Geo-tectonic evolution of the Sardo-Corsican massif and metallogeny of Sardinia

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With 2 Figures

Zusammenfassung

Die palaeogeographische Entwicklung des Sardo-Corsischen Massivs wird dargestellt. Während des Paläozoikums war das Massiv mit der Toskana verbunden. Zur Triaszeit setzte Krustendehnung ein und im Jura ereignete sich die Trennung des Massivs von der Toskana, wobei Sardinien-Corsica mit der europäischen Platte verbunden blieb, während in der trennenden Furche der Ozeanboden in Form der ligurischen Ophiolite in Erscheinung trat. Gegen Ende der Kreide wurde der Ligurische Trog geschlossen, weil der Afrikanische Kontinent sich wieder an Europa heranschob. Im Untermiozän begann das Massiv sich abermals von Europa zu trennen. Im Massiv ist der „Metallvorrat" in zwei Hauptgruppen von Vorkommen einzuteilen: in echte Lagerstätten und in Metallgehalte der Gesteine. Zumeist sind die Lagerstätten von den älteren (paläozoischen) Gesteinen abgeleitet; dabei sind exogene Bildungen bedeutender als endogene.

Geological History along the Thetys Evolution

After the end of the Paleozoic up to Messinian time, the Sardo-Corsican Massif was affected by a number of movements, that account for its present position and for the evolution of the Western Mediterranean.

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During the Upper Paleozoic Sardinia and Corsica were involved not only in the latest Hercynian collapses, but also in horizontal translations, along the North-Pyrenean transcurrent fault, approximately along the Provence area (ARTHAUD & MATTE, 1977b).

The former movements evidently affected also the basement of Tuscany, whose Paleozoic terrains appear strictly analogous to the Sardinian ones (CARMIGNANI & MECCHERI, in print). Thus some of the present major transverse faults of the Northern Apenines are likely to be related with the same fault system of late Hercynian age.

During this period Sardinia emerged and was characterized by structural highs and lows; a long continental period began, and a wide peneplanation was reached.

Also during the Mesozoic, extensive movements went on and intracratonic sea basins, controlled by different morphology, were formed (GANDIN et al., 1982).

At this time the western margin of the Massif (together with the adjacent north-western areas) wide platforms and shallow, narrow basins have been formed where Germanic facies sediments were being deposited, while its eastern margin represented the western border of the Triassic Alpine Basin.

In opposition to what some authors believe, the Punta Bianca (Tuscany) complex, which includes alkaline volcanics (RICCI & SERRI, 1976), is part of the eastern border of the last basin; this is also in agreement with the paleogeographic and structural situation of the Cape Argentario (DECANDIA & Lazzarotto, 1980; DECANDIA et al., 1980).

A transgression started in Triassic time and, during the Jurassic, extended gradually toward the eastern part of the Massif and on the platform a Provençal facies carbonatic complex was deposited. Confined pelagic episodes testify the presence, inside the platform area, of basins related to the synsedimentary extensive tectonics, that are the early signs of the opening of the Ligurian-Piedmontese oceanic basin.

The tearing of the sialic crust in the intracratonic Triassic Alpine Basin, during the Upper Jurassic, separated the Sardo-Corsican Massif from the Tuscan one (DURAND-DELGA, 1981). In fact an oceanic basin was formed, with simatic crust (ophiolites) and pelagic sediments, which evolved, in the Upper Cretatic, to flysch. After the tearing of the sialic crust, the Sardo-Corsican Massif continued evolving together with the stable side of the European plate up to present, while the Tuscan basement followed the new evolution phenomena of the Apennines continental margin.

The paleographic differentation, which was evident since Cretaceous time with carbonatic platform sediments on the western side and a mainly pelagic deposition on the eastern one (FOURCADE et al., 1977), is consistent with such a structural evolution.

Nearly at the end of the Cretaceous, the closure of the Ligurian-Piedmontese basin commenced and, as a consequence of the consumption of the related simatic crust, the African continent approached again the European one. The collision took place during the Middle Eocene. However, it has to be pointed out that clear evi-

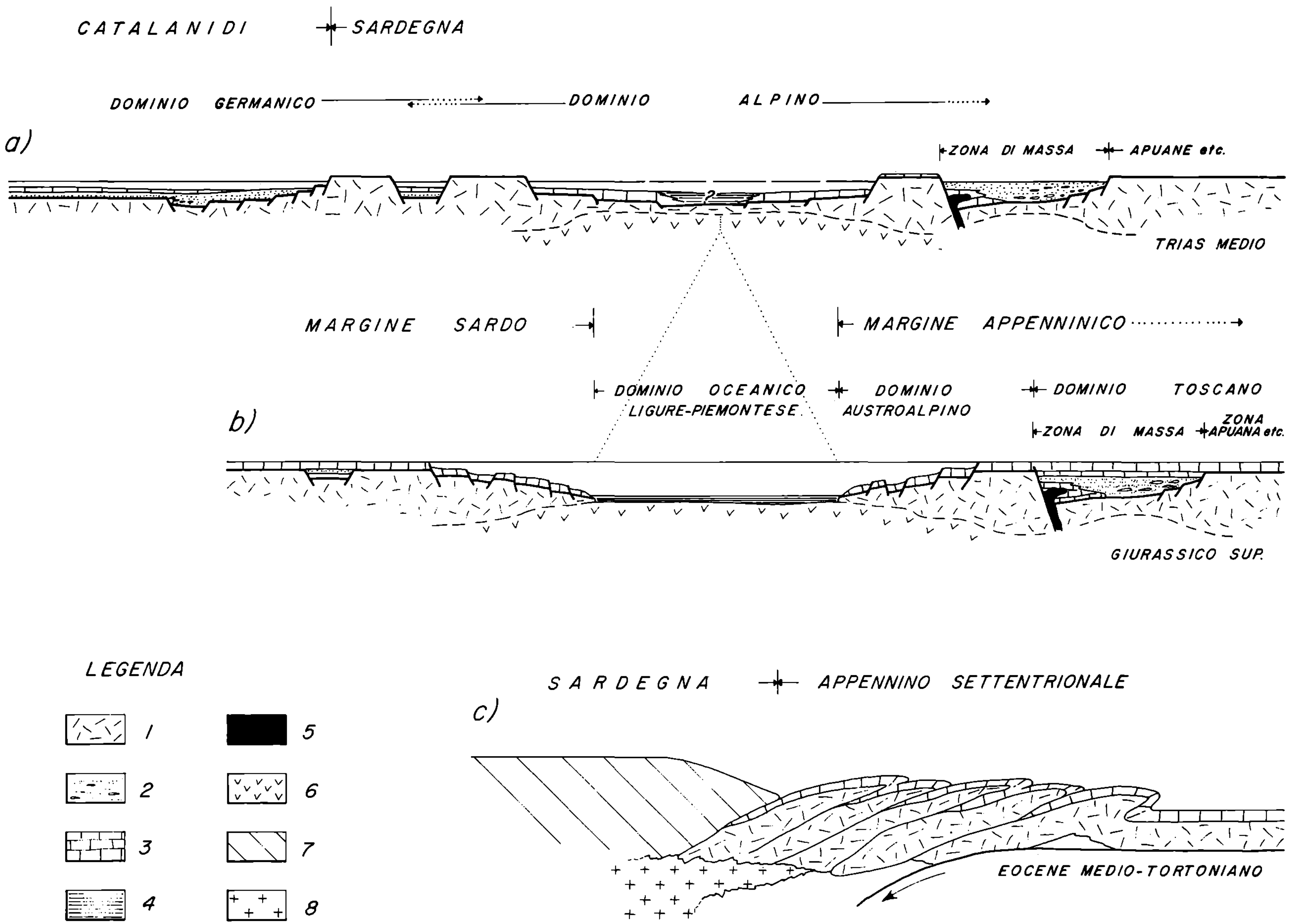

Fig. 1. Interpretative sections (not in scale) relative to the main phases of tectonic-sedimentary evolution of the Western Mediterranean. Section C from BOCCALETTI et al. (1981). — 1 = Pre-triassic basement; 2 = Mostly continental deposits; 3 = Platform marine deposits; 4 = Pelagic deposits; 5 = Alkaline volcanics; 6 = Oceanic lithosphere; 7 = Basement and cover; 8 = Synkinematic granites.

dence of compressive phenomena related to this event are lacking in Sardinia. On the contrary, all its post-Hercynian evolution seems to be characterized by distension phenomena (ALVAREZ & COCOZZA, 1974).

After the collision, the structural evolution of the Apennine chain strictly matches with that of the Sardo-Corsican Massif. During the Upper Eocene, extension structures developed in Sardinia (COCOZZA & SCHÄFFER, 1973); these structures caused, in the Lower Miocene, the separation of the Massif from the stable Europe and then its counterclockwise rotation. At the same time, in the Apennines, the ensialic tectonics started with the deformation of the continental margin, that became shortened by overthrusting phenomena, which are younger and younger eastwards (BOCCALETTI et al., 1980).

Some Sardinian structural lows were covered by epicontinental seas, some formed lagoonal or lacustrine basins.

During the Oligocene continental conditions prevailed, and an intense calc-alkaline magmatic activity, related to the rotation of the Massif, developed.

After this long continental phase, during the Miocene the sea covered the area of the "Sardinian Rift" and separated two emerged areas: the western one and the eastern one. This transgression, characterized by mainly terrigenous deposition, is related to the opening of the Algerian-Provençal basin (BARBERI & CHERCHI, 1980).

In the Upper Miocene almost the whole Sardinia emerged again, only a few, marginal areas being still characterized by lagoonal conditions.

In that moment the counterclockwise rotation stopped, and an alkaline magmatism followed; at the same time the extension phase commenced in the area of the Apennines.

The Metallic Stock in the Sardinian Paleozoic Terrains

As a metallic stock we mean the presence of "metallic" elements of economic interest, apart from their concentrations and mineralogical framework. However, two groups mut be considered:

a) anomalous concentrations of "metallic" elements (ranging from geochemical anomalies up to ore-bodies);

b) presence of "metallic" elements in rock-forming minerals (in normal concentrations, according to rock types).

Taking into account these definitions, we can divide the paleozoic Sardinia into a few main sectors, characterized by the presence of a given set of elements and by their relative abundance.

NW Sector (Nurra). It is the smallest of the Paleozoic sectors, and completely separate from the others.

In it a few ore bodies (group a) are known: Pb-Zn veins of some importance, Sb veins of lesser importance, and Fe lens-shaped bodies exploited in the past; in granites and metamorphic rocks (group b) Fe and Al are occuring.

NE Sector (Gallura-Logudoro-Nuorese). In this sector, mainly granitic, many ore-bodies (group a), mainly vein-shaped, are known, but their importance is low; they contain Pb-Zn ores, barite and fluorspar. Cu, Mo (and minor W) are known in a few localities as low-grade disseminated and stockwork mineralization or scattered veinlets, in intrusive rocks. Also a few lens-shaped Fe-bearing bodies are known in roof-pendants. The group b includes Al, Fe and heavy minerals (especially monazite) in granitic and metamorphic rocks. Also U as geochemical anomalies (group a) in microgranites has been reported.

SW Sector (Arburese-Iglesiente-Sulcis). Many and important ore-deposits of several types (group a) are known in this sector. They can be summarized as follows: Pb-Zn in vein-shaped and stratabound bodies, numerous and often important; a few veins of minor importance bear minerals of Sn, Ni, Co and As; F and Ba are widespread in vein-shaped and stratabound bodies, sometimes important; mixed sulphides (mostly Pb-Zn and minor Cu) in numerous lens-shaped bodies; also widespread, but seemingly less important, Mo and minor W in greisen-type mineralization, and disseminations and quartzose veinlets in granites; a few lens-shaped bodies contain Fe and less W and F; yet, for the group a, geochemical U anomalies in microgranites are known. For the group b, still Al, Fe and heavy minerals in granites and metamorphic rocks are worth mentioning.

SE Sector (Barbagia-Ogliastra-Sarrabus-Gerrei). Also in this sector several ore-bodies (group a) are known. Veins containing F-Ba and minor Pb-Zn-Ag are widespread and sometimes important. Frequent, but less important, are mixed sulphide ores (Pb, Zn, Cu, Fe, As) in lens-shaped bodies.

Scarce, but exploited in the past, stratabound Sb-ores with minor amounts of W are existing.

In the intrusive rocks, poor disseminations of Cu and less frequently Mo, as well as a few veins containing Mo (-W-Sn) minerals are known. Always Fe, Al and heavy minerals represent the group b in granitic and metamorphic rocks.

Metallogenic Process in Sardinia during the Tethyian Evolution

The previous outline of the geological history shows that Sardinia, in the Thetian domain, represented a continental fragment, episodically covered by shallow seas. Thus its metallogenic evolution is dominated by the following phenomena:

i) the long continental period after the Hercynian uplift;
ii) the recurrent marine transgressions;
iii) the intense volcanic activity in Tertiary times, with possible intrusive episodes;
iv) the final general uplift.

On the basis of these elements, two main groups of metallogenic events must be distinguisched:

A—Exogenous phenomena: they include all the processes of erosion and leaching in subaerial environments, those of deposition in continental and marine basins, and phenomena of mobilization and remobilization. In all these processes almost only "metals" inherited from Paleozoic rocks are involved.

B—Endogenetic phenomena: they are related to the phases of magmatic activity.

A Paleozoic heritage is likely in some cases, while in other cases a supply of "new" elements is more probable.

Group A. The occurrences belonging to this group are numerous and sometimes important. On the basis of the already described main characters of the evolution of Sardinia, they can be further subdivided as follows.

1. Mobilization and remobilization phenomena: They started in connection with the erosional cycle subsequent to the Hercynian uplift in the Upper Paleozoic. During the Mesozoic the landscape reached the stage of senility, and consequently these processes became less and less active. The rejuvenation related to the Alpine uplift activated similar phenomena, that are often superimposed on the older ones, so that it is difficult to make a distinction between the two phases.

From the economic point of view, the mobilization processes were effective only in already mineralized carbonatic rocks, i. e. in the Cambrian districts of the south-western part of the island (Fig. 2, site a). The ore-bodies are mainly the result of the filling of karst cavities (PADALINO et al., 1973). The main ore minerals in these bodies are: barite (MARCELLO et al., 1983), galena (sometimes very rich in silver) and oxidized lead minerals, oxidized zinc minerals. Important lead and zinc occurrences are known, and exploited, near Iglesias.

In rocks other than carbonatic, these phenomena, even though frequent, and displaying a wider range of minerals (at least Ag, Ba, Cu, F, Fe, Pb, U and Zn minerals are known), never gave birth to economic occurrences. The most remarkable example consists of thin fracture fillings and veinlets of oxides and phosphates of uranium, in thermometamorphic rocks at the north-eastern edge of the Sulcis granite (Fig. 2, site b).

All the "metals" involved in these processes were present in the Paleozoic rocks mostly as both true ore bodies and geochemical anomalies; only Fe was present also as a normal component of the rocks. Thus we can infer the origin of the most part of these ores from a stock of type (a).

2. Sedimentation in lakes, lagoons, coastal basins: Many of the known deposits are related to Mesozoic sediments. In other cases their age is uncertain, ranging from Permian to upper Tertiary or even Quaternary times.

They can be classified in four main types.

i) Thin-bedded barite-galena-silica layers (BRUSCA et al., 1971) (Fig. 2, site a). The known occurrences, associated with sandstones, are always related to the Cambrian carbonatic rocks, in a senile morphological framework (post-Hercynian peneplain). Althoug they are not yet dated, a relation between them and the Sulcis Basin of Eocene age is likely. Their rich content in $BaSO_4$ and the proximity to the main remobilized barite-bearing bodies allow their economic exploitation, in spite of their generally small size. Both barite and galena of these beds belong to type (a) stock.

ii) Pb-Zn (and minor Cu) sulphides in carbonatic depositions. Only one, very small example is known in central-eastern Sardinia (SALVADORI & ZUFFARDI, 1966) (Fig. 2, site c).

Its stock is always of type (a). A few other occurrences are but geochemical anomalies.

iii) U oxides and phosphates in fluvial-lacustrine clays, associated with carbonized wood. Only one occurrence has been discovered so far; it is a small basin in a granitic area (northern Sardinia) possibly of late Tertiary-Quaternary age, as its morphological characteristics allow to infer (Fig. 2, site d). The uranium was supplied by the surrounding granites, where it occurs in geochemically high values [type (a) stock].

iv) Fe oxides, associated with clays and/or carbonatic rocks (MARINI, 1983) of the basal Mesozoic in central Sardinia (Fig. 2, site e).

The ores occur both as impregnation of the Paleozoic footwall rocks (thus belonging rather to the next subgroup) and as thin beds in the Mesozoic.

These occurrences are widespread and remarkably extensive, but never reach a satisfying thickness. The stock of the iron is likely to be both of type (a) and of type (b).

3. Residual concentration: Two types of deposits developed from the Mesozoic onwards. The first one is related to the long lasting continental conditions in the Cambrian area; it consists of mainly clastic accumulations of barite with minor galena (Fig. 2, site a). One important occurrence is known, and exploited near Iglesias; others are less explored, and some might be important. The stock is obviously of type (a); for the younger occurrences, related to the last rejuvenation, at least a part of the ore is likely to stem from post-Paleozoic bodies belonging to the subgroups 1 and 2.

The second type is related to an infra-Cretaceous continental phase in the Mesozoic basin of north-western Sardinia (Nurra) (Fig. 2, site f). It is a fairly continuous bauxite bed, resting on carbonatic rocks; the interest in them is growing more and more as the exploration goes on.

The stock of the aluminium is obviously of type (b).

4. Alluvial and eluvial accumulation of Tertiary and Quaternary age. Barite, with minor galena, is known in scarcely explored, perhaps important occurrences, always in the Cambrian districts (MARCELLO et al., 1983) (Fig. 2, site a). The stock is of type (a), possibly derived from both Paleozoic and post-Paleozoic pre-existing bodies.

Interesting placer indications of other heavy minerals (mostly monazite, cassiterite and Fe-Ti minerals) have been discovered in recent times (MARCELLO et al., 1978).

Their stock is mostly of type (a), but some occurences of Fe-Ti minerals, that have been known for several tens of years along the north-western coast, emanate from Tertiary volcanic rocks, thus a post-Paleozoic stock of type (b).

Group B. The endogenetic ore-forming phenomena did not give rise to orebodies comparable, in size and importance, to those of the former group.

A further division of this group is possible, as follows.

1. Hydrothermal veins. Several, but worthless veinlets occur in Tertiary volcanic rocks of the western half of Sardinia, mainly barite-bearing (MARCELLO et al.,

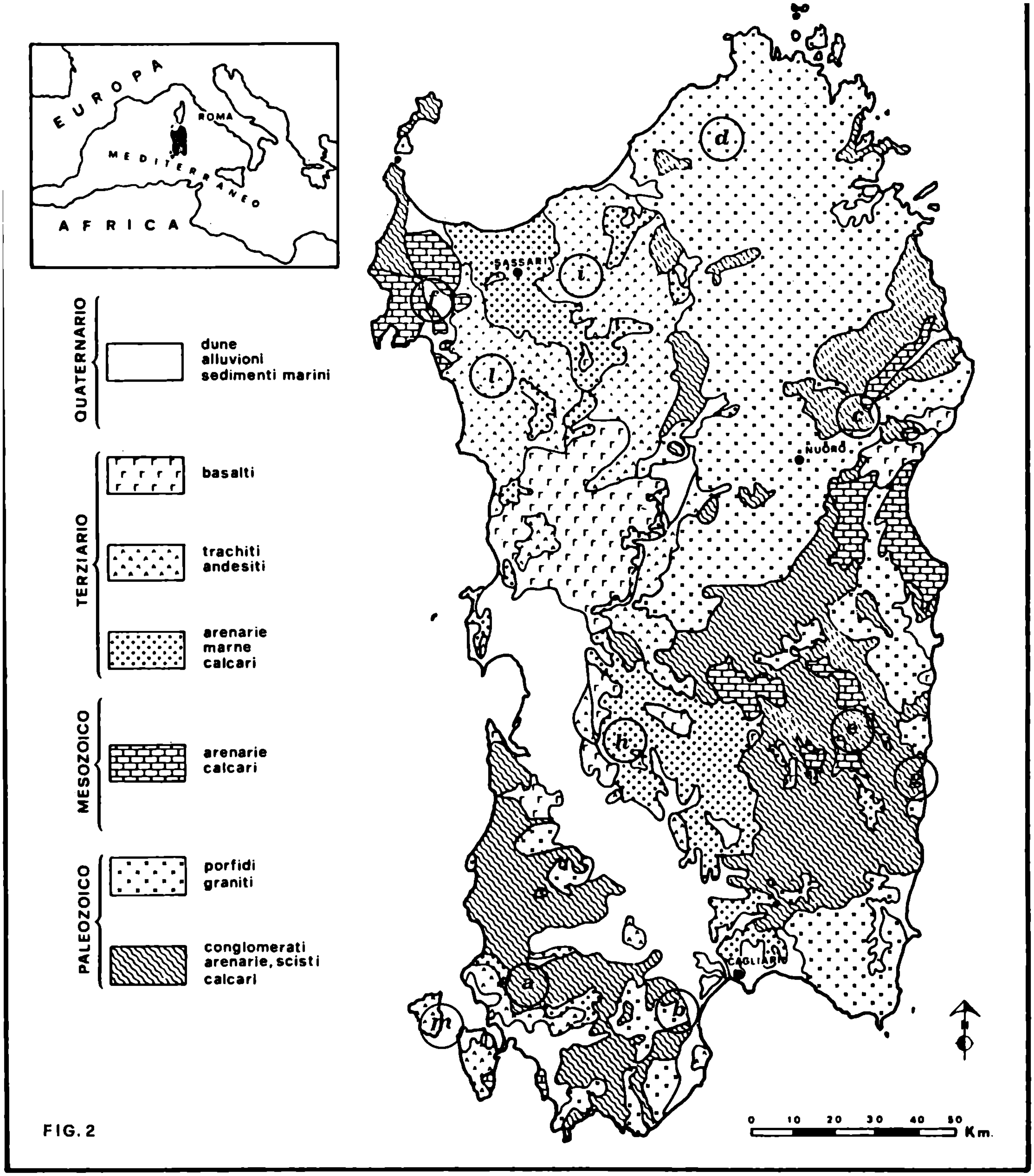

Fig. 2. Ore occurrences and indications in post-Paleozoic terrains.

a – Ba-Pb-Zn in bodies of various origins: mobilized and remobilized, sedimentary (clastic to chemical), residual (numerous and often important occurrences).

b – U oxides and phosphates mobilized in veninlets (single occurrence).

c – Pb-Zn sulphides in carbonatic rocks (one occurrence and a few indications).

d – U oxides in continental clays, associated to organic matter (single occurrence).

e – Fe oxides in thin beds and impregnations (several occurrences).

f – Bauxite interbedded in carbonatic rocks (broad occurrence)

g – Barite in veins (elongated vein system).

h – Fluorspar in veins, associated to volcanic rocks (one occurrence, a few indications).

i–l – Mn in stockworks and lenses, and disseminated Cu-Fe sulphides, in volcanic rocks (several occurrences and indications).

m – Mn in beds, stockworks, and veinlets (several occurrences).

1983). The only noteworthy barite occurrence is a NS-striking vein system, in the south-western sector, hosted in Paleozoic terrains (Fig. 2, site g).

Isotopic studies on these barites commonly show heritage from Paleozoic rocks.

Also very small are a few fluorite occurrences, both in volcanic and sedimentary Tertiary rocks (CAVINATO, 1954); among them, only one vein-shaped occurrence in central Sardinia was an object of prospecting (Fig. 2, site h). Also in this case, a Paleozoic heritage is likely. A last occurrence, an iron-bearing vein in tertiary volcanics in central-western Sardinia, was also explored, and abandoned. Its iron ore may or may not be inherited.

2. Volcano-sedimentary Mn bodies (Fig. 2, sites i, l, and m). They occur in the western side of Sardinia, strictly related to Tertiary volcanic rocks (URAS, 1965). These occurrences, both stratiform and stockworks, were explored and partially exploited in several places in the past; to-day they are under re-examination.

While Mn looks to be a "new" metal in Sardinia, in some occurrences of the northern districts also W was detected in several assays; this last metal might be inherited from Paleozoic rocks.

3. Stockworks and disseminated occurrences of mainly Cu-Fe sulphides in Tertiary calc-alkaline volcanics (Fig. 2, sites i and l). Several indications of this type are known, but exaustive investigations have not yet been performed. Even though copper-bearing mineralization is known in Paleozoic terrains, a porphyry-copper-type phenomenon of formation of these bodies should exclude any important derivation from occurrences of this kind.

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