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TRANSFORMATION IN ORES OF STRATIFORM LEAD-ZINC DEPOSITS . . . AS INDICATOR OF THE CONDITIONS OF THEIR FORMATIONS

(Figs. 5)

Abstract: Study of textures, structures and ore mineral compositions permited to find out that stratiform lead-zinc deposits in carbonate rocks differ by conditions of their formation in different geotectonic positions. The latter are responsible for one-stage or multiple hydrothermal process of ore deposition; temperature changes, distribution, redeposition and recrystallization of mineral aggregates. The three groups of stratiform lead-zinc deposits were distinguished by the degree of ore transformation: in platforms, miogeosynclines and deep-seated zones between platforms and geosynclines.

Резюме: Изучение текстур, структур и минерального состава руд позволило установиь, что стратиформные свинцово-цинковые месторождения в карбонатных породах различаются по условиям их образования в различных геотектонических позициях. В зависимости от последних происходило одностадийное или многостадийное рудоотложение, изменение температур рудообразования, перегруппировка, переотложение и перекристаллизация минеральных агрегатов. По степени преобразования руд выделяются три группы стратиформных свинцово-цинковых месторождений: на платформах, в миогесинклинальных структурах, в зонах глубинных разломов на границах между платформами и геосинклиналями.

In recent years close attention has been given to stratiform lead-zinc deposits. They are playing an important role in the mining of non-ferrous metals. But the genesis of this type of deposits is widely discussed. As it was evidenced in the series of publications (Смирнов — Горжевский, 1974; Попов — Яковлев, 1984; Пелисонье, 1984; Зартман, 1984 and others) this type of deposits was investigated from different points of view: geological, structural, historico-temporal ones. In discussing stratiform deposits practically no use is made of data on the ores proper. There are available only some articles (Шадлун, 1983; Митряева, 1979; Roedder, 1968; Gerdemann — Myers, 1972; McLimans et al., 1980; Sass-Gustkiewicz, 1982) which have shown the great significance of the textural and microtextural study of the ores for understanding the genesis of stratiform lead-zinc deposits, for elucidating the relationships of syngenetic and epigenetic processes.

Basing on the study of the composition of the ores and their transformations, we shall attempt to show that stratiform lead-zinc deposits are multifarious by the conditions of ores formations.

In the large group of stratiform deposits we shall consider only those in carbonate rocks, which are characterized by numerous common features: the enclosing rocks are dolomites and dolomitized limestones; stratal deposits are typical, banded-impregnated zones are infrequent and veins are less frequent;

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magmatic manifestations are non-existent; the mineral composition is quite similar.

Dominant ore minerals are sphalerite and galena, pyrite and marcasite relatively minor constituents, occur locally in bedded bodies and the sulphosalts of lead, silver, and copper are accessory and rare. Non-metallic minerals are dolomite, calcite and quartz, barite and fluorite have been recorded in subordinate quantities.

Similarity in the geologic-structural conditions of localization and in the mineral composition of these deposits have led to consider them as a single type-stratiform. However, they are perceptibly different by physico-chemical conditions of the deposition and transformation of the ores. By the degree of transformation of the carbonates and sulphide aggregates the stratiform lead-zinc deposits could be classified in three groups:

1. Deposits formed in the quiet conditions in the covers of the ancient and young platforms within activized structures. The deposits in the Mississippi Valley in the U.S.A., Upper Silesia in Poland, Central Massif in France are the most representative of this group. The ores have not been subject to any significant alterations.

2. Deposits in miogeosynclinal structures (Mirgalimsay, Shalkiya in South Kazakhstan, U.S.S.R). The ores are insignificantly transformed during the folding and tectonic deformations.

3. Deposits in linear zones of deep-seated faults situated along the boundaries of platforms and geosynclines (Sardana and Pereval'noe in Yakutia, U.S.S.R.; Kerzet-Yusef in Algeria). These deposits were formed in not quite tectonic conditions which are characterized by repeated sinking of sedimentary rocks, it was responsible for change of pressure and temperature of hydrothermal solution. It leads to the sequence mineral deposition and their significant transformation. The study of textures and structures of lead-zinc ores permits us to define the relationships between syngenetic and epigenetic processes, the features of sulphide deposition, the role of metasomatic and metamorphic processes.

The first group is considered mainly from literary data of Upper Silesia and the Upper-Mississippi Valley deposits. The sphalerite-galena ores of Upper Silesia (Fig. 1 a, b, c, Бетехтин и др., 1964) and Upper-Mississippi Valley (Fig. 1 d; McLimans et al., 1980) give rise to colloform, rhytmically- and zonally-banded textures, as well as in combination with impregnated, stratified ones. The alternation of variously-coloured bands of sphalerite (light and dark-coloured bands in Fig. 1 c, d) into fragments of host rocks are also typical. In Upper Sileasia's ores there have been noted the crustal formations of sulphides and the overgrowth of sphalerite into dolomite, galena and pyrite.

The formation of such textures of sphalerite-galena ores is differently explained by the researches. Some of them consider as syngenetic with host rocks, others — as epigenetic. The latter point of view is agreed with the of growth of sphalerite and with the character of the gas-liquid inclusions in it (Roedder, 1968; 1967; 1971) as well as with the nature of the banding of the sphalerite zones differing in colour and corrosion of earlier formed, dark-coloured bands prior to deposition of the light-coloured sphalerite (Fig. 1 d; McLimans et al., 1980). Wolter—Schneider (1983) confirmed epigenetic formation of lead-zinc ores by experiments of leaching rocks.

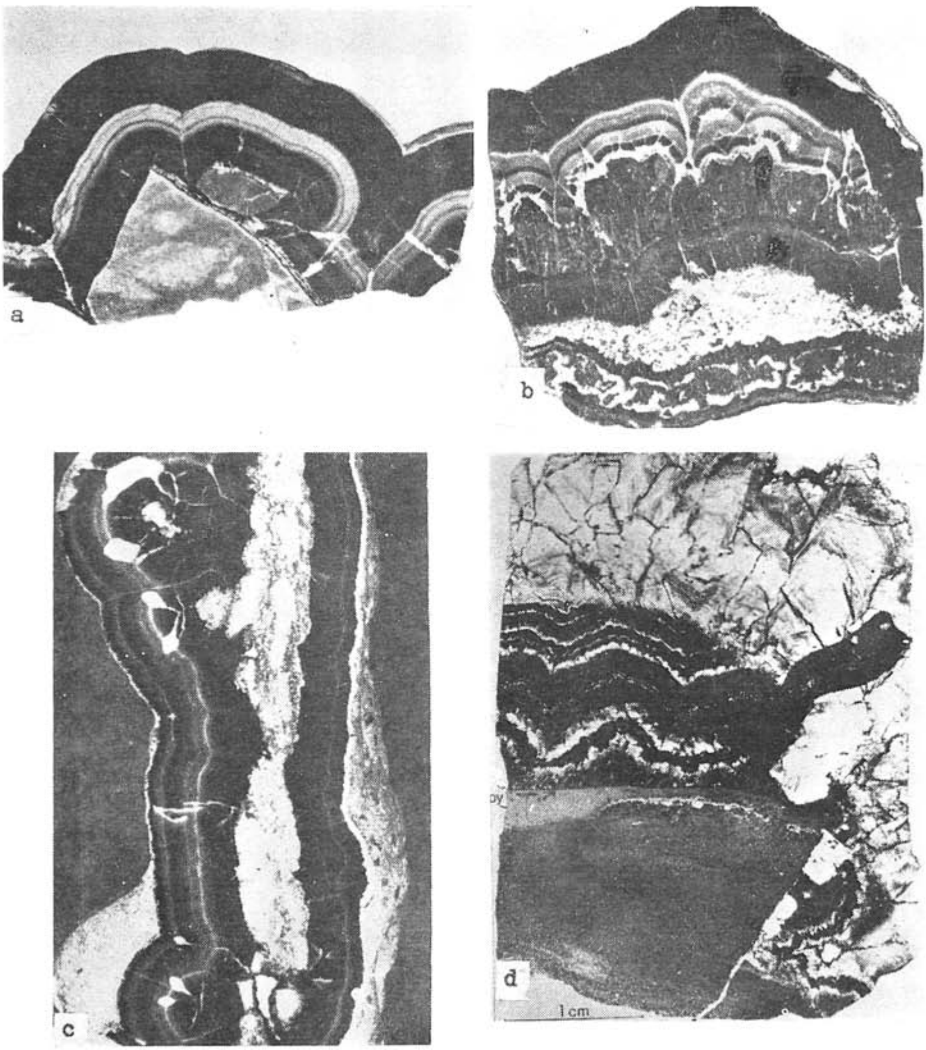


Fig. 1. Rhytmically-banded and zonally-concentric textures of galena-sphalerite ores in the deposits of Upper Silesia (a, b, c) and Upper Mississippi Valley (d). Overgrowths on fragments of host rock (gray and dark gray) by light and dark-coloured bands of sphalerite and dissolution of rocks are typical. The white material is calcite. Polished section in the reflective light.

Thermobarometric researches point to the relatively low temperatures of formation of the ores (40—150 °C) during a single stage from the fluids of high salinity (more than 30 ‰) (Roedder, 1971). One-stage crystallization of sulphides was accompanied by the leaching, dissolution and redeposition of carbonates in the form of metacrystals and veinlets. Deformations of sulphide aggregates are expressed in partial crushing of aggregates and information of diagenetic fractures.

The second group of deposits shall be discussed on the example of Mirgalimsay in South Karatau (Kazakhstan). The geological structure of this deposit (Fig. 2) comprises carbonate rocks of the Upper Devonian and the Lower Carboniferous, giving rise to brachyform fold structures disturbed by thrusts and upthrows. Ore-bodies are confined to the horizon of dolomites, calcareous dolomites and limestones with a thinly-stratified, massive, occasionally lump textures.

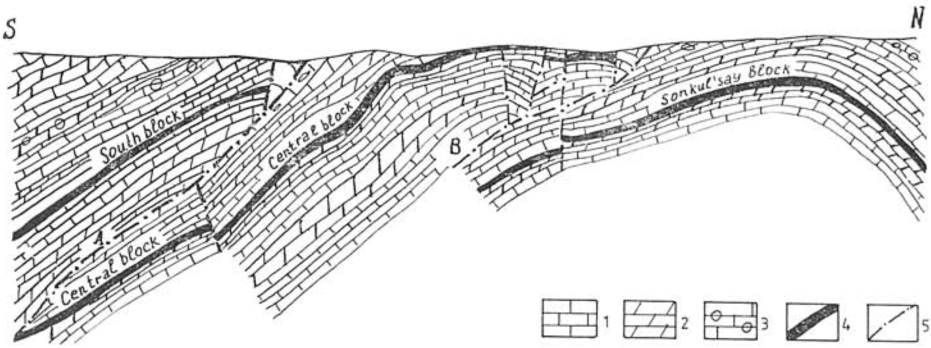
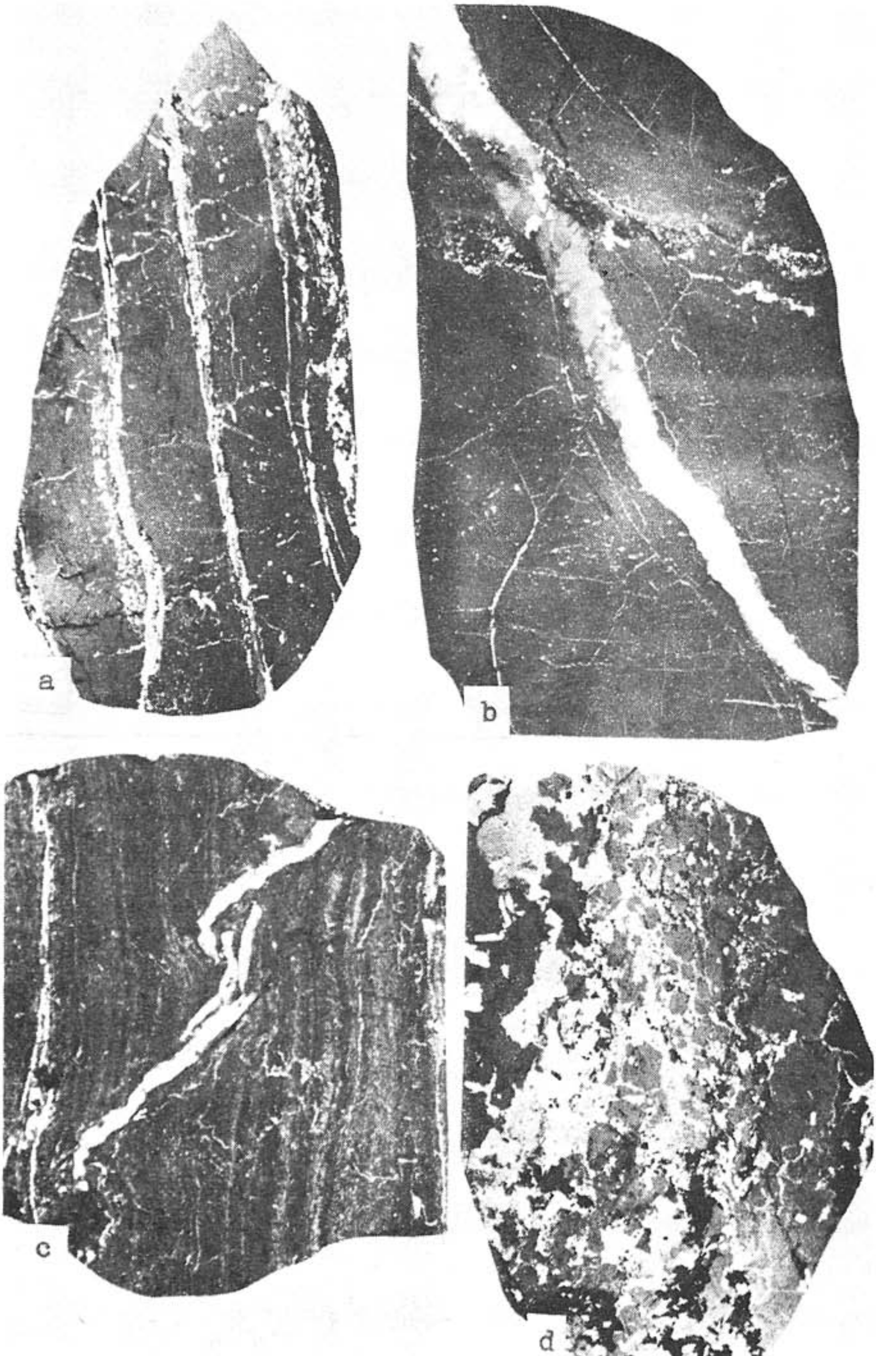


Fig. 2. Schematical geological section of Mirgalimsay deposit area. *Explanations:* 1 — limestone; 2 — dolomite; 3 — breccia limestone; 4 — ore-bodies; 5 — tectonic structure; A — South thrust; B — Main thrust.

The textures of sphalerite-galena ores are versatile (Fig. 3). Alongside disseminated ones, there occur disseminated-banded, layered, less frequently massive textures. Relationships between sulphides and rock-forming minerals point to the formation of ores during three stages.

The finely-disseminated and layered sulphide mineralization of the first stage is represented by the quartz-dolomite-pyrite-sphalerite association and appears as syngenetic with the host rocks. The galena-sphalerite and calcite-galena associations of the second stage make up lenses and veinlets intersecting the bedding. The hydrothermal solution of the second stage caused the recrystallization and redeposition of sulphides and non-metallic minerals of the first stage. The evidence is found in the magnitude and degree of crystallization of the grains of the redeposited minerals and in the variation of their chemical composition. The later generations of sulphides are enriched with trace elements, such as silver, antimony, arsenic. In some cases there appear

Fig. 3. Disseminated-banded, layered, veinlet and massive textures of ores in Mirgalimsay deposits. Fig. 3a shows primary textures and diagenetic structures. The thin white veinlets are galena, they follow layers of host rocks (a, c). The veinlets crossing host rocks (b, c) are redeposited calcite with recrystallized galena and sphalerite. Polished section in the reflective light.


a
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neoformations of minerals or their associations, for instance, cobalt-containing pyrite, freibergite, pyrite-arsenopyrite association.

Hydrothermal reworking of host rocks and ores at the second stage is confirmed not only by the structure of mineral aggregates, but also by an increasing of gas release at T — 320 ± 20 °C (А л е к с е е н к о и др., 1978). These researches noted an increase in the intensity of gas release at T — 270—340 °C

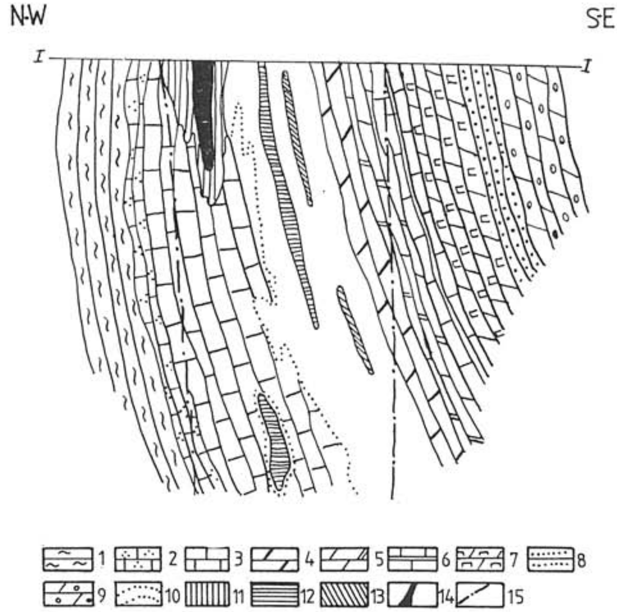
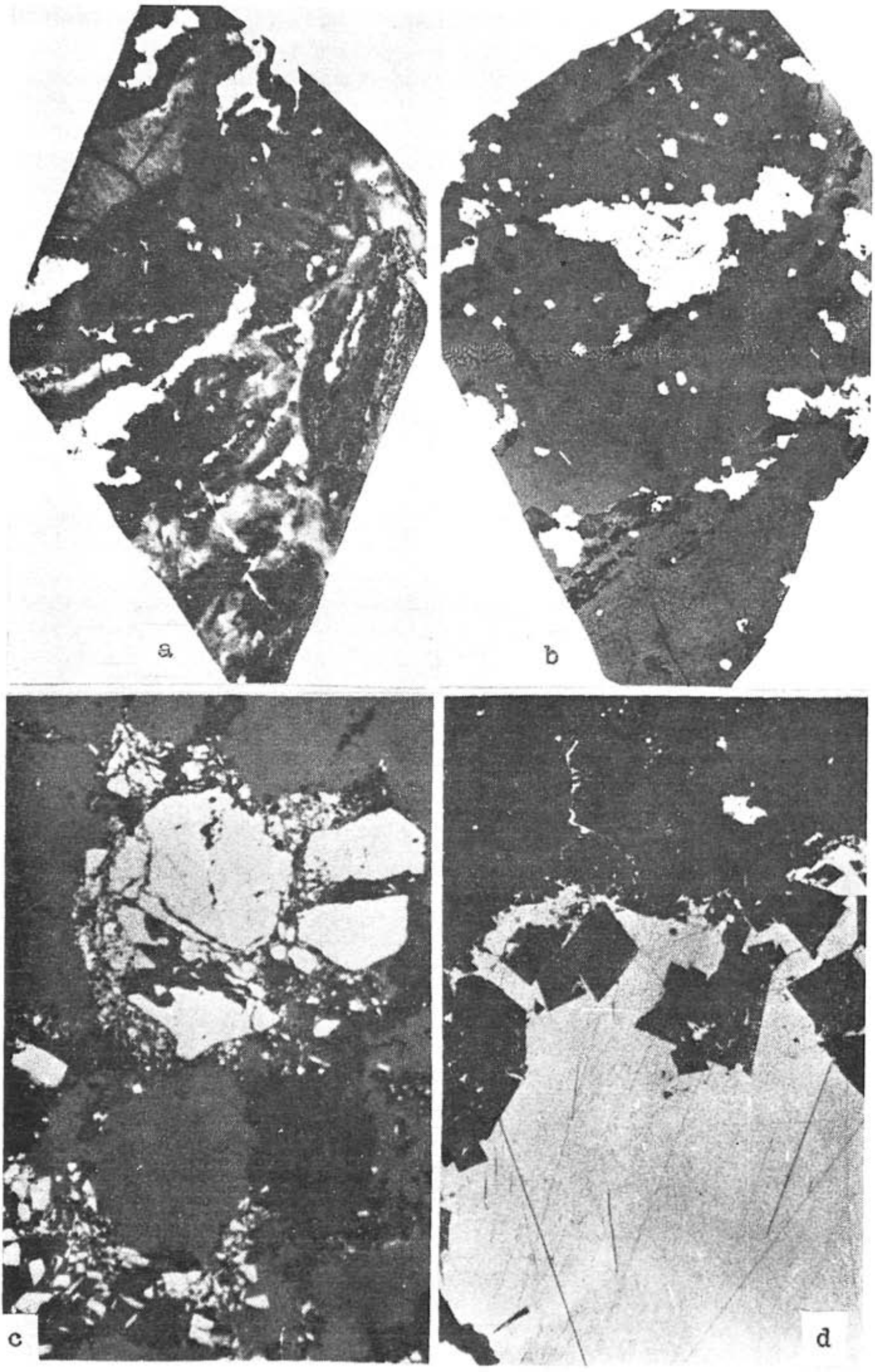


Fig. 4. Schematical geological section of Sardana deposit area.
Explanations: 1 — schist; 2 — limestone of mottled series; 3 — limestone; 4 — dark dolomite and limestone with bitumen; 5 — grained dolomite; 6 — plate dolomite; 7 — mottled dolomite; 8 — sandstone; 9 — fine-grained dolomite; 10 — contour of spread of metasomatic dolomite; 11—13 — ore zones; 14 — lead-zinc ore-bodies; 15 — tectonic structures.

namely in that samples where galena and calcite are in veinlets. Hydrothermal solutions were responsible for the alteration of rocks and ores only at isolated stretches. Thus, there are combinations of the textures of the primary and redeposited ores in the stratabound ore-bodies.

Fig. 5. Spolted and massive textures and microtextures of galena-sphalerite ores in the Sardana deposit.
Explanations: a — repeated redeposited and recrystallized ore, there are four generations of dolomite (gray and dark-gray, white-calcite, the late formations); b — the earlier formed sphalerite (dark) with spots of the late galena (white); c — crushed pyrite and markasite (light) of the first stage cemented by sphalerite (gray), dark-carbonate, Magn. 96 x; d — metacrystals of dolomite (dark) in galena (light), Magn. 96 x. Polished section in the reflective light.



Solutions of the third-stage mineralization did not induce any perceptible transformations in galena-sphalerite ores but they were partly dissolving dolomite and limestone.

The ores of the deposits in miogeosyncline are characterized by the features of sulphide accumulation syngenetic with the host rocks and of a subsequent transformation of the rocks and ores under the impact of high-temperature hydrothermal solutions.

The transformation of ores was even more conspicuous in the deposits of the third group (Sardana, Yakutia, U.S.S.R.). Lead-zinc mineralization is concentrated in the Vendian rocks, mainly in dolomites (Fig. 4). According to Ручкин with co-authors (1977), the position of ore bodies was determined by tectonic zones among which substratal fractures and dislocations of north-eastern striking are particularly wide-spread. Sulphides formed disseminations, veinlets, lenses and bands in banded dolomites, occasionally they cemented dolomite breccias. Banded, spolted and massive textures are wide-spread (Fig. 5).

Textures and structures of these ores and sequence of mineralization point the repeated hydrothermal processes were responsible for the formation of ores during the four stages. At the first one the pyrite-marcasite association was formed, its sulphide aggregates and dolomite were crushed and cemented by the second-stage minerals. The second stage is represented by two associations — dolomite-sphalerite and pyrite-arsenopyrite. The third stage involved the deposition of the calcite-dolomite-galena association with lead and arsenic-bearing sulphosalts. Anthraxolite-dolomite-calcite veinlets completed the mineral-forming process.

Repeated injection of hydrothermal solutions caused a significant recrystallization of host dolomites both in the premineral period and during ore emplacement. The sulphide aggregates were subjected to crushing, dissolution, recrystallization and redeposition. The ores contain a lot of dolomite and galena metacrystals. Often in one sample of the massive galena-sphalerite ores (Fig. 5 a) there are three or four generations of dolomite: 1) the relics of the primary dolomite with disseminated sulphides; 2) the aggregates of pre-ore metasomatic dolomite; 3) metacrystals of dolomite in sphalerite and galena; 4) veinlet occurrences of the late dolomite. These generations as well as a change in chemical composition of some minerals were produced by active interactions of the earlier mineral aggregates with subsequent hydrothermal solutions. For example, the later sphalerite generation enriched with iron at the expense of the dissolution of pyrite disseminated in dolomite. Sardana's ores are characterised by new generations of not only individual minerals, but also of their associations, for instance, the pyrite-arsenopyrite association of the second stage.

The multiplicity of stages in ore-formation is confirmed by thermometric data. For each of the four stages Флеров and co-authors (1978), point out the following temperature intervals: 360—300°, 380—135°, 258—200°, 310—140 °C. Алексеенко и др. (1978) have noted an increasing gas release within the T — 320—400 °C. Perhaps, just at these temperatures sulphide ores and dolomite were transformed.

The examined data allow us to make the following conclusions. The stratiform lead-zinc deposits in carbonate rocks differ in dependence of their geotectonic position. Under platform conditions regardless of the age of platform the primary textures of ores in the deposits were conserved. There are typical tectonic and metasomatic breccias of dolomite, as well as dissolution, leaching and replacement of dolomites.

In the miogeosynclines the ores of lead-zinc deposits are characterized by the primary disseminated and banded textures which in some cases were transformed during the folding and tectonic activities. Typical textures are those of replacement, filling, redeposition.

In the deep-seated zones between platform and geosynclines stratiform lead-zinc deposits differ by the most complex textures due to the repeated redeposition of mineral aggregates by the multiple injections of the high-temperature hydrothermal solutions.

So, the investigations of the textures and structures of stratiform lead-zinc ores in combination with geological conditions contribute to deeper understanding of the genesis of ore deposits.

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