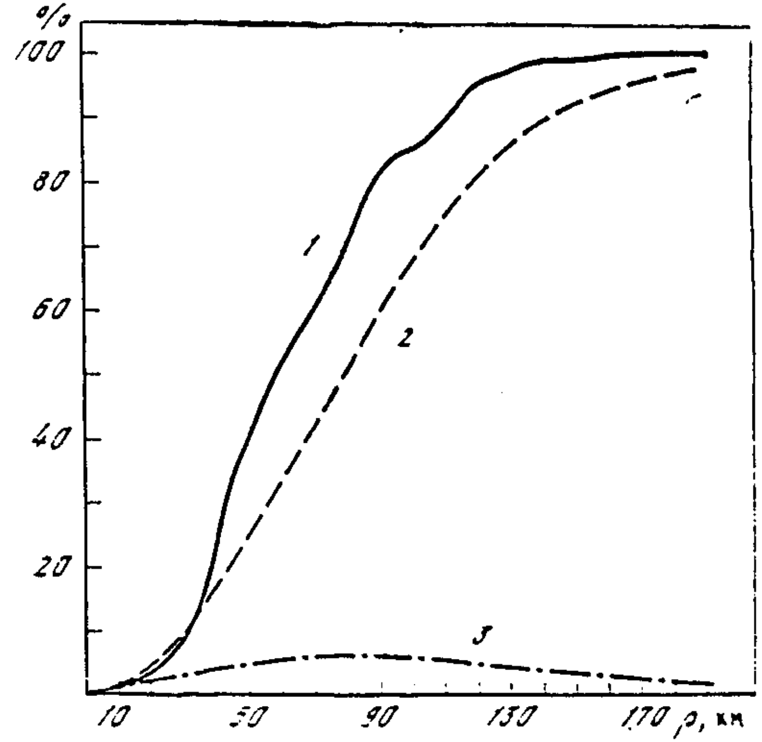

Fig. 2. The functions $N_Q(\rho)$ (1), $MN_\xi(\rho)$ (2) and $SN_\xi(\rho)$ (3).

3. Intersections of lineaments and mineral deposits

The described method can also be used to estimate correlation between mineral deposits and intersections of lineaments.

This estimation was made for Western Alps. The scheme of lineaments is represented in Fig. 3. All large enough mineral deposits were considered. It was obtained that

$$N_Q(\rho) - MN_\xi(\rho) \sim SN_\xi(\rho) .$$

So there is no strong correlation between mineral deposits and intersections of lineaments. But it is due to the fact that all mineral deposits were considered. The result is substantially improved if only metallic mineral deposits of endogenic origin are considered. When such mineral deposits are considered their correlation with intersections of morphostructural lineaments is obvious.

Also it is necessary to note that almost all such mineral deposits are near intersections which were recognized as dangerous (near of which earthquakes with $M \geq 5.0$ are possible).

The same situation is in Pyrenees. In Fig. 4 - 9 the metalic mineral deposits are shown together with the results of recognition of earthquake-prone areas in Pyrenees ($M \geq 5.0$). The main part of such mineral deposits is near to dangerous intersections.

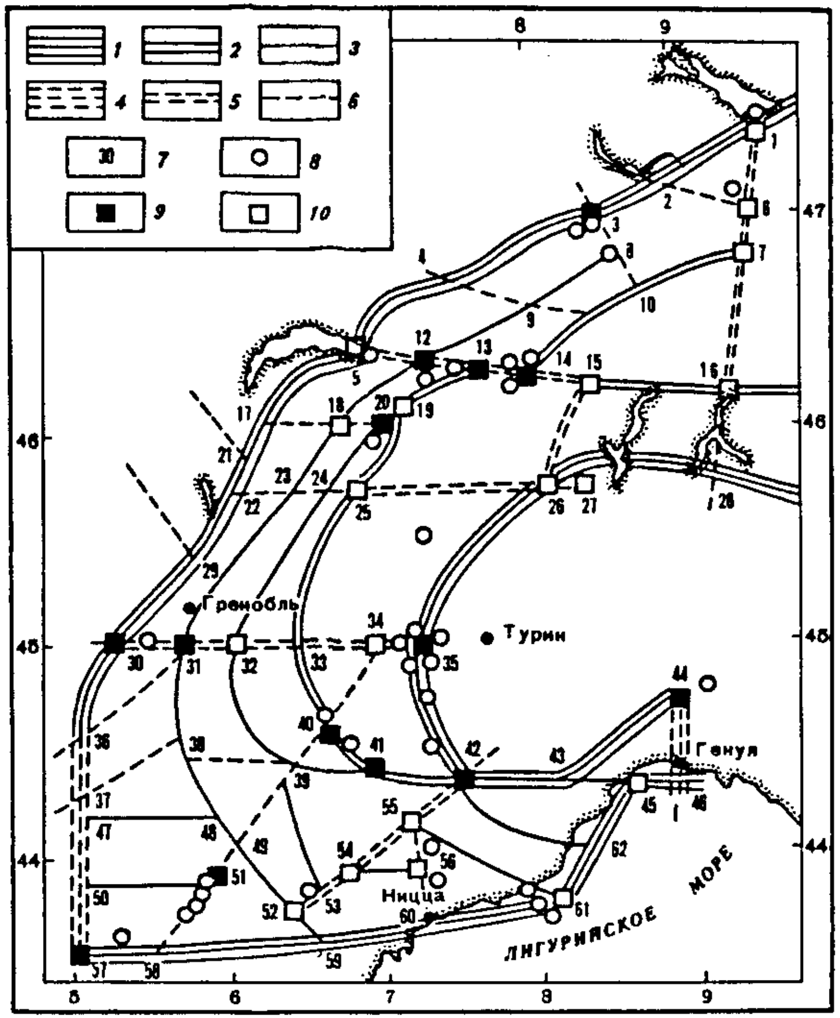

Fig.3. The morphostructural sceme of Western Alps and the result of recognition of earthquake-prone areas for $M \geq 5.0$ (8 - epicenters of earthquakes with $M \geq 5.0$; 9, 10 - dangerous intersections).

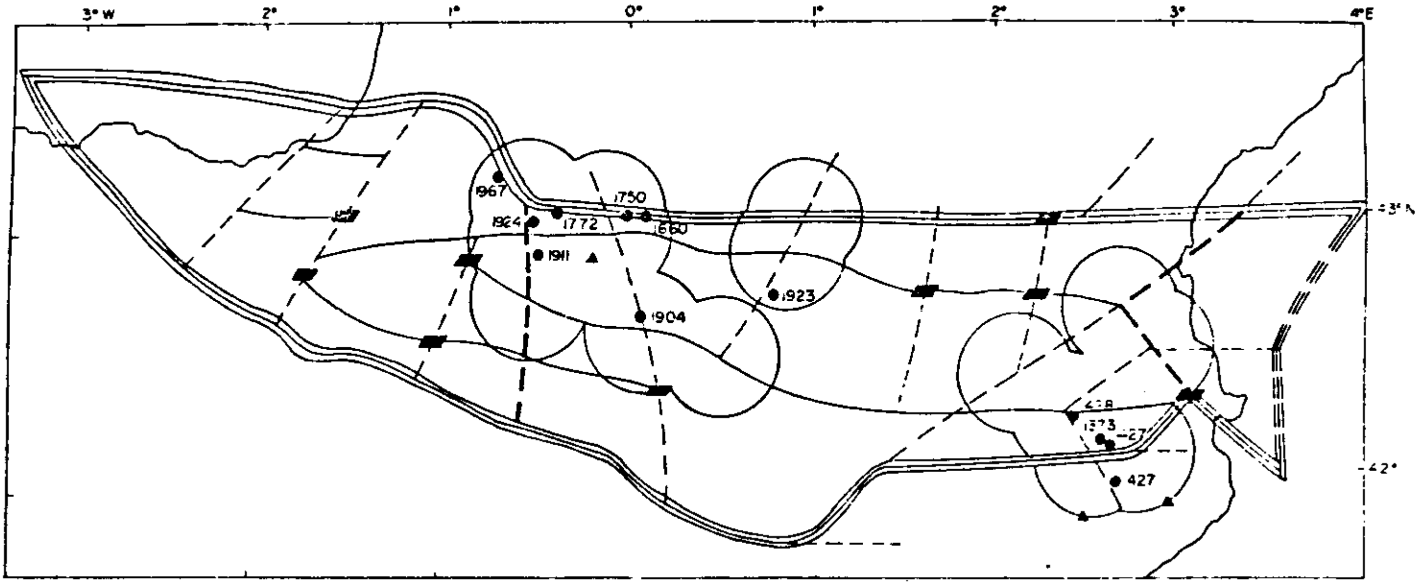

Fig. 4

Results of recognition of earthquake prone-areas and locations of Baryum deposits

- ▲ Locations of Barium deposits
- ● Epicenters with M≥5,0 or I≥VIII
- ▰ Intersections recognized as prone for M≥5,0 by Alpine criteria
- ◯ Zones recognized as prone for M≥5,0 by Pyrenean criteria

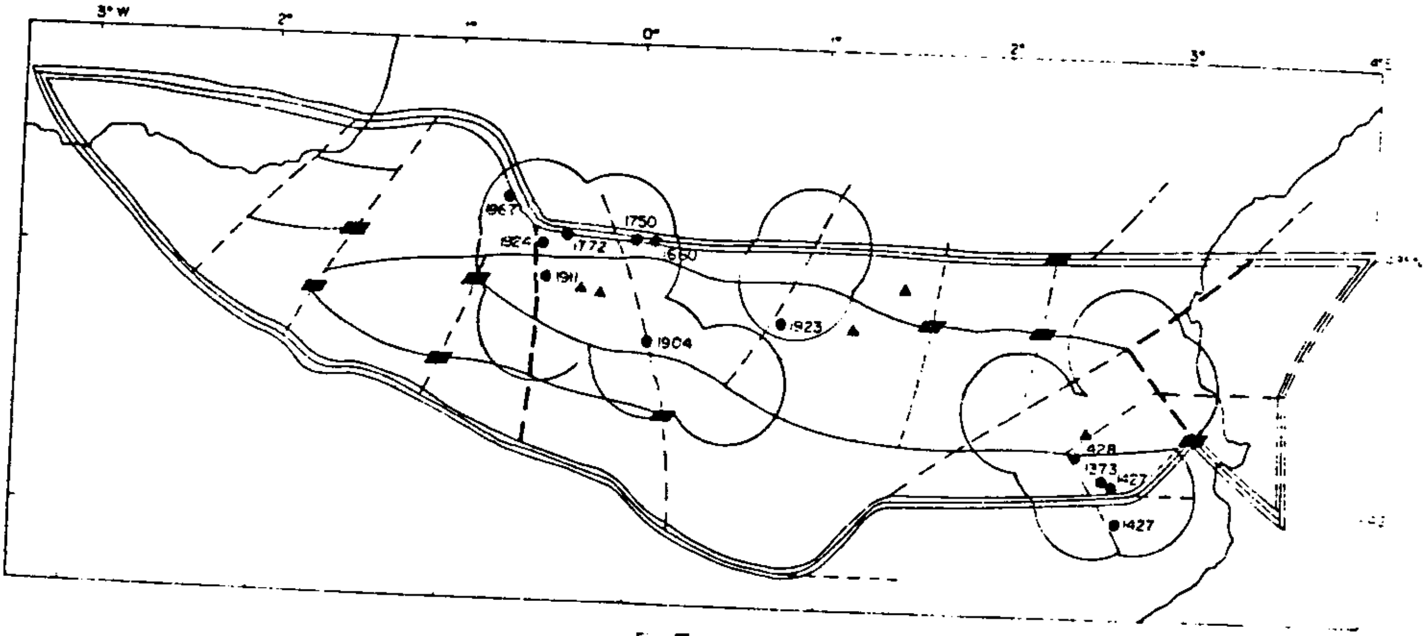

Fig 5

Results of recognition of earthquake prone-areas and locations of Tungstene deposits

▲ Locations of Tungstene deposits

(Other symbols see on legend to Fig 4)

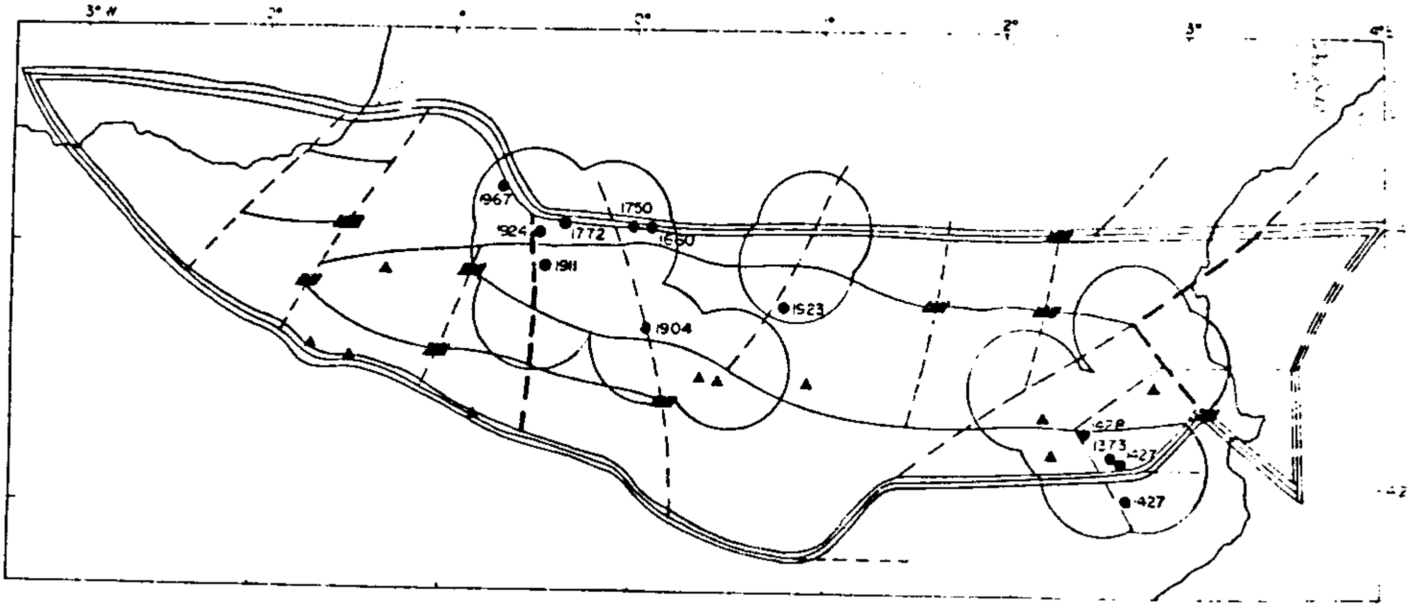

Fig 6

Results of recognition of earthquake prone-areas and locations of Copper deposits

▲ Locations of Copper deposits
(Other symbols see on legend to Fig 4)

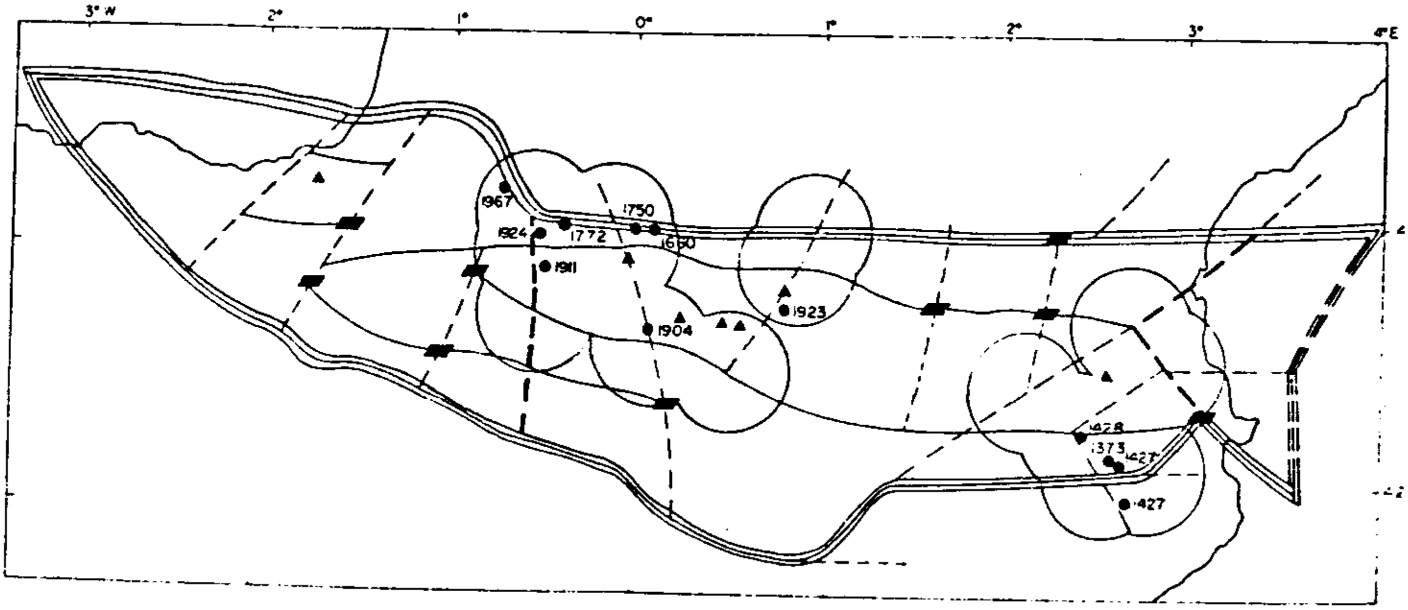

Fig 7

Results of recognition of earthquake prone-areas and locations of Lead-Zinc deposits

▲ Locations of Lead-Zinc deposits
(Other symbols see on legend to Fig 4)

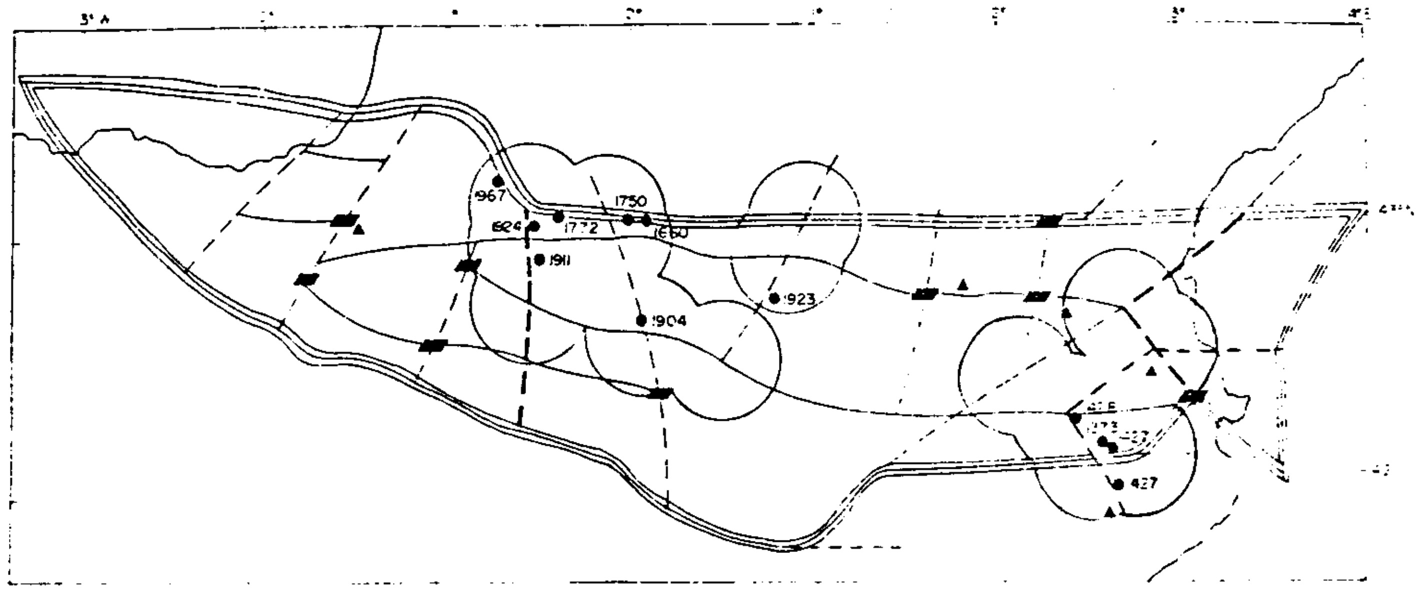

Fig. 8

Results of recognition of earthquake prone-areas and locations of Magnesium deposits.

▲ Locations of Magnesium deposits
(Other symbols see on legend to Fig 4)

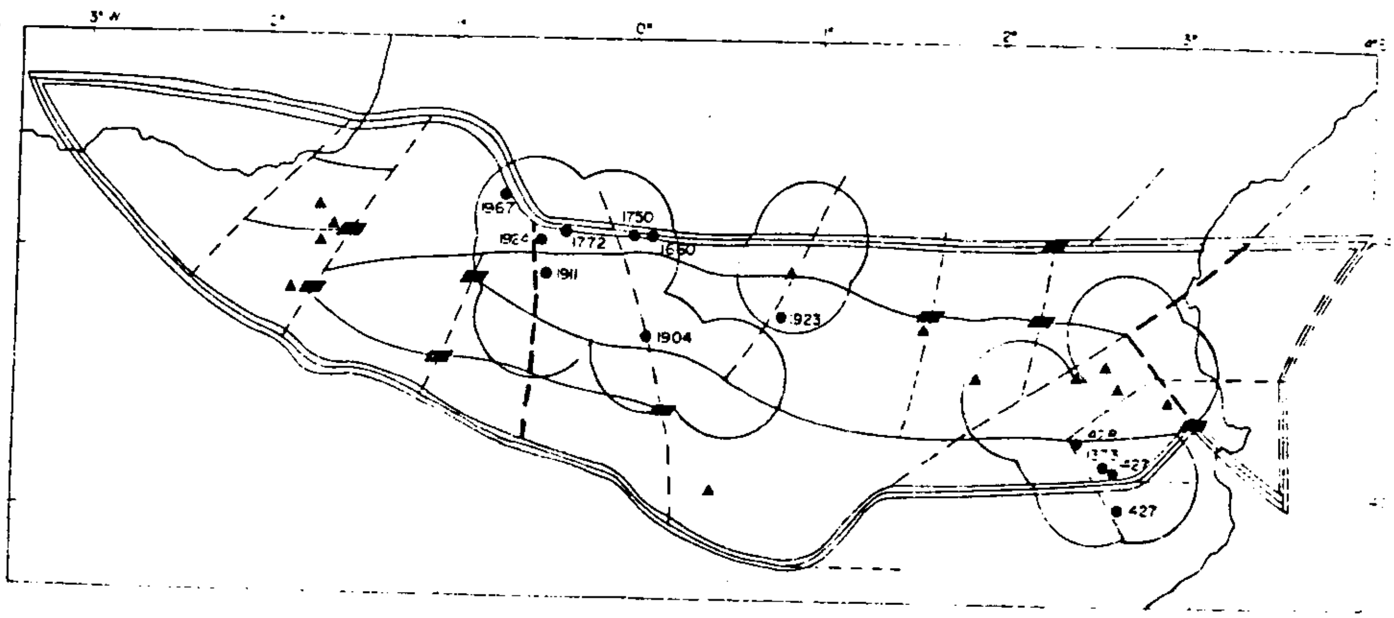

Fig 9

Results of recognition of earthquakes prone-areas and locations of Iron deposits

▲ Locations of Iron deposits
(Other symbols see on legend to Fig 4)

These results give arguments to the conclusion that places where earthquakes are possible and places where there are metalic mineral deposits of endogenic origing may have similar features.

Another experiment was made for Italy. The scheme of lineaments with the result of recognition of earthquake-prone areas for $M \geq 6.0$ (Fig. 10) and all mineral deposits from the geological map of Italy were considered.

For circles of radius R with centers in intersections the number n(R) of mineral deposits which are in these circles was calculated.

Also the number $n_D(R)$ of mineral deposits in the circles with centers in intersections which were recognized as dangerous was calculated.

For various values of R ($20 \text{ km} \leq R \leq 75 \text{ km}$) the ratio $n_D(R)/n(R)$ was 0.75 - 0.8 and differed slightly. It means that the main part of mineral deposits which are close to intersections are close to dangerous intersections.

Note that only 44 intersections among 113 were recognized as dangerous.

In connection with mineral deposits two pattern recognition problems can be formulated:

1. Recognition of intersections near of which mineral deposits can be located.

2. The same, but only for dangerous intersections.

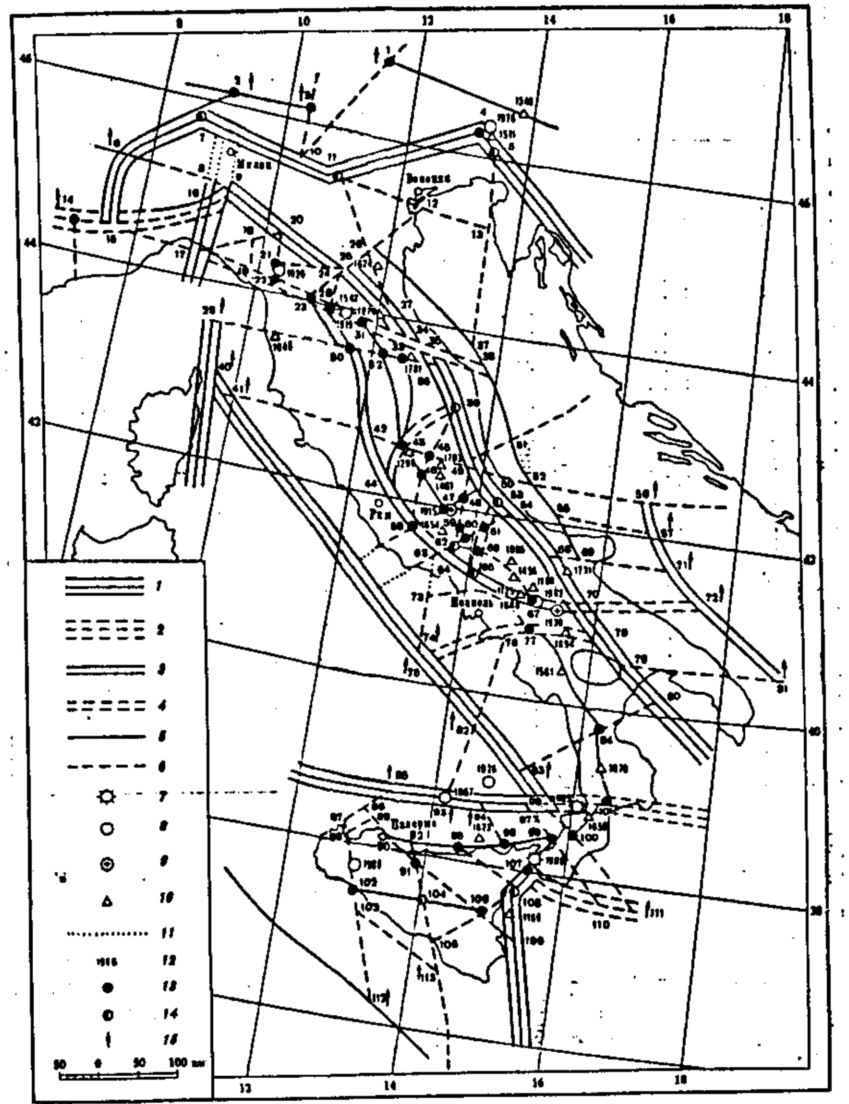

Fig. 10. The morphostructural sceme of Italy and the result of recognition of earthquake-prone areas for $M \geq 6.0$ (7-9 - epicenters of earthquakes with $M \geq 6.0$; 13, 14 - dangerous intersections).