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SIGNIFICANT ORE FABRIC RELATIONSHIPS IN THE LEAD, ZINC, FLUORITE AND BARITE DEPOSITS OF THE TRIASSIC PROVINCE (ITALIAN SOUTHERN ALPS) [1]

by

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(1 figure, 1 table and 1 plate)

RESUME.- L'analyse géologique des secteurs exploités ou en exploitation de la province triasique à Pb, Zn, fluorine, barytine des Alpes Méridionales italiennes a démontré que la caractérisation métallogénique relative se fonde sur l'association d'événements d'âge triasique et post-triasique :

a) à l'échelle régionale : évolution sédimentaire et métallogénique différenciée de la séquence permo-triasique en correspondance d'éléments structuraux préexistants ("plateformes" et "bassins");

b) à l'échelle du district minier : localisation des concentrations économiques en liaison avec des situations paléogéographiques particulières (métallotectes triasiques);

c) à l'échelle du dépôt minéralisé (exemples : gisements plombo-zincifères de Gorno, Raibl, Salafossa) : évolution différenciée de la minéralisation "primaire" à sulfures de Pb-Zn, contrôlée par la persistance (p. p.) à l'époque post-triasique des paramètres géologiques définissant les métallotectes triasiques originels.

d) à l'échelle des corps minéralisés : variations significatives de paragénèse, texture et géochimie des minéralisations à sulfures en connexion avec les processus évolutifs indiqués en c).

La prospection en cours se développe par la vérification progressive des points a), b), c) et d). Les premiers résultats ont été atteints en Valcamonica (Lombardie) et Valbruna (Frioul) avec la découverte de minéralisations inédites à fluorine et sulfures de Pb-Zn.

ABSTRACT.- Detailed studies carried out on the exploited areas of the lead, zinc, fluorite and barite Triassic province of the Italian Southern Alps show that the related metallogenetic characterization must be regarded as the consequence of concurrent Triassic and post-Triassic geological events :

a) on the regional scale : differentiated sedimentary evolution and ore distribution along the Permo-Triassic sequences, controlled by pre-existing structural "platforms" and "basins";

b) on the ore district scale : individualization of economic ore-enriched areas in connection with "special" Triassic paleogeographical situations;

c) on the ore deposit scale (selected examples : Gorno, Raibl, Salafossa lead-zinc deposits) : differentiated post-depositional ore evolution, influenced by the local persistence in post-Triassic times of some geological parameters conditioning the original Triassic metallotects;

d) on the orebody scale : significant paragenetic, fabric and geochemical variations of sulfide ores, in connection with the evolution processes indicated at the point c).

Outstanding ore exploration, in progress over the remaining areas of potential ore-enrichment, relies upon the gradual verification of the above-mentioned assumptions. First positive result is the discovery of new mineralized zones in the Lombardic and Carnian regions.

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FOREWORD

The Triassic Southalpine lead, zinc, fluorite and barite province in Northern Italy includes some economically very important deposits : Gorno (Bergamo), Salafossa (Belluno) and Raibl (Udine). The comprehensive ore production of these deposits up today amounts to about 2.5 million tons of metal (lead + zinc). Together with the famous Bleiberg-Kreuth (Austria) and Mežica (Jugoslavia) mines, the Italian deposits pertain to the "strata- and time-bound alpine ores" (MAUCHER & SCHNEIDER, 1967).

Former studies (Gorno : VACHÉ, 1966; OMENETTO, 1966; VAILATI, 1966; FRUTH & MAUCHER, 1966; Salafossa : COLBERTALDO (Di) & FRANCESCHETTI, 1960; LAGNY, 1969, 1974, 1975; Raibl : COLBERTALDO (Di), 1948, 1967; ROMAGNOLI, 1966; ZELLER, 1970) deal basically with the genetic aspects of ore concentration (syngenetic/Triassic *versus* epigenetic/Alpine). Recent studies, essentially taking into account the geological evolution of the ore concentration environments (both on the regional and ore district scale) proved that there is a close genetic connection between the distribution of the mineralization (with its present facies) within well-defined geological volumes and a significant association of paleogeographic and paleotectonic parameters of Triassic age (ASSERETO *et al.*, 1976; BRIGO & OMENETTO, 1976; ASSERETO, JADOUL & OMENETTO, 1977; ASSERETO *et al.*, 1977; BRIGO *et al.*, 1977; BRIGO & OMENETTO, 1977; OMENETTO & VAILATI, 1977; RODEGHIERO, 1977; BRIGO & OMENETTO, 1978; RODEGHIERO & VAILATI, 1978;JADOUL & OMENETTO, 1978, 1980). Nevertheless, ore facies (fabric, minor element geochemistry, sulfur isotopes, physiography) varies considerably within the single deposits and from one to another. Detailed analysis indicates that these facies changes are connected to the persistence in post-depositional times and within the same original metallotect, of some "protore" concentration parameters. The subsequent phases of the progressive, polyphasic ore evolution are still partly recognizable in the different ore facies and, for certain deposits, suggest possible ore re-deposition during very recent geological times.

TRIASSIC METALLOGENESIS

ON THE REGIONAL SCALE

In the Southern Alps, some regionally extended, N-S-trending structural features (Luganese, Atesine and Julian "platforms"; Lombardic and Carnian-Bellunese "basins") controlled the paleogeographic evolution of the Permo-Triassic sedimentary cover overlying the crystalline basement (fig. 1). The sequences are discontinuous and condensed on the "platforms", thick and complete in the "basins" (BOSELLINI, 1965). In this context, the metallogenic evolution of the "platforms" and "basins" shows consistent differences, as follows (BRIGO & OMENETTO, 1977) :

a) in the "platforms" :

- ore distribution essentially at the base of the Permo-Triassic sequence;
- recognizable "heritage" relationships with the mineralized crystalline basement;
- stratiform deposits : Pb-Zn in the Anisian of Luganese "platform", U-Pb-Cu in the Valgardena Sandstone and in the Bellerophon Limestone (Permian cover of the Atesine "platform");

b) in the "basins":

- ore distribution along the whole Permo-Triassic sequence (in the Lombardic "basin" Permian, Skythian, Anisian, Ladinian/Carnian, Norian are mineralized);
- clear paragenetic differentiation : Fe-Ba-U in the Permo-Skythian, Pb-Zn-F (Ba) in the Anisian and Ladinian/Carnian, fluorite in the Norian;
- strata-bound deposits (stratiform and/or discordant) often connected with restricted metallotects, controlled by localized paleogeographic and paleotectonic parameters;
- economically important concentrations (essentially at the Ladinian/Carnian boundary : Gorno, Salafossa, Raibl; fig. 1).

ON THE SCALE OF MINERALIZED SEQUENCES

We refer here to the most conspicuous and representative examples : the ore-bearing sequences of the important mining districts of Gorno in Lombardy (Ladinian-Carnian series), Auronzo-Salafossa in the Bellunese region (Anisian and Ladinian/Carnian series) and Raibl in Friuli (Ladinian/Carnian series).

1) **Gorno district (Lombardic "basin")** (ASSERETO *et al.*, 1976; ASSERETO & FOLK, 1976; ASSERETO & KENDALL, 1977; ASSERETO, JADOUL & OMENETTO, 1977; OMENETTO & VAILATI, 1977; ASSERETO, BRIGO *et al.*, 1977; RO-

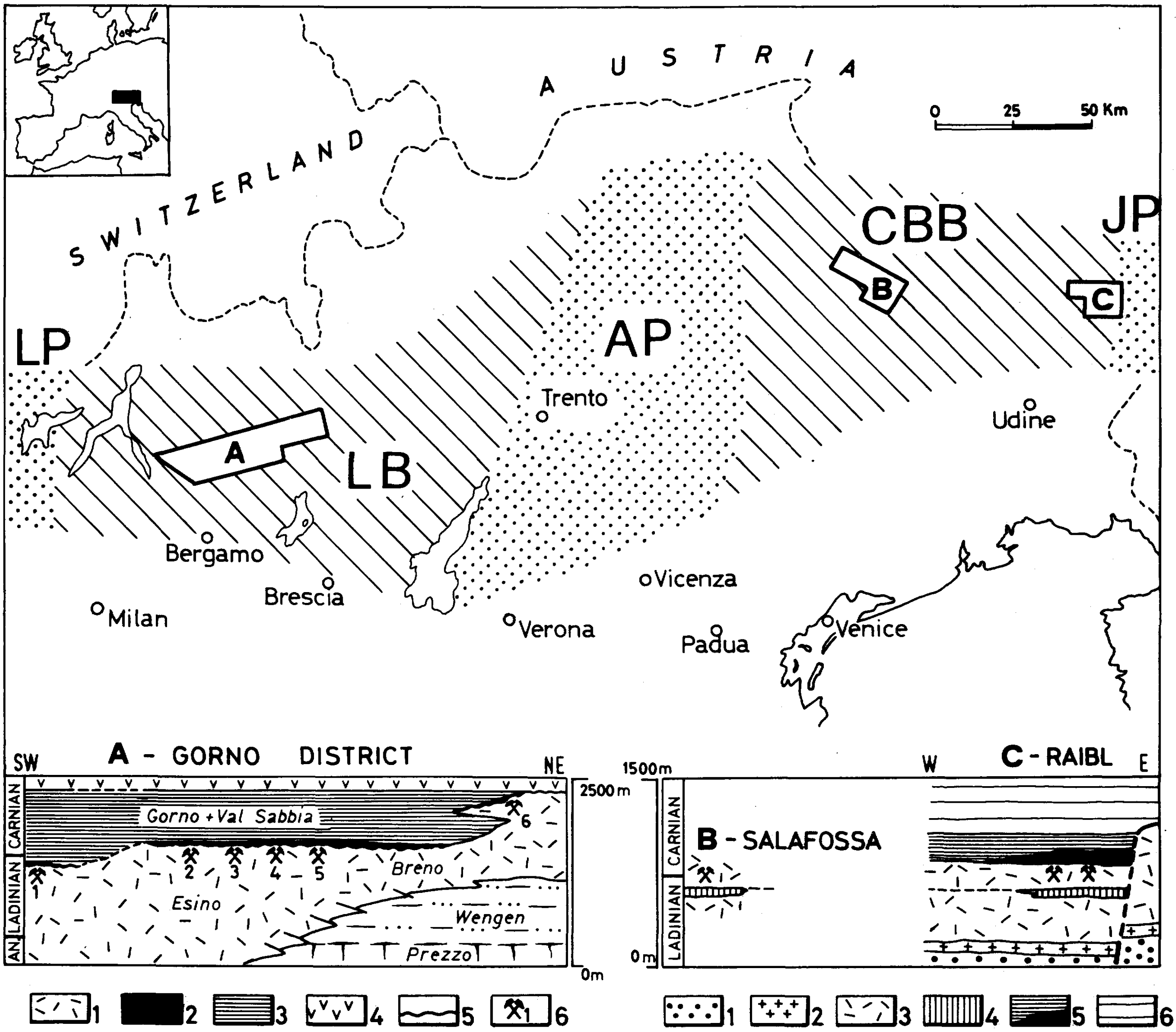

Figure 1

Regional Permo-Triassic structural features in the Southern Alps (BOSELLINI, 1965) : LP = Luganese "platform"; LB = Lombardic "basin"; AP = Atesine "platform"; CBB = Carnian-Bellunese "basin"; JP = Julian "platform".

A-Gorno District :

1) carbonate platform facies (Esino Limestone + Breno Formation); 2) backplatform limestones + black shales (Metallifero Bergamasco Limestone + Lower tongue of the Gorno Formation); 3) lagoonal-deltaic facies (Gorno Formation + Val Sabbia Sandstone); 4) S. Giovanni Bianco Formation (evaporites); 5) emersion surfaces; 6) Pb, Zn, CaF_2, $BaSO_4$ deposits : 1-Lecco; 2-Paglio Pignolino; 3-M. Vaccareggio; 4-Val Vedra; 5-Val Riso; 6-Presolana.

B-Salafossa and C-Raibl :

1) Kaltwasser Formation; 2) Rio Freddo volcanites; 3) carbonate platform facies below the "Pseudobuchenstein" (Salafossa : Sciliar Dolomite; Raibl : Lower Dolomia Metallifera) and above the "Pseudobuchenstein" (Salafossa : Cassian Dolomite; Raibl : Upper Dolomia Metallifera); 4) "Pseudobuchenstein"; 5) Calcare del Predil Formation (black = basal bituminous dolomites); 6) Rio del Lago + Rio Conzen + Tor Formations (Carnian).

DEGHIERO, 1977; JADOUL & OMENETTO, 1978; RODEGHEIRO & VAILATI, 1978; JADOUL & OMENETTO, 1980) : the analytical data show that future ore exploration programs in the outcropping Ladinian/ Carnian series (2.000 Km^2) in Lombardy may be founded upon the following geological facts (fig. 1-A).

a) the lead-zinc (fluorite) ores belong to a sequence (70-150 m thick : "Metallifero" of the miners) litho-sedimentologically characterized by the superimposition of a lower, peritidal (epicontinental) carbonate platform facies, and an upper facies of restricted, internal backplatform basin. This sequence develops between the top of the Ladinian carbonate platform (Esino Limestone) and the base of the Carnian deltaic-lagoonal series (Val Sabbia Sandstone/ Gorno Formation);

b) the facies transition within the "Metallifero" occurs at progressively higher stratigraphic levels from the west (Lecco lead-zinc area : Upper Ladinian) to the east (Presolana fluorite mine : Middle Carnian);

c) in the "Metallifero" the mineralization appears to be linked to the following paleogeographic events :

- at the facies transition : emersion of the backplatform limestones over a tectonically determined (by syngenetic block-faulting) network of near-shore mounds;
- erosion and karstification of emerged mounds;
- marine transgression : deposit on the littoral fringe of bituminous black clays (black shales). In this context, the economic ore presents two facies : 1) syndiagenetic stratiform at the base of black shales deposited above the mounds transformed into drowned highs; 2) epigenetic, by polyphasic filling-up of karst vadose and phreatic cavities, connected to the downward extension of undercover karstification within the highs. Facies 1) and 2) are co-genetic, the **trait d'union** being marked by the seeping-down and **soutirage** of ore-bearing black shales within the karst cavities nearest to the emersion surface/transgression base.

For future ore exploration we may consider as established both **the geological structures favourable to the ore concentration** and, above all, **the close genetic connection between the ore formation and the time of black clay deposition.**
This is because the stratigraphic position of the ore-bearing horizons in the Gorno district becomes higher and higher from west to east : this chronological migration results from the contemporaneous migration, recognized on the regional scale, of carbonate platform facies progressively replaced by the Carnian terrigenous sediments.

2) **Salafossa-Auronzo and Raibl district (Carnian-Bellunese "basin")** (ASSERETO *et al.*, 1976; ASSERETO, BRUSCA *et al.*, 1977; BRIGO & OMENETTO, 1976; BRIGO, KOSTELKA *et al.*, 1977; BRIGO & OMENETTO, 1978) : in the **Salafossa-Auronzo district**, recent studies showed that a clear link is observable between the Anisian and Ladinian/Carnian paleogeographic evolution and the distribution of the ore deposits. To the Anisian cycle belong the lead-zinc ores of Auronzo district (Argentiera, Grigna, Ferrera, Pian da Barco, Val Marzon) and of M. Rite-Valle Inferno. Stratigraphically the deposits are located within the Anisian carbonate platform (Serla Dolomite). The paleogeographic position remains constantly at the platform border towards the adjacent basinal areas. In the Ladinian/Carnian carbonate platform (Cassian Dolomite), and not far from the platform/basin border lies the important lead-zinc orebody of Salafossa (Fig. 1-B). The Pb-Zn sulfides in the Auronzo-Salafossa district are concentrated within solution breccias and tectonically controlled karst cavities.

At Raibl (Cave del Predil, Tarvisio, Udine) modern studies proved that this great lead-zinc deposit too (1.5 Mt metal produced up till now) is a good example of ore concentration strictly controlled by exceptional paleogeographic and paleotectonic conditions of Triassic age (fig. 1-C) :

a) localization of the deposit at the eastern border of the E-W-trending, Raibl-Valbruna Carnian basin;

b) ore stratigraphic position within the Ladinian/Carnian carbonate platform (Upper Dolomia Metallifera);

c) vertical distribution of the lead-zinc orebodies along the whole thickness of the Upper Dolomia Metallifera, between the top of a volcano-sedimentary horizon ("Pseudobuchenstein") and the bituminous-dolomitic base of the Calcare del Predil Formation;

d) equal lateral extension both of the Upper Dolomia Metallifera ore-bearing septum and of the top/bottom niveaus ("Pseudobuchenstein" and lower unit of Calcare del Predil Formation, developed only at the basin border and heteropical with the carbonate platform facies);

e) spatially, concentration of the lead-zinc ores along Triassic faults, active since the "Pseudobuchenstein" depositional phase.

POST-DEPOSITIONAL EVOLUTION OF THE LEAD-ZINC MINERALIZATION (SELECTED EXAMPLES : GORNO AND RAIBL)

GORNO

The economic importance of the Gorno district is essentially dependent on the past zinc and lead ore production from the central mines (at present essentially the underground Val Vedra area remains intensively explored for future exploitation). As previously indicated, the sulfide mineralization is observable within the "Metallifero" sequence in the form of :

1) stratiform orebodies in the lower part of the black shale unit;
2) discordant orebodies in the underlying karstified backplatform limestones.

Macroscopically, the most typical facies of the **stratiform mineralization** appears in the form of nodular aggregates of crystalline sphalerite, developed as rounded "porphyroblastic" grains and crystals (Ø from 0.5 mm to several cm), associated with minor amounts of fine crystalline galena and pyrite, within a calcite + bituminous matter + illite (± quartz and gypsum) black shale matrix. Macro- and microscopically the "nodular" aggregates of sphalerite and galena grade to massive patches, in which galena normally includes and replaces sphalerite (pl. 1 : 1). As a rule, the mineralization associated with abundant interstitial bituminous black schist matrix provides the best examples to explain the present nodular/massive fabric as a recrystallization product. In fact, early diagenetic growth of lead and zinc sulfides is recognizable in the form of thin laminated sulfide/bituminous schist alternances, rich in disseminated, fine-grained crystalline and framboidal pyrite. These alternances are observable as "remnants" within the recrystallized ore (pl. 1 : 1 b,c). The diagenetic recrystallization involved not only the lead-zinc sulfides but also the bituminous matter, progressively expelled during the sulfide recrystallization and observable at the periphery of sulfide crystals as laminae with graphite-like optical properties. In the recrystallized ore, galena shows very frequently inclusions and forms local intergrowths with Cu-Sb-As-sulphosalts (tetrahedrite, bournonite, jamesonite, tennantite, boulangerite, As-bournonite).

The **discordant mineralizations** show a more or less pronounced spatial connection with the stratiform ores, depending on the stratigraphic position of the ore-filled karst cavity networks (fissures, breccia zones, subcylindrical chimneys, pockets) within the limestones underlying the sulfide-bearing black shales. From the paragenetic viewpoint, the discordant mineralization appears to be almost identical to the stratiform one. Only the clayey-bituminous matrix (and the early diagenetic ore remnants, however locally observed) show progressive, downwards diminution in favour of a relative enrichment of massive sulfides, associated with abundant white spathic calcite in the cavities at the base of the karst system. It is important to emphasize that the discordant ores are foreign to their host rock : lead and zinc geochemical anomalies are totally lacking in the "Metallifero" karstified backplatform limestones (KRISCHE, 1972).

In fact, ore composition and carbonate host rock geochemistry suggest that both conformable and unconformable mineralizations result from syndiagenetic metal enrichment within highly bituminous muds, disconformably transgressive on karstified paleohighs and pervading (by seeping-down and **soutirage**) the first-formed karst cavities, directly connected with the emersion surface. Massive sulfide + calcite mineralizations within the deeper cavity systems (highly purified by depletion of ultradetritic fraction) can be alternatively interpreted as the precipitation product of metal-bearing brines, mobilized *(per descensum/ lateralum)* from the black shale, during the compaction stage.

The close relationship between the conformable and unconformable mineralizations at Gorno can be stated also on the basis of available geochemical and sulfur isotope analyses of the zinc sulfide, although the resulting data have been interpreted using doubtful geological asumptions (FRUTH & MAUCHER, 1966). Significant differences are not detectable in the trace-element microparagenesis of the sphalerite samples collected at different stratigraphic positions within the "Metallifero" column. Principal trace elements are Cd, Fe, Ga, Ge, Sb and Hg. The presence of Sb and Hg in the Gorno sphalerites (and of Sb in galenas; DESSAU, 1967) connected, following FRUTH & MAUCHER (1966) to the proximity of supposed volcanic centers, in fact confirms a common geochemical character of the Lombardy metallogenic region (presence of strata-bound Sb- and Hg-ores in the crystalline basement, ubiquitous traces of Sb and Hg (tetrahedrite and cinnabar) in the Mn-siderite stratiform ores of the Servino (Skythian), abundance of Sb-sulphosalts in the Triassic lead-zinc ores). Sulfur isotope analyses, carried out by FRUTH & MAUCHER on the same sphalerite samples, revealed $\delta^{34}S$ o/oo values comprised between + 3,8 and - 9,8, and therefore within a range of variability much more restricted when compared, for example, with the Raibl sulfide ores (see later). The above-mentioned facts suggest a common post-depositional evolution for the whole lead-zinc mineralization in the central Gorno district.

In the author's opinion, this evolution took place essentially as a diagenetic recrystallization process of already spatially defined, conformable and unconformable primary ores, with only limited mobilization and replacement of country limestones during the burial and compaction stages.

Some facts (mineralized layers cut by porphyritic veins of probable Mesozoic age; stratiform ores (Val Vedra mine) tectonically deformed and laminated to a "phyllitic" fabric under the action of regional overthrusts of alpine age) seem to confirm that the post-depositional evolution of the sulfide ores may have been settled before the end of the Mesozoic.

RAIBL

At Raibl both dominant bimetallic character and Pb/Zn ratio (1/5) are similar to the Gorno ones. Ore fabric, "gangue" minerals and minor element geochemistry (p. p.) differ considerably, showing instead close similarities with the lead-zinc paragenesis of Salafossa. Practically the whole ore-grade mineralization (veins and columnar stocks within the Upper Dolomia Metallifera) appears as the epigenetic, *per descensum* filling-up of fissure- and solution cavity systems, spatially connected with N-S (Abendblatt-Morgenblatt, Struggl, Aloisi, Fallbach), NE (Rinnengraben-Bärenklamm) and NNW to NW (Abendschlag, Vincenzo) faults. The epigenetic ore is foreign to the country rock : primary stratiform zinc and lead anomalies in the Dolomia Metallifera are lacking (KRANZ, 1974). Values above the background (ZELLER, 1970) show the "Pseudobuchenstein" marly limestones (122 ppm Zn, 10 ppm Pb). Stratiform anomalies (1460 ppm Zn, 650 ppm Pb) are present only in the basal Calcare del Predil strata. Nevertheless, stratiform mineralizations of Gorno type in the basal bituminous black schists and dolomites of Calcare del Predil Formation are practically lacking : the described samples (SCHULZ, 1964) are probably mineralized re-sediments, belonging to a "stratiform" ore-grade dark breccia body observable along the Struggl fault zone at the Dolomia Metallifera/Calcare del Predil transition. Discordant geochemical anomalies (ZELLER, 1970; KRANZ 1974) in the Dolomia Metallifera close to orebodies (maximum values in the various breccia types) show very rapid lateral downfall (in the range of 20-30 m) to background (15-30 ppm Zn, 2-5 ppm Pb, foll. KRANZ).

As previously indicated, the faults of Raibl have been active since the "Pseudobuchenstein" depositional stage (Upper Ladinian). Successively, during the Lower Carnian, this syngenetic block-faulting conditioned the sedimentary environment of the dolomitic-bituminous top of the deposit (basal Calcare del Predil Formation) with variation of facies and thickness on both sides of the faults. Afterwards the faults remained "failles vivantes" under the action of alpine tectonics (as is well-analyzed by previous authors : COLBERTALDO (Di), 1948, 1967; ZELLER, 1970). Displacements along the faults have been observed in modern times (for example, during earthquakes). We can therefore admit that, among the Triassic geological parameters conditioning primary ore concentration, the faults represent the only parameter **persisting in post-Triassic times.**

The epigenetic mineralization consists of macro- and microcolloform sphalerite (Schalenblende) of dominant yellow and red colour, with high Ge- and Tl-contents (HEGEMANN, 1960; DESSAU, 1967) associated with silver-free crystalline galena, normally in coarse-grained aggregates and crystals. We must note here the second difference as compared with the Gorno ores : at Gorno, Schalenblende is lacking. Moreover, the fabric, paragenesis and geochemistry of the Gorno economic lead-zinc mineralization are the same over the entire ore-district. On the contrary in the Raibl deposit some significant variations are clearly recognizable :

1) in the central-southern sector of the deposit, **yellow Schalenblende** prevails, associated with relatively abundant, coarse-grained galena. Typical examples of this ore facies are visible in the Struggl zone and the southern prosecution of the Erzmittel orebody (5th Layer Level). Particularly significant appears to be the Erzmittel mineralization, linked to a N-S Triassic fault without evidence of alpine tectonic reworking. The mineralization forms the filling-up of a network of cavities, in the form of : a) mm-rhytmic sphalerite-barite-dolomite and/or sphalerite-dolomite mechanical internal sediments; b) mm-rhytmic recrystallized micro-colloform sphalerite (Schalenblende), galena and pyrite crusts; c) residual voids filled with coarse dolomite, recrystallized macrocolloform sphalerite, barite, coarse grained galena (see table 1, n. RA3) and pyrite. The a), b) and c) facies show repeated deposition alternances. Late-stage spathic dolomite largely reworked and

Table 1.- Sulfur isotope composition of some selected samples of the Raibl deposit (*)

Sample N°	Mineral	Orebody	δ ³⁴S%
	Southern sector of the Raibl deposit		
RA1	Microcolloform yellow to brownish-yellow Schalenblende (+galena crystal aggregates)	Struggl-17th Clara Level	-8,59
RA11	Galena (+yellow recrystallized Schalenblende)	Struggl-17th Clara Level	-14,43
RA12	Yellow-brownish Schalenblende (massive, recrystallized; ZnS-colloform fabric largely destroyed by recrystallization)	Struggl-17th Clara Level	-9,60
RA3	Galena (+recrystallized grey sphalerite, colloform). Description in the text.	Erzmittel-5th Layer Level	-6,43
	Central sector of the Raibl deposit		
RA8	Galena (rhythmic intergrowth with reddish-brown Schalenblende)	Colonna Principale-10th Clara Level	-16,85
RA4	Reddish-brown Schalenblende	Aloisi-15th Clara Level	-18,07
RA5	Reddish Schalenblende (macrocolloform)	Colonna Principale-10th Clara Level	-18,29
RA6	Reddish Schalenblende (traces of PbS)	Aloisi-15th Clara Level	-20,34
	Northern sector of the Raibl deposit		
RA9	Red (with brownish tinge) Schalenblende (+minor galena)	Aloisi Nord-14th Clara Level	-21,71
RA2	Melnicovite-pyrite/pyrite (+red amorphous Schalenblende)	Bärenklamm NE-13th Clara Level	-22,09
RA7	Red Schalenblende (poorly crystallized)	Bärenklamm NE-13th Clara Level	-22,79
RA13	Melnicovite-pyrite	Bärenklamm-15th Clara Level	-25,60

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replaced the ores, before and independently on the late alpine tectonic effects. As regards the sulfur isotope composition (1), table 1 shows that the ores of the central-southern sector present the lower negative values (constantly in the range of "light" sulfides : δ ³⁴S o/oo varies from -6,43 to -14,43). Strong recrystallization of the sulfides is typical, with or without superimposed effects of the late alpine tectonics (Erzmittel at 5th Layer). The "**grown old**" **character** of this sulfide facies is recognizable on hand specimen by the "felsic" ore fabric, together with the yellow colour of the Schalenblende (microscopically cry- and recrystallized) and the progressive obliteration of the macrocolloform texture;

2) in the northern sector of the deposit (along the NE-trending Bärenklamm fault zone) **red Schalenblende** prevails (pl. 1 : 2) associated with abundant pyrite and melnicovite, dolomite, barite with minor galena and traces of jordanite. Following Di COLBERTALDO (1967) germanium (average : 400 ppm in the ZnS-concentrates) is more abundant (> 1000 ppm) in the red Schalenblende. The ores show evidence of primary fabric (amorphous or poorly crystallized Schalenblende, red or red-brown in colour, melnicovite-pyrite) with a less "ripe" diagenetic evolution as compared with the ores of the central-southern sector. In addition, the associated mechanical internal sediments are poorly sorted, black bituminous dolomite-sphalerite-, pyrite- and barite-bearing micrites. The sulfur isotope composition of red Schalenblende and melnicovite-pyrite of the Bärenklamm zone shows maximum negative values (δ ³⁴S o/oo : -21,71 to -25,60);

3) transition between groups 1) and 2) (as regards both sulfur isotope data and macro- and microscopic evidence : see table 1) characterizes the central sector of the deposit.

At Raibl, the δ ³⁴S o/oo variations are similar to those quoted for Bleiberg sulfides (SCHROLL & WEDEPOHL, 1972) : -6,9 and -7,2 respectively for galena and sphalerite of primary stratiform (schichtig) mineralization; highly negative values for later marcasite (-20,2) and Schalenblende (-25,9). On the other hand, the Raibl δ ³⁴S o/oo sequence is analogous (generally speaking) to that found at Aachen-Stolberg by BAYER, NIELSEN & SCHACHNER (1970) : (δ ³⁴S o/oo) PbS < ZnS (crystalline and **light** Schalenblende) < ZnS (**brown** Schalenblende) < FeS_2 (essentially marcasite). These data argue both for a fractioning between the different coexisting sulfides (low-temperature deposition) and for a polyphasic evolution, very probably protracted over the Triassic epoch, of the Raibl deposit. In this sense, the outstanding studies on the evolution of organic matter and on paleobiological processes, respectively of J. J. ORGEVAL (BRGM, Orléans) and J.P. DEVIGNE (University Paris-Sud, Orsay) should prove very interesting.

The parallelism between the polyphasic formation of new ore traps (open cavity system) along the "living" faults and new sulfide deposition is also suggested by a peculiar although very rare mineralized facies : the **stalactitic ores** (Röhrenerze = tubular ores) described by POŠEPNÝ (1873), GÖBL (1903), KRAUS (1913), COLBERTALDO (Di) & FERUGLIO (1963). The samples preserved in the museum of the Raibl mine

(1) The sulfur isotope analyses were carried out at the Institute Jožef Stefan of Ljubljana (analyst J. Pezdič) thanks to the courtesy of Prof. Dr. M. Drovenik and Dr. Ing. I. Štrucl.

appear to be partly aggregates of typical stalactites, formed by coarse galena and oxidized Pb-Zn-Fe products and partly fragments of stalactitic Zn-Pb-Fe gel-sulfides, recrystallized and floating within a groundmass of white spathic dolomite. Although both stalactitic ore facies pertain to the same orebody (Colonna Principale) there are fabric and paragenetic differences indicating chronologically separated depositional phases.

CONCLUSIVE REMARKS

The most significant result acquired during our research on the lead, zinc, fluorite and barite Triassic province of the Italian Southern Alps is the following : a relationship exists, on both the regional and ore-district scale, between the presence of mineralization (at least as "protore") and a precise paleogeographic and paleotectonic situation of Triassic age. Moreover, comparative analysis of Gorno and Raibl lead-zinc deposits indicates that the present ore-grade concentration shows variations of paragenesis, fabric and geochemistry, suggesting differentiated post-depositional evolution. At Gorno, the Triassic geological events appear to have conditioned both the primary concentration phase of the lead-zinc ores and their post-depositional diagenetic evolution (and consequently, the present fabric and geometric pattern of the orebodies). At Raibl, the connection between the "protore" deposition and a specific Triassic geological environment is unequivocal. As compared with Gorno, the ore post-depositional evolution developed polyphasically, leading to repeated and progressively younger colloform sulfide precipitation phases, some of which are still recognizable owing to their well-differentiated fabric and sulfur isotope composition. This evolution depends very probably on the space/time persistence of the Triassic syngenetic faults, therefore responsible for the continuous restoration of the circulation paths of the local hydrogeologic system, with subsequent polyphasic remobilization and reconcentration of the sulfide ores.

A comparison, at least from the post-depositional ore evolution viewpoint, between Raibl and Salafossa deposits seems to be possible, by taking into account the close paragenetic, fabric and geometric similarities of the Salafossa orebody (LAGNY, 1974, 1975) with some Raibl stocks (for example, the Colonna Principale) and the probably "revived" character of the Salafossa "fault" (of Triassic age following LAGNY, 1975; alpine following ASSERETO, BRUSCA *et al.*, 1977). In fact, the stratigraphic position of these two important deposits also coincides, owing to the common presence of the characteristic "Pseudobuchenstein" horizon at the base of the ore-bearing carbonate sequences (fig. 1-B,C).

At this point, a very important fact must be emphasized : in the analyzed deposits the post-depositional remobilization and reconcentration phenomena, although intense, seem not to have displaced the ores out from their original Triassic metallotects. Therefore, the research of these ore-favourable geological structures (outcropping and/or hidden) must be regarded as the principal object of future exploration programs in the Triassic province of Italian Southern Alps. This conclusion is supported by the first positive results, obtained by implementing complete and interdisciplinary geological techniques (discovery of fluorite and lead-zinc mineralizations of Gorno type in the Valcamonica; and of lead-zinc sulfide outcrops in the Valbruna, at the western border of the Valbruna-Raibl Carnian basin, in the same paleoenvironment when compared with Raibl).

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PLATE 1

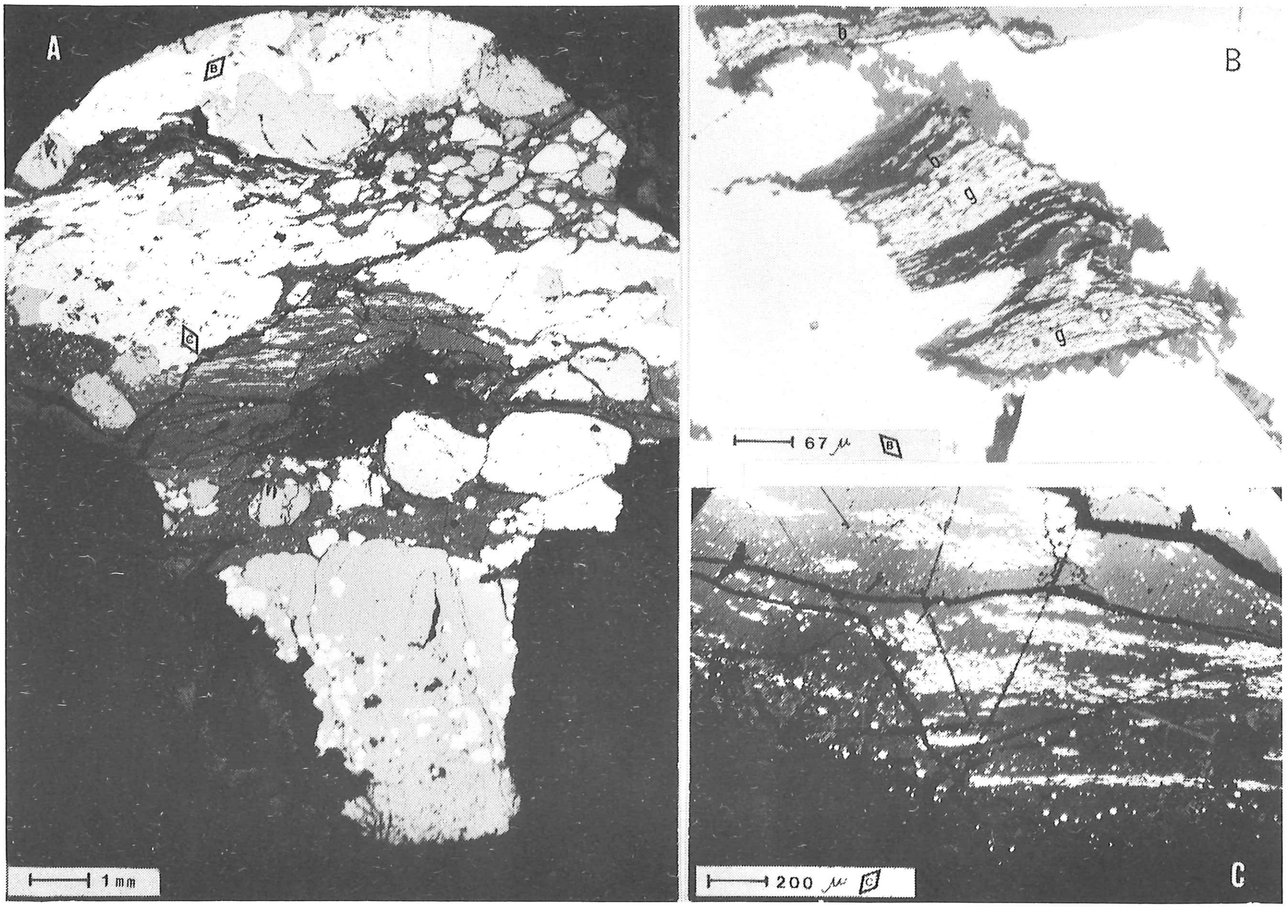
1. Val Vedra mine--Colonna di Ponente orebody. Polished section.

   A. Recrystallized, partly "porphyroblastic" aggregate of crystalline sphalerite (grey), galena (white) and pyrite (milk-white idiomorphic crystals included in sphalerite in the lower portion of the specimen). The recrystallized sulfide facies co-exists with preserved patches (C) and included remnants (B) of early diagenetic, thin-laminated alternances of galena +sphalerite + pyrite + bituminous matter.

   B. Detail (B) of fig. 1.A : residual fragments of thin-laminated "primary" ore (white = galena (g), grey = sphalerite (b); dark = bituminous matter; some framboidal pyrite is also visible). The fragments are separated from the matrix of recrystallized galena (white) by a rim of cerussite (grey).

   C. Detail (C) of fig. 1.A : "schistose" alternances of early diagenetic galena within pyrite-rich bituminous matrix.

2. Mineralized cavity within the Upper Dolomia Metallifera-Bärenklamm zone. The filling-up consists of red Schalenblende + pyrite-melnicovite (cockade-ore) partly reworked and replaced by late spathic dolomite. Raibl mine-12th Clara Level.


A
1 mm
B
b
g
67 µ
C
200 µ