Verh. Geol. B-A.	Jahrgang 1978	Heft 3	S. 279–283	Wien, Dezember 1979
Proceed. 3rd ISMIDA (Leoben, Oct. 7–10, 1977)			S. 105–109	Wien, Dezember 1979

Structural Control of Mineralization in the Apuan Alps (Tuscany, Italy)*)

By L. CARMIGNANI, G. DESSAU and G. DUCHI**)

With 1 figure

Schlüsselwörter

Apuaner Alpen
Erzmineralisation
Tektonik
Barite
Deckenbau
Geochronologie

Abstract

The strongly uplifted and deeply eroded massiv of the Apuan Alps allows deep insight into the overall nappe structure of the Northern Apennines. Its present setting is the result of several tectonic phases. The lowest unit, the so-called "Autochthon", contains several polymetallic and barite deposits, which originated during the first tectonic phase and were later metamorphosed.

1. The geological background

The "Apuan Alps", a mountain massif roughly ellipsoidal in shape, stretches 30 km in a NNW–SSE direction along the Tyrrhenian Sea. They constitute a tectonic window where the most complete succession of the tectonic units of the Apennines is exposed. Besides one metamorphic rock-type of outstanding economic value, – the "Carrara marble" – they also contain small deposits of various ores and barite.

We know from classical literature that the marble quarries were flourishing at least since Roman times. Most probably, the mines of iron, lead and silver go back to the same, if not to greater depths of antiquity, but historical records are available only since the Middle Ages. The exploitation of the ores terminated a few years ago, and only barite continues to be mined today (apart from the quarrying of marble).

The structurally lowest unit is a sequence characterized by syntectonic greenschist facies metamorphism. It ranges in age from at least Silurian to Oligocene. We maintain for it the traditional name of "Autochthon", and we distinguish a basement of Paleozoic phyllites, porphyroids presently considered to be Permian, and quartz pebble conglomerates and quartzites ("Verrucano") of Lower Triassic age. The basement is overlain by a cover beginning with Upper Triassic dolomitic limestones ("Grezzoni") and by the Liassic marble. This is followed by a mainly carbonatic sequence and by an Oligocene flysch ("Pseudomacigno").

*) Research carried out with grants from the Italian Council of Scientific Research.

**) Author's addresses: Institute of Geology and Paleontology, University of Pisa, 56100 Pisa, Via S. Maria 53.

The "Autochthon" is structurally overlain by the "Tuscan Nappe", a sequence similar to the Mesozoic and Tertiary portion of the "Autochthon", but it is not metamorphosed and it begins with Triassic evaporites. Interposed between the two units is the "Massa Unit", a set of tectonic slices, which might have been the original basement of the Tuscan Nappe.

The Tuscan Nappe is in turn overlain by eugeosynclinal sequences, the "Ligurian Nappes", which as a result of erosion are presently exposed only on the periphery of the massif.

The actual setting of the Apuan Alps, as schematicaljy shown in its tectonic evolution as in Fig. 1 (showing also the emplacement of the mineral deposits), is the result of three Oligo-Miocene compressive phases, followed by a Plio-Quaternary distensive phase.

During the first compressive phase – by far the most important one – the "Autochthon" was metamorphosed, overthrusted by the Tuscan and Ligurian Nappes, and subsequently altered into large-scale isoclinal recumbent folds. Most of the crustal shortening across the massif occurred during this phase, which according to radiometric investigations by KLINGFIELD, HUNZIKER & SHAMEL (1977) is dated at 26 m. y. The second phase generated folds with axes at right angles to the prevailing NNW–SSE trend of the massif, whereas the third phase affected the whole sequence with its large folds trending again in the NNW–SSE direction, – having westward vergences on its western and eastward ones on its eastern flank. The result was that the whole massif assumed the shape of a large conjugate box fold. The radiometric age of the third phase is 11–14 m. y.

The uplift of the fault-bounded massiv is related to the late, Plio-quaternary distensive phase.

The mineralizations are related to the first tectonic phase, which had generated isoclinal recumbent folds. These were accompanied by a penetrative axial plane schistosity (S_1), which often completely transposed the original bedding, resulting in L–S tectonites.

The greatest first-phase folds sometimes have lower limbs extending 2–3 km. These structures are often accompanied by ductile faults parallel to the axial plane of the folds, which at a late stage can develop into true overthrusts. As we shall see, these late tectonic surfaces are the structural guides for the most important mineralizations.

On the S_1-surfaces an extension lineation is well developed, which trends NE-SW in the whole massif. On the other hand the hinge lines of the first major and minor folds do not maintain a constant attitude, but form variable angles with the extension lineation.

On the western slope of the metamorphosed Apuan Alps the first phase axes trend NW–SE, and therefore form an angle of 90° with the extension lineations. Advancing further to the East these axes gradually rotate, until they grow parallel to the extension lineation (CARMIGNANI & GIGLIA, 1977). The progressive change towards parallelism between the direction of maximum extension and the first phase fold axes is well known in the case of considerable stretching due to simple shear (SANDERSON, 1973; ESCHER & WATTERSON, 1974).

Summing up, the structural investigations of CARMIGNANI, GIGLIA & KLIGFIELD (1977) show that the Apuan metamorphic complex exhibits flat-lying schistosities, strongly developed mineral extension lineations, rotated fold axes, L–S tectonites, which, according to ESCHER & WATTERSON (1974) and MATTAUER (1975), are all characteristic of mobile belts. The latter are gently dipping, deep-rooted shear zones, found in orogenic belts associated with great overthrusts.

The Apuan mobile belt originated on the western margin of the Italo-Adriatic continental crust, as a result of the collision with the Sardinian-Corsican continental fragment. The accompanying shears might have supplied the channelways for the mineralizing fluids, perhaps coming from a syntectonic acid magma. These fluids deposited the epigenetic mineral deposits, all of which belong to the first tectonic phase.

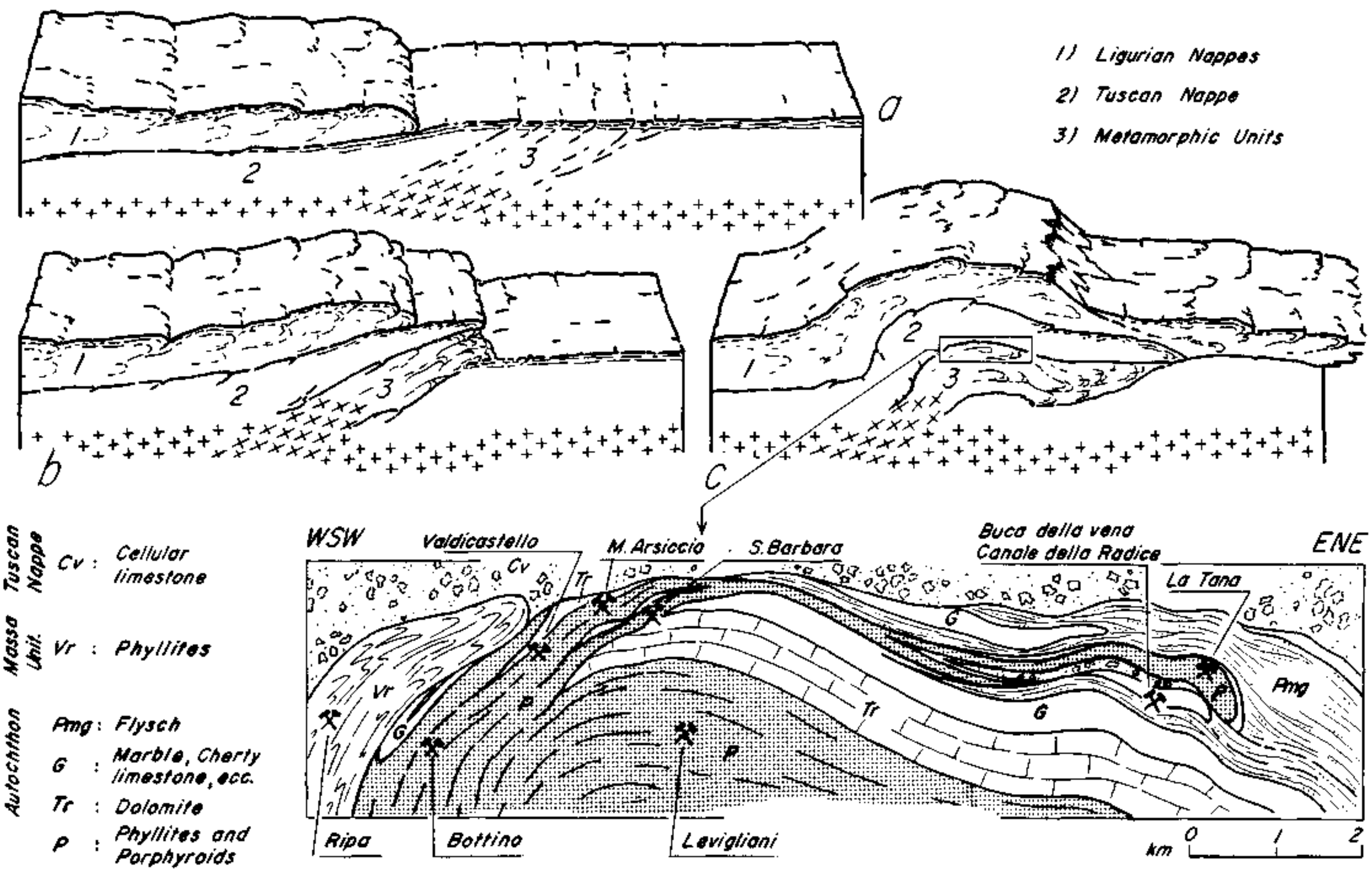

Fig. 1: Tectonic evolution of the Apuan Alps. a and b = Two stages in the evolution of the first tectonic phase. c = The late tectonic phases refold the overthrusts and the structures of the first phase. At the bottom = Interpretative section of the Southern Apuan Alps, with the mineral deposits in place.

2. The Mineral Deposits

We shall only briefly mention the insignificant ores of sedimentary origin within the "Autochthon" of the northern part of the massif:

near Vagli; quartz stringers with some chalcopyrite, probably originated through the geochemical concentration of Cu contents of the Cretaceous-Eocene sediments (now metamorphosed into sericitic slates), and near Scòrtico; a seam of manganese silicates and carbonates of a metamorphic paragenesis, interstratified within the same formation.

The epigenetic, mineral paragenesis, of any present or past importance include:

1. Polymetallic veins of galena, sphalerite and lead-antimony sulphosalts in chiefly quartzose gangue, situated in the basement of the "Autochthon".

2. Deposits of barite, pyrite and iron oxides, with traces of sulphides and sulphosalts, located mainly in metasomatic bodies in the dolomitic limestones of the Upper Trias, but also in veins in the basement of the "Autochthon" and in the phyllites of the "Massa Unit".

3. Small quartz veins with cinnabar in the phyllites of the "Autochthon" and of the "Massa Unit".

These deposits are all clustered in the southern part of the massif, around Monte Lieto and Monte Ornato, where epigenetic tourmalinization is widespread near the contact zone between the "Autochthon" and "Massa Unit". For their setting within the stratigraphic and tectonic framework, we refer again to Fig. 1.

Not fitting within this scheme is the paragenesis:

4. The frigido vein farther north, a rather undisturbed fissure vein cutting through the phyllites of the "Massa Unit". Its main ore is spatic siderite, – with some calcopyrite containing cubanite and sphalerite starlets, some pyrite with pentlandite, and traces of several other sulphosalts, such as fahlerz, ullmannite, vaesite, etc.

The only important example of paragenesis (1) is the vein known as the "Bottino vein", which strikes NW–SE for several km through the Paleozoic phyllites, more or less conformably with their schistosity (S_1). It is folded and tectonized by the later compressive phases. Its main ores are galena, extremely Fe-rich sphalerite, chalcopyrite, pyrrhotite, and in addition to tetrahedrite, a whole array of silver-rich lead-antimony-sulphosalts (as well known from metamorphic deposits). Quartz is the dominant gangue-type, often studded with microscopic tourmaline needles, and Sn is present in traces. The brittle gangues are strongly cataclastic and kneaded with the ores, which also show evidence of the endured stresses. In vugs, however, the iron-rich sphalerite and all other ores and gangues are found in excellent, totally undisturbed condition, therefore testifying to post-tectonic crystallization. The vein also shows zoning vertically and along its strike. In the vicinity, unimportant outcrops within the marble are more copper-rich, containing Hg-bearing tetrahedrite and much fluorite as well.

We have grouped as "Paragenesis (2)" the deposits of barite, pyrite and iron oxides, which appear, however, in two completely different settings, – namely in fissure veins within the phyllites, and in replacement lodes in the dolomitic limestones (and sometimes in marbles). They occur along tectonic or stratigraphic contacts between the carbonatic and the phyllitic rocks, always within the "Autochthon". At Valdicastello barite veins cut ore veins of Paragenesis (1), and therefore are somewhat younger, although belonging to the same tectonic phase.

The most important deposit, belonging to the second type and presently under exploitation, is the one of Monte Arsiccio. It has already produced around one million tons of barite, as well as minor quantities of pyrite and iron oxides. It shows vertical zoning, with pyrite towards the phyllites at the bottom, and iron oxides (we presume derived from siderite) towards the upper contact with the carbonatic rocks. For a tentative physico-chemical explanation of these characteristics we refer to our forthcoming paper (Carmignani, Dessau & Duchi, 1976). Notwithstanding the different settings, there are similarities between the barite veins and the lodes, – for instance traces of the same sulphides and sulphosalts, and the fairly uniform strontium contents (see later); the sulphosalts point also towards Paragenesis (1). The veins might have been the feeders of the lodes. Evidence against a sedimentary origin of the lodes is their emplacement frequently along tectonic contacts, and replacing rocks of different ages. A further example of the Monte Arsiccio-type deposit is the smaller one of Buca della Vena near Stazzema.

According to Barbieri, Masi & Tolomeo (in print), and to the kind verbal information of Barbieri, the strontium content (7 analyses for the three deposits) is fairly uniform, near 5000 ppm, and might have been extracted by a convective circulation from the generally Sr-bearing Tuscan evaporitic rocks. Although the same explanantion is tentatively advanced also for the barium contents, the latter would rather point towards the Ba-contents of the feldspars of a magmatic rock.

Paragenesis (3) is represented by two practically monomineralic vein deposits; of cinnabar in quartz gangue, at Levigliani within the Paleozoic of the "Autochthon", and at Ripa within phyllites of the "Massa Unit", now attributed to the Trias. The Ripa vein shows the same significant feature of the Bottino vein – vugs with undisturbed, perfect ore crytals within a surely tectonized vein.

As schematically shown in Fig. 1, the more important mineral deposits are within the "Autochthon", in the proximity of the overthrust of the "Massa Unit". Smaller deposits are instead contained in slices ("Parautochthonous slices of Stazzema") torn from the Autochthon and transported to the north-east by the Tuscan Nappe. The latter deposits are therefore uprooted, without continuity in depth. On the other hand the "Autochthon" might deserve further investigation where it is hidden below the "Massa Unit".

The age of the Apuan deposits is of the order of 26 m. y., whereas the far more important ore deposits of Southern Tuscany are connected with post-tectonic granitic intrusions aged 7 m. y. or less. The two groups of deposits belong therefore to different metallogenic cycles.

References

The present "abridged version" has space for a few principal references only, quoted below. In these, and in the "full version", detailed bibliographies may be found.

Barbieri, M., Masi, U. & Tolomeo, L.: Significance of strontium for the origin of the epithermal barite deposits from the Apuan Alps (north–western Tuscany, Central Italy) – In press, 1978.

Carmignani, L., Dessau, G. & Duchi, G.: I giacimenti minerari delle Alpi Apuane e loro correlazioni con l'evoluzione del gruppo montuoso. – Mem. Soc. Geol. It., **11**, 417–431, Roma 1972.

Carmignani, L., Dessau, G. & Duchi, G.: Una mineralizzazione sintettonica: il giacimento di Valdicastello (Alpi Apuane). – Boll. Soc. Geol. It., **95**, Roma 1976.

Carmignani, L. & Giglia, G.: Analisi mesostrutturale della zona occidentale delle Apuane metamorfiche. – Boll. Soc. Geol. It., **96**, Roma.

Escher, A. & Watterson, J.: Stretching fabrics, folds, and crustal shortening. – Tectonophysics, **22**, 223 – 231, 1974.

Kligfield, R., Hunziker, J. C. & Schramel S.: K/Ar ages of multiply deformed metasedimentary rocks from the Alpi Apuane, Northern Apennines, and their tectonic implications (Abstract). – Paper read at the "ECOG V – Fifth European Colloquium of Geochronology, Cosmochronology and Isotope Geology", Pisa, 5–10, Sept. 1977.

Mattauer, M.: Sur le mécanisme de formation de la schistosité dans l'Himalaia. – Earth and planetary science letters, **28**, 144–154, 1975.

Sanderson, D. J.: The development of fold axes oblique to the regional trend. – Tectonophysics, **16**, 55–70, 1973.