Plate Tectonics and Ore/Mineral Provinces in Western European Mediterranean Region

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Summary

Many ore/mineral deposits, of different type and/or metallogenic epochs, occur in the Western Mediterranean Region. An attempt is made to investigate whether their (comparable) characters support or contradict or are neutral to the most generally accepted pre-Tertiary paleogeographic reconstructions of the region, which imply that Sardinia, Corsica and Calabria were located close to Southern France in front of the Lyon Gulf.

Even on the basis of a very preliminary investigation, like the one carried out in this paper, it seems evident that some characteristics of the strata-bound Pb-Zn Georgian ore deposits, the characteristics and aereal zonality of the Pb-Zn Hercynian ones, the characteristics and distribution of the mesozoic ophiolitic deposits are all consistent with those paleogeographical schemas.

More detailed investigations are necessary for the manifold types of middle Paleozoic strata-bound deposits and — especially — for the Mesozoic ones, the latter showing big differences in paleogeographical environments of their formation. The study of (paleo)-placers/stream sediments and their source beds seems to indicate spreading in this region; more investigations are recommended to confirm or refuse this assumption.

1. Introduction

The pre-Tertiary paleography of the Western Mediterranean has been reconstructed, on the basis of: (i) paleo-magnetism; (ii) possible correlations among characteristic geological/petrological complexes; (iii) contourlines of the continental plates at different levels (—1000, —2000 b. s. l.).

The most generally agreed scheme (ALVAREZ et alii, 1974; BOSELLINI—HSU, 1973) is shown in Fig. 1.

The aims of the present paper are: (i) to carry out very preliminary investigations on the characteristics and distribution of the ore/mineral deposits of that area, in order to find out if they show obvious evidences supporting or contradicting or are at least neutral to this scheme; (ii) to try to give suggestions for more detailed studies to solve the problem of western Mediterranean paleogeography.

2. Outline of regional geology and of ore/mineral deposits

2.1. The regions to be investigated are: The Pyrenees, the Betic Cordillera, the Southern side of France, the Western Alps, the Sardic-Corsic Massif, the Western side of the Italian Peninsula and Sicily.

2.2. Some geological characters of the area under investigation are to be pointed out, for a better understanding of the difficulties in facing the proposed problems

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and the uncertainities in looking for their solutions. As a matter of fact, even if the geological history of this area is not so long (the oldest complexes are Cambrian; the pre-Cambrian basement is known only in a few small outcrops), it is quite complicated. One, thus, has to bear in mind:

(i): The interference of various (at places superimposed) orogenies and metamorphisms; they are: the Caledonian, the Hercynian, the Alpine, each one being subdivided in a number of phases.

(ii): The interference of various thermometamorphisms and magmatic cycles, at places superimposed, and with different lithofacies and intrusive levels. Very broadly one may list them as follows:

a) acid and/or mafic platform volcanism was active, from time to time, during the whole Paleozoic, and — at times — it was related to some large ore/mineral deposits;
b) mafic-ultra mafic, ophiolitic, ore bearing magmatism took place in Jurassic-Cretaceous;
c) calc-alkaline magmatism (either plutonic-with quite different intrusive level-or volcanic) took place in connection with the main orogenies: some of them played important roles in the metallogenesis of this area,
d) basic volcanics were (and are) emplaced in recent times.

(iii): Different development of either the above mentioned orogenies, metamorphism, and magmatism in the various parts of the area under investigation.

Thus, the Hercynian ones are present in the most of the area, but are absent in the Italian peninsula, except in Calabria and the very northern corner of Sicily.

The Alpine orogeny and metamorphism are still more irregularly distributed: they are present, with very strong intensity, in the Alps, in southern French Central Massif, in a small part of Corsica, the Italian Peninsula and Sicily, in the Pyrenees. The Alpine magmatism is mainly plutonic in this area, with important volcanics only in Tuscany and Latium. Only disruptive tectonics may be related to the Alpine orogeny in the remaining part of Corsica and in Sardinia; here the Alpine magmatism mostly yielded calc-alkaline volcanics.

(iv): Fairly quick changes of paleogeographical conditions of some horizons, even over short distances. F. e., the Cambrian sequence in Sardinia has more littoral characteristics in Inglesiente and more pelagic characteristics 15 km southernly in Sulcis. The Triassic system shows sabkha environments in Tuscany and northern Sardinia, lacustrine in southern Sardinia, fluviatile-coastal environments along the eastern border of the French Central Massif, and — outside our area, in the central Eastern Alps — has characters of carbonatic platform. These differences have obviously repercussions on the related ore/mineral deposits.

2.3. The Western Mediterranean region is very crowded with generally small to medium size ore/mineral deposits, some districts being remarkably large (f. e.: some Pb-Zn districts of the Southern French Central Massif, and of Sardinia-Italy; the FeS_2-Cu belt of southern Spain and Portugal; the U deposits of the French Central Massif; the Hg district of Tuscany; the CaF_2 vein of Silius-Sardinia).

A broad grouping of the ore/mineral deposits existing in the area under investigation is shown in table nr. 1. The broadness of this grouping is evident; but we think that it is sufficient and effective for this (very) preliminary investigation.

Not all the types will be dealt with this paper, but only those which occur in more than one part of the area and/or show — at this stage of knowledge — a sufficient number of distinctive characteristics to help to solve the correlation

problems. Thus, the Huelva FeS_2-Cu deposits (type nr. 3), the porphyry copper of North-Western Sardinia (type nr. 7) the Hg-Sb and the U-Th deposits of Tuscany and Latium, and the ones of Pb and/or Cu-FeS_2 and/or Mn-Fe, related to Alpine volcanism (type nr. 8) will be neglected, because each one of them occurs in one district only.

3. Reflexions on some ore/mineral deposits types

As it was mentioned in the proceeding chapter, only some types of ore/mineral deposits, which — at this stage of knowledge — can contribute to the correlation-problem, will be (briefly) discussed.

3.1. Deposits in the Cambrian system, strata bound, some intensely metamorphosed and remobilized

We shall not consider, in this paragraph, the vein type and the stratiform deposits occuring in the Cambrian system, with proved or probable Hercynian affiliation; f. e.: the Pb-Zn vein system of Peyrebrunne, the vein and the stratiform Pb-Zn ore body of Saint-Salvy, the Au vein of Salsigne, all of them occuring in the Black Mountain. They will be discussed in paragraph 3.3.

The Cambrian system is surely known in only two regions of the area under investigation; namely the Iglesiente-Sulcis (Sardinia-Italy) and Southern French Central Massif (out-cropping in the Black Mountain and in depth in the Southern Cevennes).

The Cambrian sequences are quite similar, consisting of (from bottom to top) detrital sediments (at places with slates and carbonatic beds, and — in France — with rhyolites grading into a thick at places finely bedded, at places massive, sometimes silica-bearing) calcareous-dolomitic complex (the "Metalliferous" of Sardinia) with occasional intraformational breccias and slates; a narrow member of nodular limestones ("wild cherry limestones" of the Black Mountain) and a slaty complex conclude the sequences. The age in both cases is medium-upper Georgian to lower Acadian.

Strata-bound deposits, generally intensively metamorphosed and remobilized, occur in the calcareous-dolomitic member of the sequence: let's quote from Iglesiente the large tonnage Pb-Zn deposits of Monteboni and S. Giovalli; the important Zn-FeS_2 massive deposit of Campo Pisano; from the Black Mountain the noteworthy Pb-Zn deposit of La Loubatiere and the Pb, Zn, Cu, Fe, As ore body of Ceilhes. Other deposits held in the same member are epigenetic with karstic origin: f. e. the large Pb-Zn-$BaSO_4$ deposit of Les Malines in the Southern Cevennes;; the "silver rich pipes" of S. Giovanni and S. Giorgio and numerous $BaSO_4$-PbS deposits of Iglesiente-Sulcis, the most renowned among them being Arenas and Barega.

All these deposits have some common characteristics, namely:

a) their macro/and micro-parageneses are very simple; Ag-content is low in the stratiform deposits and can become high only as a consequence of strong supergene enrichment, as it is in the case of (some) karstic accumulations. They are grouped together under the type nr. 14 of BAUCHAU classification of Pb-Zn deposits (BAUCHAU, 1971).

b) The second common characteristic feature is the strong correlation of accumulations to analogous paleogeographic large scale and small scale conditions, thus proving the strong control of sedimentation and diagenesis on the ore /mineral accumulation during the Cambrian times.

There are however also some differences: first of all, the absence in the French region, of two types of deposits, which are present in Sardinia; namely: (i) the massive, volcano-sedimentary deposits Campo Pisano type along the base of the carbonatic main member; (ii) the barite/evaporitic deposits along the transition between the main carbonatic member and the underlying quartzites.

A second difference can be found in the formation and evolution of the karstic deposits in the Cambrian of the different regions: whilst in Sardinia karst formation and filling started very early in some places (since lower Ordovician at Arenas-Sardinia, Italy) and evolved at different subsequent times (till the present times in a number of localities), the same phenomena took place or started in Triassic times in other localities, f. e. at Les Malines-France (according to BERNARD, 1958) and at Barega in Sardinia (Padalino et al., 1973).

This fact proves not negligible differences in the geological evolution of the area under investigation, even short distances apart.

From the above mentioned factual observations it is possible to draw the following obvious deductions:

(i) the striking similarity between the Cambrian geology (particularly the metallogenic epochs) in Sardinia and in Southern France is suggestive of uniquity of a geological province.

(ii) The characteristics of some deposits considered in this paragraph (namely: the Pb-Zn strata bound ones) are consistent with this outline.

(iii) The characteristics of the karstic deposits particularly: their paragenesis may be considered as supporting, even if the geological history of their formation differs in some details, specially so far as the times of karst formation and filling are involved.

(iv) The absence of Zn-FeS_2 volcano-sedimentary massive deposits in a part of the area has to be explained.

3.2. Deposits in middle Paleozoic, strata bound, more or less metamorphosed and remobilized

The deposits evidently related to the Hercynian magmatism will be considered later on (see paragraph 3.3.).

This group includes 3 types of deposits: namely:

3.2.1. The volcano-sedimentary ore deposits of the Ordovician-Silurian systems

Not numerous, but important Pb-Zn-Fe deposits of this type occur in North-Eastern Pyrenees (Pierrefitte, Sontein, Carboire). They are strata-bound, strictly related to calc-alkaline volcanics, and are held either in carbonatic levels or in volcanodetrital sequences of upper Ordovician, immediately below the Silurian black shales.

No evidence, either of volcanism or of ore deposits is known in the Ordovician sequences of the other parts of the area under investigation.

At the most a slight similarity with the volcano-sedimentary oolithic Fe-deposits with minor sulfides of Nurra (North Western Sardinia) may be proposed; these deposits however, are Silurian.

No sound criteria for our purposes can evidently be achieved — at this stage of knowledge — from this group of deposits.

3.2.2. The Silurian polymetallic "black shale type" sedimentary deposits

A number of generally small sedimentary deposits of FeS_2, FeS, (FeO_3) and Zn, Cu, As, Pb-ores, Rammelsberg type, occur in the Silurian black shales of Sardinia.

For detailed description, see ZUFFARDI, 1968. The main example is "Funtana Raminosa".

Silurian black shales are known also in the Provence (southern France) and their possible connection with the similar sequence of North-Western Sardinia is considered as one of the supporting evidence for the paleogeographical reconstruction shown in fig. 1. They also hold scattered occurrences of polymetallic (mainly pyritic) stratiform deposits.

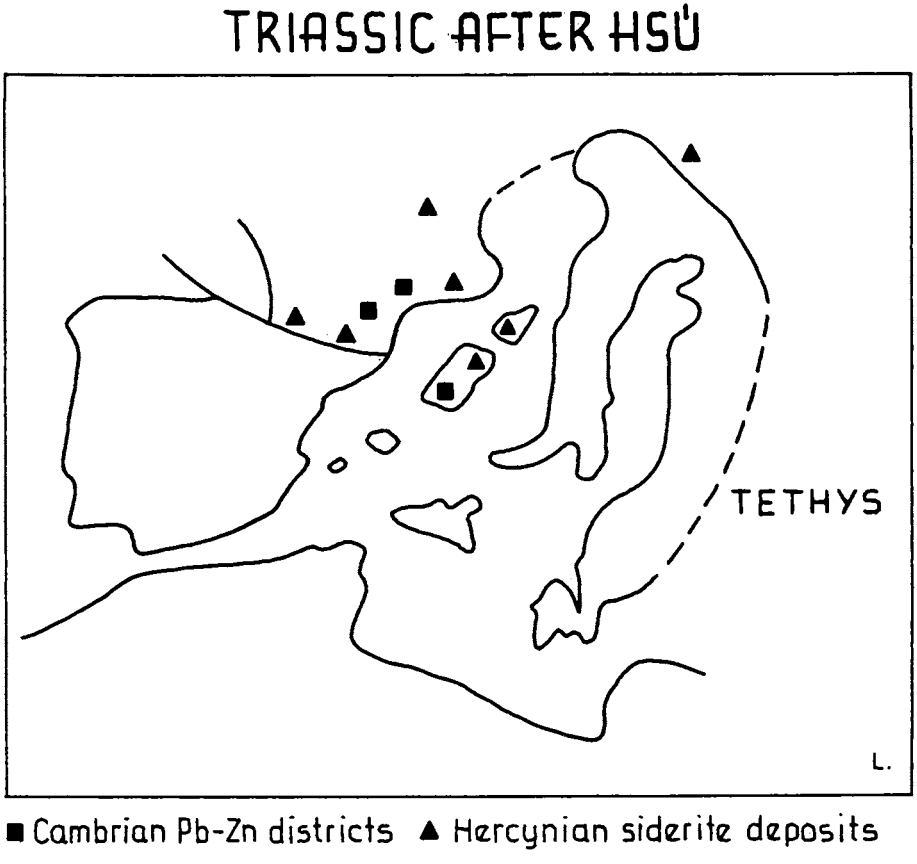

Fig. 1

3.2.3. The middle Paleozoic Sb-W-Hg sedimentary deposits

Such deposits, first described and classified by MAUCHER (1972), occur all along the Alps (further east, where they are mainly scheelite bearing) and are known in South-Western Sardinia, where they have been intensively exploited for their Sb-content in the first half of this century; they are not Hg-bearing; $CaWO_4$ is always present, at places in conspicuous accumulations.

The ore-bearing horizon is Silurian and is related to meta-tuffites in Sardinia; a number of $CaWO_4$ bearing horizons have been recently discovered in the Alps, ranging in age from upper Ordovician to lower Devonian, but the main horizon is Silurian, where the most important $CaWO_4$ concentrations occur, FELBERTHAL being the best known one.

A possible lateral continuity of these ore occurrences into Spain (occurrences of $CaWO_4$ in upper Ordovician and in lower Devonian) should be carefully investigated both from the theoretical and the practical standpoint. At the moment no contribution for our problem can be achieved from these mineralizations.

3.3. Deposits related to the Hercynian magmatism

We include in this group those ore deposits (mostly vein-type) that are strictly related to the Hercynian granitization, even if generated by (long range) remobilization of pre-existing accumulations.

We exclude from this group the deposits, which even if partially metamorphosed and remobilized — show clear evidence of their pre-Hercynian origin. Thus many Cambrian stratabound deposits evidently affected by the Hercynian metamorphism (f. i.: La Loubatiere, in Black Mountain, and a number from Sardinia have been included in the group 3.1 deposits of in the Cambrian system).

The main characteristics of the deposits strictly related to the Hercynian magmatism, which we are dealing about in this paragraph, are:

(i) large variety of paragenesis (see Table nr. 1, type nr. 4). This variety is still more evident if the micro-paragenesis and/or the gangue minerals are investigated: f. e. it is possible to subdivide the Pb-Zn deposits of Sardinia at least in 3 subgroups according to their content in Bi, As, Ag, Sb (Bianchini et Alii, 1961). Demange (1973) singles out 3 Pb-Zn groups of Pb-Zn deposits on the basis of their content of Ba, Fe, siderite-ankerite, in France.

(ii) strong prevalence of Pb-Zn-(FeS_2) deposits, generally with very complex (micro)-paragenesis.

(iii) rather irregular areal distribution; this troubling feature is related to three controlling factors; namely:

a) the most obvious controlling factor is the dismemberment of the area, related to the Alpine tectonics.
This is not, however the only factor; as a matter of fact irregular zonality is also present in those areas (f. e.: Sardinia) where the Alpine orogenesis was not effective.

b) another important controlling factor is the difference in granitization conditions (such as: intrusive level; apexes distribution of the granitic batholite; major feeding fractures).

c) a third controlling factor, that — at present state of knowledge — can only be guessed but not proved, is the zonality of ore/mineral pre-concentrations in the pre-Hercynian basement, which have been remobilized by the Hercynian magmatism.

In any case this irregular zonality is a matter of fact and the most evident example (that is especially unpleasant for the Italian mining industry) is the practical absence of Hercynian U deposits in Italy, whilst it is so abundant in the French Central Massif.

Another example is the difference in richness among different districts: f. e. the Sardinian Hercynian belt (especially thanks to its Pb-Zn deposits: Montevecchio, Ingurtosu, Argentiera of Nurra) is richer (so far as tonnage—not ore grade—is concerned) than the one of Calabria and of the Alps; only some deposits in the French Central Massif (Peyrebrune) are comparable to the Sardinian ones.

Notwithstanding the above mentioned differences, some noteworthy similarities do exist. According to BAUCHAU'S (1971) classification of Lead-Zinc deposits, the major Hercynian deposits both of Sardinia and of the French Central Massif (the above mentioned Pyrebrune) fall in the same type, namely: "type nr. 11, deposits with Pb-Zn-Ag-siderite".

Moreover, taking into consideration Demange's (1973) investigations of the French Pb-Zn deposits, one realizes that Sardic Pb-Zn deposits fit fairly well in the zonality of the French Central Massif. As a matter of fact Demange describes a zonal symmetrical distribution of these deposits around an East-West "barren axis", more or less placed in the middle of the French Central Massif and connecting the towns of Vivarais and Cantal. Moving either northwards or southwards from this barren axis, four belts (with transitions) can be distinguished on the basis of the gangue minerals; these four belts are respectively characterized by the presence, among the gangue minerals, of $BaSO_4$, of CaF_2, of $FeCO_3$ and, again, of $BaSO_4$.

A fifth belt is (partially) known in the extreme southern part, namely in the Pyrenees and in the outer Western Alps, and it is characterized by presence of siderite-ankerite; this belt is interrupted along the Lyon Gulf, exactly where Western Sardinia, and its Pb-Zn-Siderite-Ankerite deposits should be placed.

The presence of a number of Pb-Zn deposits with CaF_2 in the Maures Mountains, similar to the ones of the eastern side of Sardinia and of Calabria is also suggestive for our correlation problems.

As a conclusion of this paragraph, it is possible to say that the distribution of Pb-Zn Hercynian deposits (the most important of this group) shows evidences to support the paleogeographical pre-Tertiary reconstruction, shown in fig. 1.

Some puzzling differences do exist, however, between Sardinia and Calabria (especially in the tonnages of the deposits) and (still more troubling) between the French Central Massif and the remainder part of the Hercynian areas, so far as U deposits are concerned.

3.4. The Mesozoic ore/mineral sedimentary deposits

This group includes a number of (sometimes very important) deposits; namely:

3.4.1. The Triassic Pb-Zn-$BaSO_4$-CaF_2 deposits; they are particularly well developed outside the area under investigation, namely in eastern and Central Alps (Raibl, Bleiberg, Salafossa, Presolana, Gorno); in our area the outstanding examples are the Zn-Pb-$BaSO_4$ deposits of the South Cevenne region (Largentiere) and the FeS_2 ones from Tuscany (Niccioleta, Gavorrano), and of Fe_3O_4-FeS-FeS_2 of the Elba Island.

It is quite difficult to define correlations among these deposits; as a matter of fact the metallogenesis of the three over-mentioned districts are related to quite different paleogeographic conditions; namely: carbonatic tidal flats in eastern-central Alps; "red-bed sediments" in South-Cevennes; sabkhas in Tuscany, and Elba.

Evaporitic conditions existed also in North Sardinia and lacustrine ones in Southern Sardinia: in both cases no ore/mineral depositions are related to them.

3.4.2. Residual lateritic accumulations, with sulfides in paleo-channels, along the post-hercynian peneplain, in the basal Jurassic conglomerates. They are known in many localities: in Southern France, in Sardinia and in Calabria.

Their practical importance is scanty, but they are suggestive of very similar paleogeographical/paleoclimatic conditions in Sardinia and in Calabria during those times, in agreement with possible closer positions in the Mediterranean region.

3.4.3. A number of sedimentary FeS_2, Pb, Zn, deposits occur in the Liassic-Jurassic sequence around the French Central Massif; the Pb-Zn-Ba ore deposits of Les Malines are partially held in the Bathonian dolomite, above the Triassic marls; the Figeac Zn-(Pb) deposits occur in the Sinemurian; the Ba deposits of Lozere are located in the Hettangian dolomites.

No equivalent accumulations are known elsewhere, unless the geochemical positive anomalies of the lower Jurassic in Central Sardinia.

3.4.4. Many important bauxite deposits occur in the lower Cretaceous of Southern France (around the town of Baux, from which the name of the mineral derives); a small deposit of low grade bauxite is also present in the North-Eastern corner of Sardinia, also in Cretaceous, whilst the same complex in other parts of the Island (even along the Western coast) is barren.

This short outline of this group of ore/mineral deposits/occurrences is evidently of restricted use to solve our problem; it however points out the extreme variability, in time and space, of paleogeographic/paleoclimatic conditions during the Mesozoic of our area. And this is a not negligible step in planning more detailed inter-disciplinary investigations for correlations purposes: an example is shown in fig. 2.

3.5. Deposits related to Mesozoic (meta)-ophiolites

Not negligible deposit of Cu-FeS_2-(Zn) and of Fe_3O_4-(Ti) and others of asbestos and occasional very low grade occurrances of Cr, Ni, Pt are well known in Central-Eastern Alps, Liguria, Tuscany, Elba Island, Northern Corsica, Calabria, Southern Span (Andalusia).

They are absent in all other parts of the area under investigation. Their age of emplacement is Jurassic-Cretaceous and their locations are strongly controlled by Alpine tectonics: as a matter of fact they are always included in overthrust complexes in the Alpine region, in a part of Corsica, in Calabria, and occur as large olistolithes in Eastern Liguria, Elba, Tuscany. Also metamorphism affects them in different grade; brodly speaking it is very strong in the overthrust complexes and is at initial stage in the other parts.

Some deposits have (or had) large economic importance: f. e., Montecatine Val di Cecina (Tuscany) for Cu; Balangero-Western Alps for asbestos (it is the most productive asbestos deposits of Western Europe). Evidently the various scattered outcrops of these ophiolites represent a unique belt, streching from the Western to the Eastern Mediterranean. The paleogeographic reconstruction of fig. 1 is consistent with this obvious consideration. Another characteristic of Mesozoic (meta)-ophiolites deserves attention: namely the uneven distribution of chromite in the ultra-mafites; in fact chromite is very abundant in Yugoslavia, Albania, Greece, Turkey and is practically absent in the Western Mediterranean region, in a part of which (Western Alps) the ultra-mafites are fairly common.

It has also to be pointed out that this same characteristic is recognizable also in the ultra-mafites of the Paleozoic meta-ophiolites which occur in Central Alps (Varallo district) and in Yugoslavia.

In both ophiolitic sequences the ultra-mafites are interpreted as pieces of an ancient oceanic crust tectonically emplaced in the solid state. No obvious reasons can be found to explain why this oceanic crust has the above-mentioned irregular Cr distribution; it is however interesting to point out this example of permanence of negative/positive anomalies.

3.6. Recent alluvia

A number of fluviatile/shore placers holding Ti-ores, Fe_3O_4, monazite, zircon are known in the Western Mediterranean region. The correlation between these deposits and their source is evident in many cases; in some cases (f. e.: the presence of monazite in some stream sediments of Sardinia) the source rock is not surely established.

Moreover, according to the studies of Pannechoek, (1969) the stream sediments of a part of our area show evidences of current reversal. This type of investigations should be improved, in order to get detailed factual observations on the link between pre-spreading stream sediments and their source beds, thus helping to achieve a correct pre-spreading paleogeography.

4. Conclusions

The following conclusions can be drawn from this first very preliminary investigation on the Western European Mediterranean region;

4.1. A number of ore/mineral deposits occurs in the Western European Mediterranean region; they differ from one another in paragenesis and metallogenic processes and ages (see table nr. 1).

4.2. The geological evolution of the region is quite complex, even if its geological history is rather short (from Cambrian/upper pre-Cambrian to Quaternary): 3 orogeneses, 3 plutonic cycles, 3 metamorphisms, 2 ophiolitic magmatic cycles and a number of other volcanic activities can be recognized. The above mentioned events are unevenly distributed in the region. Paleogeographical/paleoclimatical conditions, during some periods of time, were fairly different in the different parts of the region, even over short distances: Mesozoic is typical in this respect.

Of course these geological differences have a bearing in ore/mineral formation and distribution, and sometimes make it difficult establishing correlations.

4.3. Taking into consideration the paleogeographic reconstruction of the Western European Mediterranean region, proposed by ALVAREZ et alii (1974), it appears that:

4.3.1. The following types of deposits are consistent with it:

(i) The Pb-Zn strata baound, more or less metamorphosed and remobilized deposits held in the Georgian carbonatic complex. The uneven distribution of massive volcano-sedimentary Zn-FeS_2 deposits, and of $BaSO_4$ evaporitic deposits/occurrances has to be explained.

(ii) the areal zonal distribution of Pb-Zn deposits related to the Hercynian granitization. The uneven distribution of the sizes of Pb-Zn deposits and of the U grade in granites are two problems to be solved (among others).

(iii) the Mesozoic (meta)-ophiolites, though less clearly. The irregular distribution of ore deposits in them has to be explained.

4.3.2. The distribution and characteristics of the strata-bound deposits of middle Paleozoic do not contradict the ALVAREZ et alii's scheme. More detailed investigations are necessary in order to determine:

(i) wheter there is any evidence to correlate the Ordovician volcanism and related deposits of the Pyrenees and the Silurian volcanism and deposits of North-Eastern Sardinia.

(ii) more tight correlations between the Silurian polymetallic deposits/occurrences and their paleogeographic environment (particularly: with the Silurian-Ordovician boundary).

(iii) the possible westwards continuation of the Silurian Sb-W-Hg bearing horizon and the possible occurrences of $CaWO_4$ outside this horizon.

4.3.3. More detailed investigations are needed:

(i) in order to establish correct correlations for the Mesozoic strata-bound ore /mineral deposits to clarify the fairly complex paleogeography.

(ii) the correlations between (paleo)-placers/stream sediments and their source beds, to better define the pre-spreading surface hydrology.

4.4. The distribution of porphyry copper deposits in the area under investigation suggests the hypothesis of a transcurrent margin along the Alps and of converging margins in Yugoslavia and along the Western coast of Sardinia.

Figs. 2—5

Ore Deposits in Western European Mediterranean:

Types and Distribution

Type No. 1: Deposits held in the Cambrian system, strata bound, some ones intensely metamorphosed and remobilized. Parageneses: Pb-Zn-(FeS_2); Zn-FeS_2; Zn-Cu-Pb; Pb-Zn-$BaSO_4$; $BaSO_4$-Pb. Locations: Black Mountain, Southern Cevennes (Southern France); Iglesiente-Sulcis (Southern-Western Sardinia-Italy).

Type No. 2: Deposits held in middle Paleozoic, strata bound, more or less metamorphosed and remobilized. Parageneses: Pb-Zn-FeOx-(Cu)-(As)-Sb; W-Sb-Hg. Locations: Northern Pyrenees (volcano-sedimentary, Ordovician); North-Western Sardinia (volcano-sedimentary, Silurian); Sardinia (polymetallic, black shale type); Alps, Sardinia (W-Sb-(Hg), upper Ordovician to lower Devonian).

Type No. 3: Deposits held in lower Carboniferous, volcano-sedimentary. Parageneses; FeS_2-Cu-Au-(Zn-Pb). Location: Huelva (South-Western Iberia). Remarks: it is one of the most important district in Europe.

Type No. 4: Deposits related to Hercynian magmatism. Parageneses: very various, ranging from pegmatitic-pneumatolytic types (W-SiO_2; Mo-FeS_2-SiO_2; SnO_2-Cu-Zn-Pb-SiO_2), to hypo-mesothermal (Pb-Zn-Cu-Ag-Cd-SiO_2-Siderite-Ankerite-Carbonates); FeS_2, As, Cu, Bi, Ag, Au, (W, Zn, Pb, Se, Sn, In), SiO_2 to epithermal(CaF_2-$BaSO_4$-Pb-Ag; $BaSO_4$-CaF_2-SiO_2; U-FeS_2-Fe_2O_2-SiO_2). Location: French Central Massif, Western Alps, Pyrenees, Sardinia and Calabria (Italy).

Type No. 5: Deposits held in Mesozoic, sedimentary. Parageneses: Bauxites; Laterites; Gypsum; Pb-Zn-FeS_2-$BaSO_4$-CaF_2-SiO_2, with one (or some) ore /mineral species prevailing (particularly: Pb-Zn). Location: the borders of the French Central Massif, the Alps, North-Western Sardinia, Calabria.

Type No. 6: Deposits related to Mesozoic (meta)-ofiolites. Parageneses: Cu-FeS_2-(Zn); Fe_3O_4-Ti; asbestos; at palces: very low grade dispersions of Ni, Cr, Pt. Location: Alps, Liguria, Tuscany, Elba Island, Calabria (Italy); Northern Corsica; Andalusia (Southern Spain).

Type No. 7: Porphyry copper, post-Triassic pre-Oligocene. Parageneses: FeS_2-Cu-Mo-(Au-Zn-Pb). Location: North-Western Sardinia (Italy). Remarks: small deposit; may be others could be present in depth along the Western coast, of Sardinia, along a paleo-Beniof surface, under calc-alkaline cropping volcanics. So far as porphyry coppers are concerned it is interesting to point out that important deposits of this type occur in Yugoslavia (Maidanpek and Bor), whilst no such deposits occur in the Alps. Excluding the simple (and over-simplified) hypothesis of insufficient explorations (the Alps are one of the most investigated region in the Earth!), a different evolution of plate-tectonics in the two over-mentioned areas could be thought to be responsible of porphyry copper distribution; namely: strong subduction in Yugoslavia, and no subduction (transcurrent margin) along the Alps.

Type No. 8: Deposits related to Alpine Magmatism. Paragene ses: Hg-Sb; U-Th; S; Fe-Mn; FeS_2-Cu; Fe_2O_3-FeS-FeS_2; Zn-Pb; Pb-(Zn). Location: Alps, Tuscany, Latium, Sardinia, French Central Massif, Pyrenees. Remarks: A tight genetic (or, at last, long distance remobilisation) correlation can be proposed for Fe-Mn, for S, for Hg-Sb, for U-Th in volcanites; in most other cases it is a matter of short-distance remobilisations, which do not obliterate the features of the original (strata-bound) deposits (as f. i. Gavorrano-Tuscany FeS_2 and Elba Island Fe_2O_3-FeS-FeS_2 deposits). In some cases Mesozoic/post-Mesozoic remobilization seems evident (f. i.: Pb-Zn veins of Saint-Saveur and of Florac-Southern France), but correlations to Alpine magmatism is not certainly proved. In any case the deposits related to Alpine magmatism will be not taken into consideration, because of their ill-defined characters.

Type No. 9: Recent alluvia. Parageneses: Ti-Th-Zr-Fe_3O_4. Location: In all coastal planes and shores of the region. Remarks; also non commercial accumulations are considered, for correlation purposes.

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Tableau I.- Document de synthèse

STRATIGRAPHIE		LOCALISATION GEOGRAPHIQUE LITHOLOGIE	MAGMATISME VOLCANISME METAMORPHISME TECTONIQUE				TYPES DE GISEMENTS							MINERALISATIONS												
							Syn-sédimentaires (absence de roches ignées)		Syn-sédimentaires (présence de roches ignées).			Syn-sédimentaires avec remobilisation métamorphique.	Placers fossiles	Masses stratiformes (origine à préciser)												
			Ma	V	Me	T	Sans sécrétion	Avec sécrétion	R.I. ≠ Source métal	R.I. = source métal					$MgCO_3$	Fe_1	Fe_2	Cu	Zn	Pb	Sb	Ba	Hg	Ti	Zr	U	Th
SILURIEN	DOWTONIEN LUDLOVIEN WENLOCKIEN	Nord.Est Prov. La Coruña Schistes,Chloritoschistes (Groupe Moeche)			+	+						+				+		+	+?					+		
	LLANDOVERIEN (VALENTIEN)	Almaden Quartzites du "Criadero"		+	(+)	(+)										+		(+)	(+)	(+)		(+)	+				
ORDOVICIEN	ASGHILLIEN	Sud Est Galice Calcaires, calcaires dolomitiques, dolomies Schistes (intermédiaires entre calcaires asghilliens et grès valentiens) Sierra Menera Formation carbonatée	* *			+		+	+	+	+			+	+		+				+						
	CARADOCIEN																										
	LLANDEILIEN	Nord-Ouest Schistes noirs	* (+)		* (+)		+										+										
	LLANVIRNIEN																										
	SKIDDAVIEN (ARENIGIEN)																										
	TREMADOCIEN	Cordillère Ibérique (Branche occidentale-Nord. Ouest, Ateca) Schistes noirs				+		+										+	+	+							
		Sierra Morena Couches gréso-quartzitiques											+											+	+	+	+

- (Ma = magmatisme; V = volcanisme; Me = métamorphisme; T = tectonique)
- (F_1 = fer sous forme de sulfures; F_2 = fer sous forme d'oxydes, hydroxides, carbonates, chlorites)
- (R.I. = roches ignées; ≠ la roche ignée ne constitue pas la source du métal; = : la roche ignée constitue la source du métal.
- * Volcanisme acide tardi-Llandeilien
- * Localement intrusion granitique avec métamorphisme de contact se superposant au métamorphisme régional.

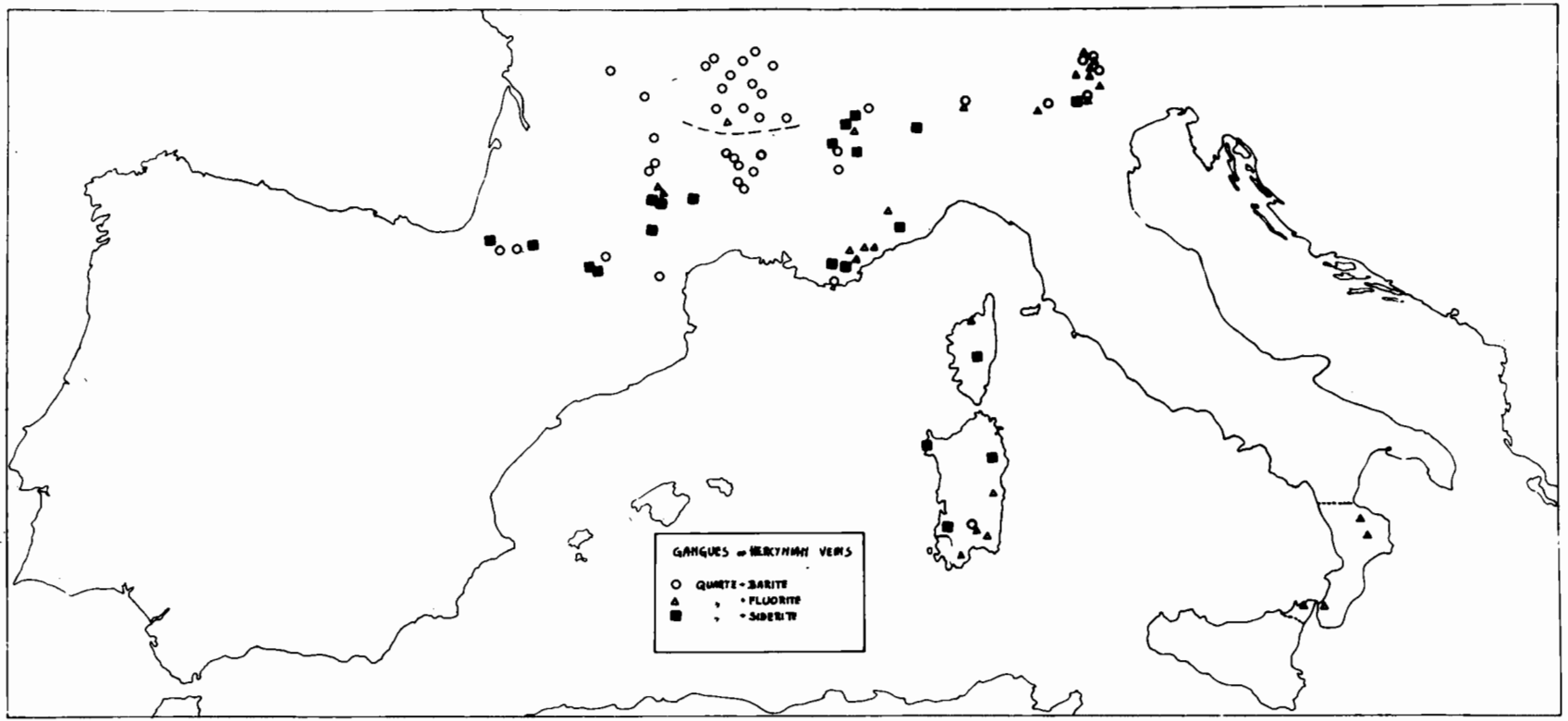
GANGUES des FILONS HERCYNIENS
QUARTZ + BARITE
+ FLUORITE
+ SIDERITE

Fig. 2

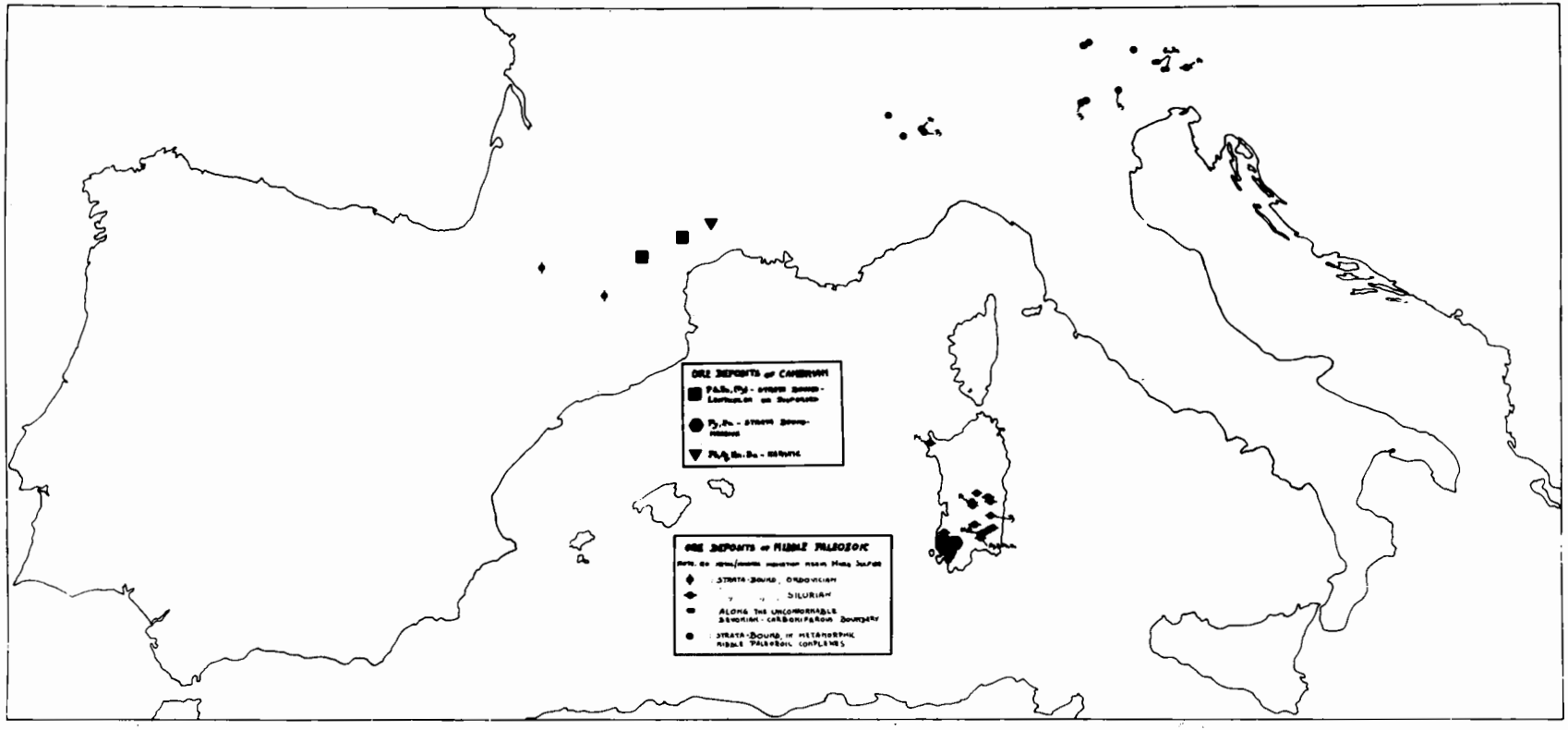
ORE DEPOSITS OF CAMBRIAN
STRATA-BOUND, ORDOVICIAN
SILURIAN
ALONG THE UNCONFORMABLE DEVONIAN - CARBONIFEROUS BOUNDARY
STRATA-BOUND, IN METAMORPHIC MIDDLE PALAEOZOIC COMPLEXES

Fig. 3

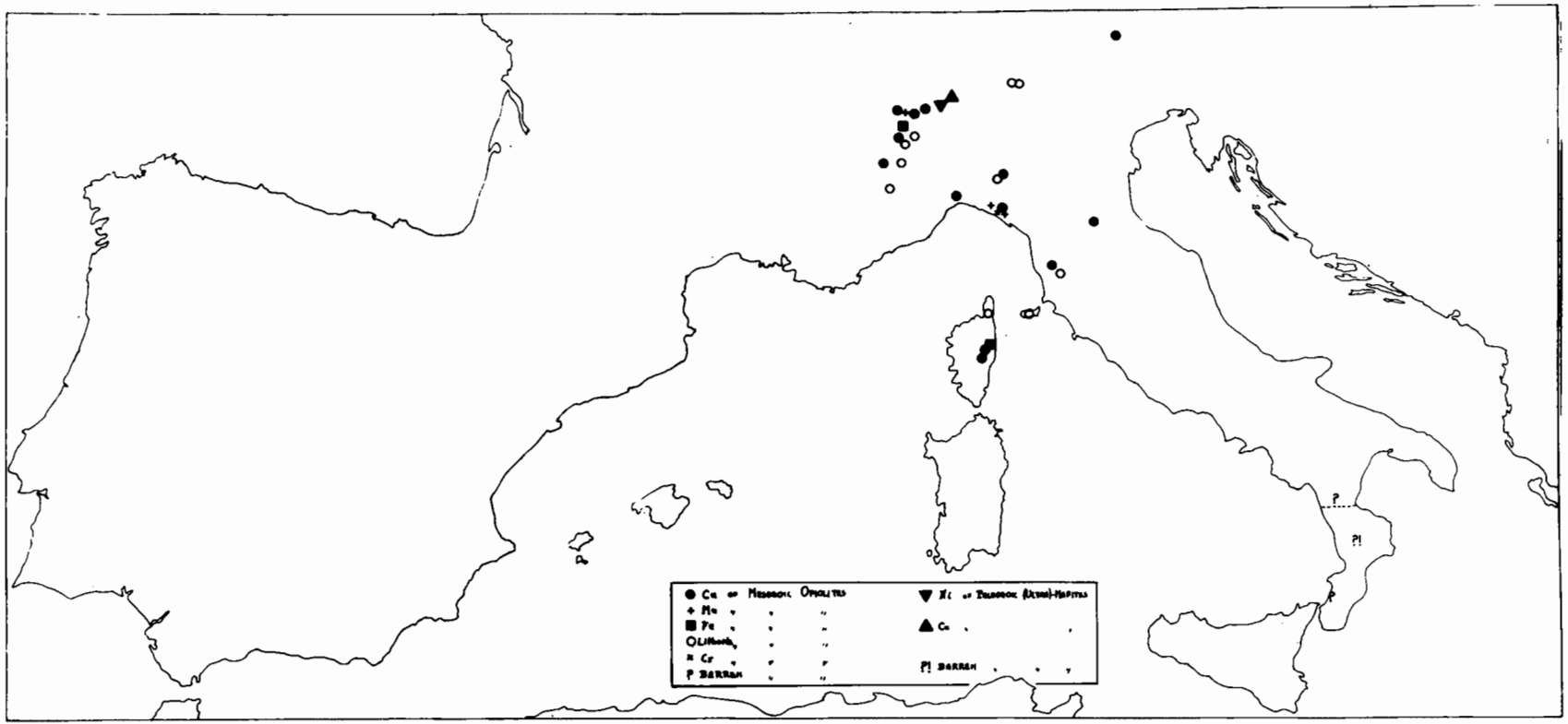

Fig. 4

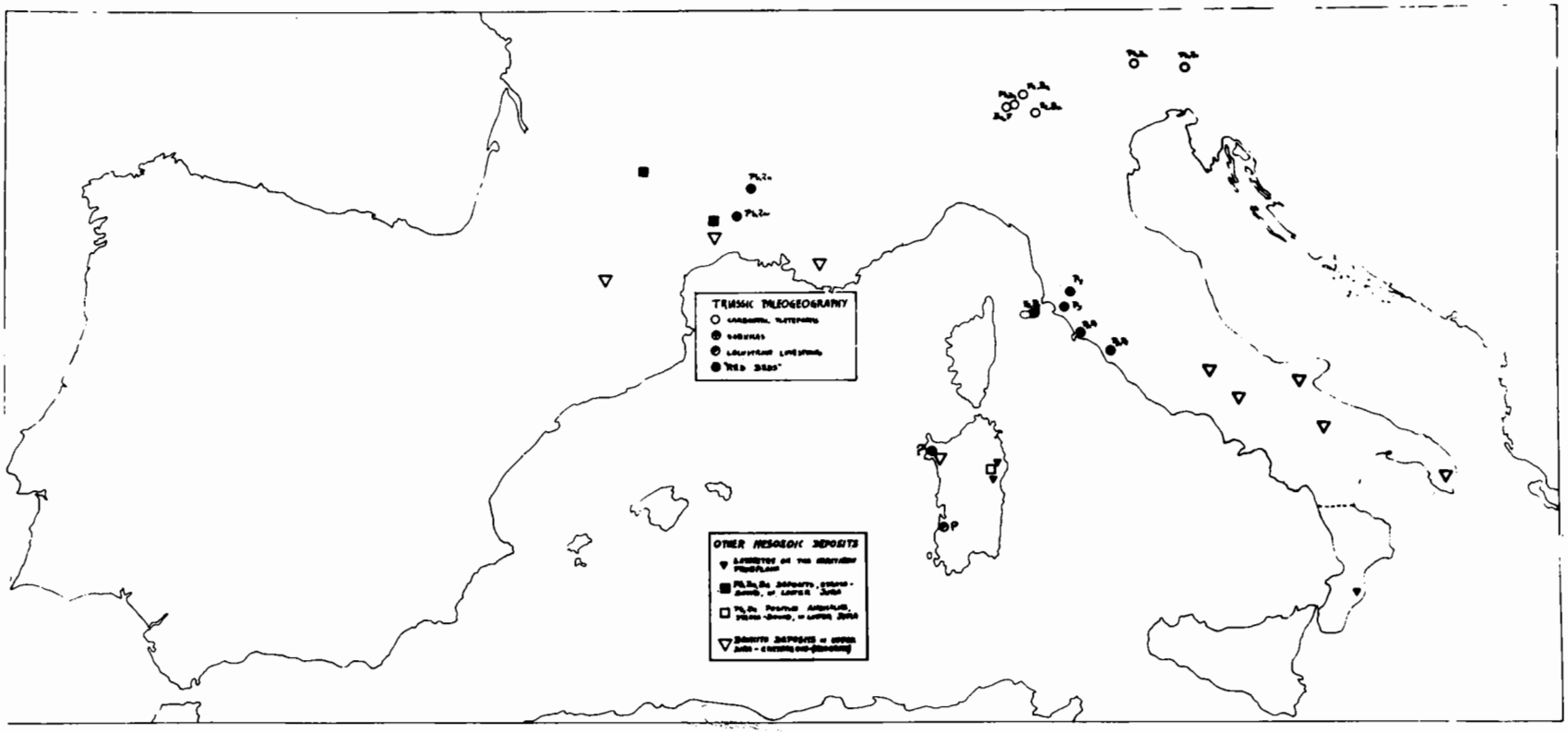

Fig. 5