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TO THE ONTOGENY OF SPIRAL-SPLIT CUBOOCTAHEADRAL BLOCK-CRYSTALS OF PYRITE FROM THE KURSK MAGNETIC ANOMALY

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The morphology and structure of cubooctahedral split crystals of pyrite with spiral rosettes of subindividuals on octahedral faces are described. It is supposed that such block-crystals were formed around axially twisted cubic germs and are in itself germinal centers of spherocrystals.
9 figures, 16 references.

Blocks of different levels (orders) of mosaic crystals of pyrite are covered with own faces resulting in specific sculptural details of the surface, reflecting the internal structure of crystals, especially of their external zones. The paper briefly discusses the genetic information received at interpretation of morphological observations and their graphic presentation on the base of fundamental ontogenetic works by D.P. Grigoriev (1909-2003) and its disciples and followers (N.P. Yushkin, A.G. Zhabin, V.A. Popov, V.I. Pavlishin and others). Pyrite crystals were investigated under stereoscopic microscope and scanning electronic microscope; polished sections — under reflected light microscope «Neophot» with devices for photographing at small enlargement. Physical and chemical studies were not conducted.

Investigated samples of pyrite were collected at the Mikhailovsky open pit of one of deposits of Kursk Magnetic Anomaly (KMA). The ore sequence is represented by hardly metamorphosed Precambrian ferruginous quartzite, which occur at a depth of about one hundred meters. The basic ore mineral is magnetite; the ore also includes hematite, quartz, chlorites, green hydromica celadonite, occasionally metacrysts of pyrite. Ferruginous quartzite is covered by Jurassic clay replaced on separate plots with limestones and, in turn, covered by Cretaceous clay and sand. Jurassic clay is hardly pyritized in separate places. As oxidizing pyrite creates an active sulfuric acid environment, the upper part of ferruginous quartzite under such plots is transformed into accumulations of so-called «ferruginous cream» — continuous masses of friable fine-crystalline hematite and quartz powder.

Plots (blocks) of the oxidation zone on the contact of ferruginous quartzite with limestone and especially along the ternary border ferruginous quartzite-limestone-clay are composed of cavernous limonite. Hollows in limonites are numerous, their size can attain tens of centimeters and more. Most of such hollows are intensively mineralized with pyrite, siderite and in immediate proximity to limestone — with calcite.

Secondary mineralization is also observed in cracks of the upper layers of ferruginous quartzite touched by oxidation.

Siderite in hollows grows on limonite as brushes and separated fine (1-2 mm) crystals of prismatic or rhombohedral habitus, and as spherocrystalline crusts with diameter of spherocrystals 3 to 5 mm in various phases of splitting. Pyrite is basically cubooctahedral, occurs as detached crystals, as crystal crusts covering in part or completely walls of cavities, forms pseudo-stalactites, growing over membrane fibers of iron oxides.

Ramified crystals and unusual for pyrite tubular and bubble forms described by B.Z. Kantor (1997) and one of authors (Slyotov, Makarenko, 2002, see Fig. 15-17 in the album) were met. As a rule, each large cavity shows a specific morphology of pyrite aggregates.

In one of large slit-like cavities about one meter long and in small cavities nearby, in limonite, numerous pyrite crystals have been detected with attributes of spiral splitting of subindividuals (Fig. 1) up to 5-6 mm in size. They grow up as groups or separately on a continuous spherocrystalline crust of siderite entirely covering walls of cavity and are considered as original germinal forms of spherocrystals of pyrite.

According to B. Popoff (1934), spherocrystals are radiate-fibrous spherical individuals formed at growth of splitting crystals. The crystal forms of siderite corresponding to various steps of formations of spherocrystals were

FIG . 1. Block-crystals of pyrite on a reniform spherocrystalline crust of siderite.
Photo of a sample sprayed-on with magnesium oxide on device FMN-2 (LOMO). The octahedron 4 mm

FIG . 2. A spherocrystalline concretion of siderite with a block-crystal of pyrite.
electronic microscopy-image in dissipated electrons. Spraying with aluminum. The edge of cube is 0.2 mm

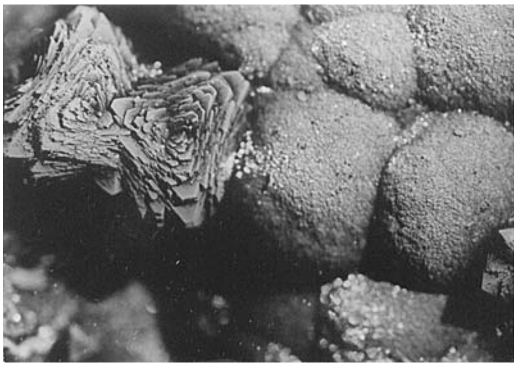

FIG . 3. Skeletal forms of block-crystals of pyrite of an octahedral habitus on a spherocrystalline crust of a siderite electronic microscopy-IMAGE in the dissipated electrons. A rib of an octahedron of ~1.2 mm

repeatedly met a siderite crust. As shown by A.V. Shubnikov (1957) mathematically as a general case, by A.A. Godovikov (1961) for calcite and Dymkov (1984) for pitchblende, germinal forms of spherocrystals sharply differ from «mature» forms — ideal spheres with smooth or microtuberous surface (Fig. 2).

Almost all pyrite crystals have cubooctahedral habitus and rarely — octahedral (Fig. 3). With increase in crystal size, the size of cube faces increases; however, forms close to correct cubooctahedrons are rare (Fig. 4). Separate spherulites (more exactly, spherocrystals) of pyrite, covered with faces of cube, were not observed, but they sometimes meet as aggregates in reniform spherolite crusts (Fig. 5).

The edge of ideal not split octahedron with smooth brilliant faces attains 0.3-1 mm, but most likely, these are crystals of the second generation. In larger crystals, at the center of octahedron faces, germs of lamellar rosettes were observed, which at further crystal growth gradually grow almost above all the surface of octahedral face (see Fig. 3). Almost all octahedral block-crystals have apices dulled by brilliant faces of a cube. Large split octahedrons with insignificant cube faces at apices have concave subradial lamellar rosettes, growing up from the center, sometimes over the total face of octahedron (see Fig. 3 and Figs. 27, 28 in the album by Slyotov and Makarenko, 2001) and respectively, concave lamellar edges between them (skeletal growth). Rosettes, as seen in prominent parts, have lamellar form, but their structure is not precisely determined. Salient «lamellar» rosettes are appreciably twisted on different faces of octahedrons in opposite directions.

Skeletal block-crystals of octahedral habitus attain ~1.3 mm, cubooctahedral block-crystals are usually three-four times larger and skeletal octahedrons can be considered as intermediate forms of splitting cubooctahedrons. «Cubooctahedral» forms — octahedrons with essential development of cube faces — attain 5 mm by edge; wedge-shaped subindividuals growing from the center of octahedron face also terminate in cube faces. Joining along octahedron edges, they form ribbed (lamellar) slightly concave surfaces (split edges), corresponding to the position of rhombic dodecahedron faces. Apices of octahedron can also extend in the initial phase of cubooctahedral habitus formation, which can be considered as skeletal growth.

Fig. 6 shows detailed pictures of face surface morphology of cubooctahedral block-crystals with spirally twisted pyramids of growing-up octahedron faces. Additional images published in works by V.A. Slyotov and V.S. Makarenko (2001, 2002) give a comprehensive impression on natural «sculpturally decorated» crystallization masterpieces.

Intermediate «transitional» forms between spherocrystalline balls and cubooctahedrons have hypertrophied faces (100) forming convex rows of stairs along directions, corresponding to cube edges. Octahedral faces of the basic individual gradually become more convex and entirely covered with fine square faces of radiantly split subindividuals. In similar forms, on covered (grown over) by subindividuals faces of octahedron remain three rectilinear seams as fine furrows on each face (Figures 1 and 5). Finally, transition occurs from a skeletal form to octahedron with insignificant development of cube faces to antiskeletal forms — to convex rounded octahedral spherocrystals entirely covered with square cube faces (Fig. 5).

Polished sections of pyrite block-crystals etched by concentrated nitric acid show a sharp anisotropy in etching of subindividuals (Fig. 7). Sections subparallel to cube faces (or these are sections of subindividuals of cubic faces?) almost do not accept etching; sections of growing over octahedral pyramid, especially on rhombic dodecahedrons (along octahedron edges) are intensively etched and show radiate-fibrous splitting. Formed textural patterns look like three-dimensional, volumetric. A little unusual chip in the cube plane helps to understand the structure of the split block-crystal. In square contours of the chip (2.5 x 2.5 mm) with rather plain surface, four smoothly extending radiate-fibrous bunches go from a dot germ at the center to angles of the square. This is presumably cross-section of lamellar rosettes on octahedron faces. It is not clear, why one angle of the square contour is truncated and poorly rounded, but practically corresponds to a cross-section of a growing up pyramid of rhombic dodecahedron face. Other radial bunches rest against right angles of the chip. In-between bunches, attributes of lamellar structure and orientation of lamellar subindividuals in parallel to radial bunches are appreciable.

As show etched polished sections, the sculpture of pyrite crystals reflects internal structure (texture) of block-crystals: each subindividual has on the surface its own apex and corresponding cut. Exclusions are accumulations of block-crystals in plots, where the second generation of pyrite — pyrite-II —

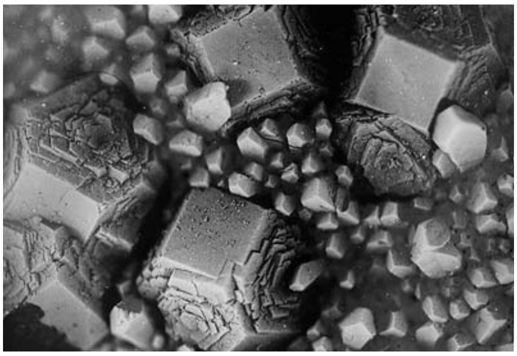

FIG . 4. Pyrite block-crystals of cubooctahedral habitus, in part grown over by a brush of calcite crystals.
Photo of a sample sprayed-on with magnesium oxide on device FMN-2 (LOMO). The cube edge is 2.5 mm

FIG . 5. Transition of a split cubooctahedron of pyrite into a spherocrystal: antiskeletal forms → initial phase of sphere formation.
Photo of a sample sprayed-on with magnesium oxide on device FMN-2 (LOMO). Magnification x10

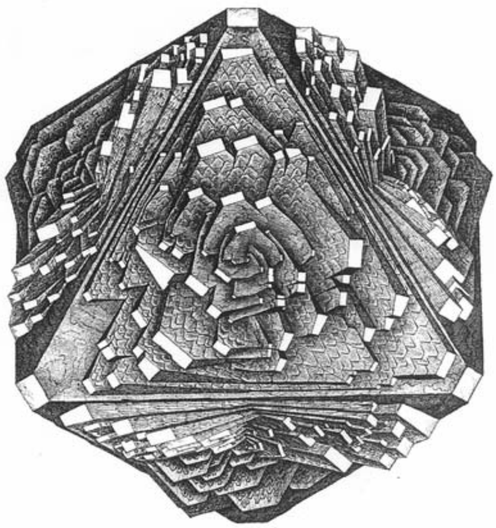

FIG . 6. Spiral-split block-crystal of pyrite; faces of octahedron. Drawing by V.A. Slyotov and V.S. Makarenko

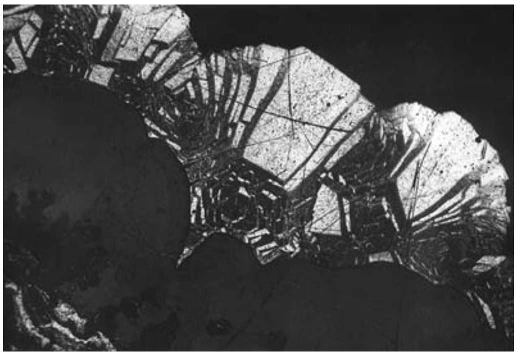

FIG . 7. Structure of crusts of split block-crystals of cubooctahedral pyrite-I on siderite, revealed by anisotropic etching of various sections of its crystals.
Microphoto of polished section after etching by nitric acid. Thickness of crust is 5–6 mm

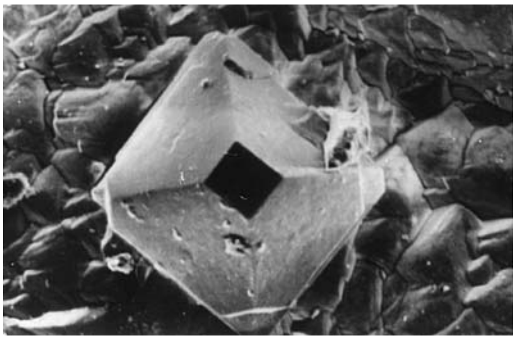

FIG . 8. Crystal of pyrite-II on the surface of siderite brush.
SEM-image in dissipated electrons. Spraying with aluminum. The octahedron edge is 0.07 mm

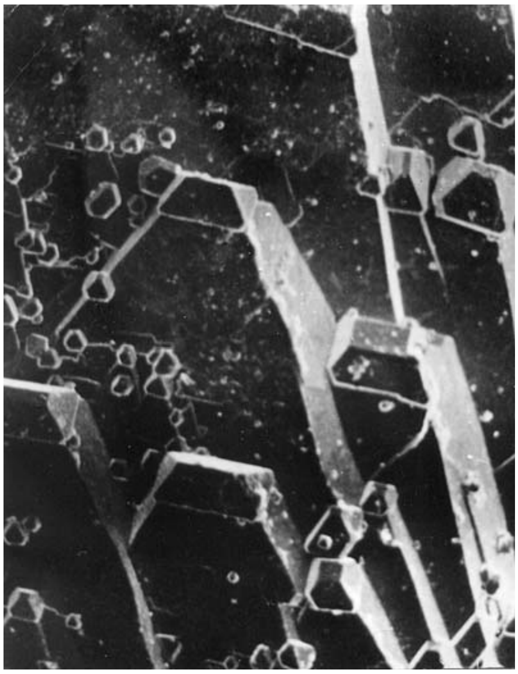

FIG. 9. Crystals of pyrite-II epitactically grown over an octahedron face of pyrite-I and covering of cube faces in apices of octahedron and «powders».
SEM-image in dissipated electrons. Spraying with aluminum. Crystals sizes in powder are ~0.04 mm

was formed. Known here two generations of pyrite can simultaneously be considered as «initiation», by the definition of D.P. Grigoriev (1949).

Pyrite of the second generations (pyrite-II) deposits as fine octahedrons or cubooctahedrons (Fig. 8) epitactically accrued on octahedron face of pyrite-I and simultaneously grows over cubic faces at apices of lamellar subindividuals (Fig. 9). Some kind of regeneration of external subindividuals occurs on block-crystals of pyrite-I. Faces of cube crowning apices of basic split block-octahedrons of pyrite-I are not entirely grown over: only a new layer appears, cut from sides by octahedron faces (Fig. 9).

Pyrite-II crystals do not bear attributes of splitting. These are fine (0.0n to 0.n millimeter in edge) independent individuals — octahedrons and cubooctahedrons — with smooth brilliant faces, epitactically accrued on octahedral faces of pyrite-I. Germinal centers of cubooctahedral crystals of pyrite-II probably had originally the form of plane-faced cube, without screw dislocations, but in cubooctahedrons of pyrite-II face (100) degenerates. This indicates the fact that simultaneously with formation of fine independent crystals on octahedrons of pyrite-I, heads of lamellar subindividuals, covered with cube faces, degenerate and acquire octahedral shape (Fig. 9).

Let's consider genetic features of described above split pyrite crystals. First of all, spirally split block-crystals of pyrite are not unique. The analogous cubooctahedral split pyrite crystals were detected in O.P. Ivanov's collection on a chalcopyrite crystal from Eghe Khiya tin deposit in Yakutia and in detail investigated crystallographically with application of goniometry and electronic microscopy by M.I. Novgorodova (1977). Her indication on analogous spiral arrangement of block subindividuals on octahedron faces and opposite directions of curling of spirals is of interest for us. At the same time, she considers that «... in spite of the fact that pyrite crystals can be qualified as split, the form and arrangement in blocks is not subject to the known scheme by Frondel established for their varieties axially curled in directions of the ternary symmetry axes» (page 100).

Using the ontogenetic approach, we shall try to understand what germ could initiate a cubooctahedron. As noted above, at resumption of sulfide mineralogenesis, the tendency of change of crystallographic forms {100} → {111} was distinctly manifested and if we admit that germs in cubooctahedral crystals were axially curled cubic crystals characterized by C. Frondel (1936) and S.A. Borodin (1961), all would become clear. Structural memory of screw dislocation in crystals of a germinal cubic crystal on a crystallographic axis of the third order is a principal cause of splitting and formation of rosettes of subindividuals on octahedron faces. Directions of their curling entirely correspond to the C. Frondel's (1936) data. Various axially curled pyrite crystals also were indicated in works by F. Bernauer (1929), A.S. Borodin (1961, 1971), M.I. Novgorodova (1977) and in «Ontogeny of Minerals» by D.P. Grigoriev and A.G. Zhabin (1975).

In summary we shall note that curled and split pyrites, in the data of S.A. Borodin (1971), are the indicator of low temperatures and pressures of mineralogenesis.

Conclusions

1. The investigated split cubooctahedrons of pyrite are block-crystals, octahedral pyramids of grow-over in which are characterized by radial-spiral splitting.

2. The sharp anisotropy of structural etching in pyrite was established showing texture of block-crystals at impact by concentrated nitric acid. Deformation or disorder of crystal lattices of subindividuals in curled block-crystals of pyrite depend on their belonging to grow-over pyramids <100> (not etched) or to saturated with defects — <111> (etched), and also (in details) on belonging to pyrites of the first or second (no-defects) generation. Crystallographic orientation of the section probably played some role. Polished sections in planes close to cubic ~||(100), which are almost not etched, while other, more disordered suboctahedral planes ~||(111) are intensively etched. The prospective reason is natural deformation and disorder of the crystal lattice of pyrite during growth.

3. Sculptural elements of octahedral faces are defined by crystallization of external parts of blocks of subindividuals and epitactically grow over plane-face pyrite crystals of late initiation.

4. By the nature, the characterized pyrite block-crystals of octahedral and cubooctahedral habitus are monomineral spiral-split heterogeneous individuals being an intermediate form of evolution of spherocrystal as a ball entirely covered with square cubic faces.

5. It is supposed that formation of pyrite block-crystals is related to their growth around axially curled cubic germs at change of forms {100} → {111}.

6. Curled cuboids — germs of pyrite — existed only in the beginning of sulfide mineralogenesis at a certain object. Later generations of pyrite, including those forming autoepitactic grow-over on faces of block-crystals, are characterized by ideally smooth brilliant faces without traces of splitting or curling.

7. The considered here pyrites from KMA make a vivid example of simultaneous joint growth of grow-over pyramids of translationally deformed octahedral and disorder-free cubic faces in one crystal.

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