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# Morphology of native copper crystals as component in modeling the mineral formation process

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## SUMMARY

The results of the crystallomorphology study of native copper crystals from the ores of Ukraine (Vendian volcanic rocks of Volyn', the oxidation zones of ultrabasic rocks of the Zhdanivka intrusion at the Berdychiv block and the Chemerpil ore occurrence of the Pobuzhzhyablock of the Ukrainian Shield) are presented.

**Introduction.** Among all the diversity of minerals, only a small part of them forms polyhedra. They most often appear in conditions of free growth, when the environment does not prevent the mineral individual to acquire a certain polyhedral shape. The appearance of certain faces and degree of their development on polyhedra are also determined by the specific conditions of growth. Therefore the features of morphology are important genetic features of the processes of minerals formation.

**Theory.** The morphology of native copper is relatively well studied; but its crystallography was created mainly on the basis of macrocrystals in the 19-20 century. Copper microcrystals (less than 1 mm in size) are poorly studied.

Although native copper is a medium wide mineral in Ukraine, its findings have not aroused much interest for a long time. The discovery of perspective ore occurrences of native copper in Volyn' and more detailed mineralogical studies of native copper manifestations attracted considerable attention to its finds. New data were obtained on native copper from ore occurrences within the western part of the Ukrainian Shield and the northwestern part of the Volyn'-Podillya plate. Here native copper associated mainly with hydrothermal activity (as the changes in basic volcanic, intrusive ultrabasic and carbonate rocks with sulfides).

Native copper from potentially economically interesting objects (Volyn' volcanic rocks, metamorphic rocks of the northwestern part of the Ukrainian Shield, ultrabasites of the southwestern part of the Ukrainian Shield) has its own specific features. However, the issue of crystal morphology and the genesis of native copper from these objects, especially volcanic rocks of Volyn', is still far from being elucidated and requires its solution, which can be of great practical importance for forecasting, prospecting and evaluation of copper deposits. The results of the study of the morphology of native copper microcrystals (size less than 1 mm) from the above-mentioned ore occurrences are the subject of our publication.

In general, native copper has a lot of crystallization forms (Goldschmidt, 1918; Vernadsky, 1955; Chukhrov (Eds.), 1960; Leslie et al., 1967; Olson, 1986; Wilson et al., 1992; Jaszczak, 1998; Rosemeyer, 2001). There are three main types: idiomorphic, hemiodiomorphic, xenomorphic. Idiomorphic crystals are polyhedra, their intergrowths and some dendrites; most dendrites and dendritoids, imperfect crystals refer to hemidiomorphic forms; xenomorphic crystals include lamellar, film, spongy, drop-like, cloddy, veined, amoeboid and solid massive forms. Native copper is also characterized by the formation of pseudomorphs over some minerals (cuprite, calcite, aragonite, azurite, chalcocite, etc) and other substances. The cause of the formation of various forms is the action of a number of external factors: the degree of permeability of the environment in which copper is deposited, the composition of ore-forming solutions, the physicochemical conditions of ore formation, etc.

Polyhedra of minerals, the external shape of which is determined by a combination of a number of factors, is great interest. Since the influence of many of them is not yet clear enough, generally speak of two types of factors: external and internal. The former are related to the growth environment, these are temperature, pressure, pH, chemical composition of fluids, their movement and variability over time. The second affect the shape through various defects and impurities in the crystals, but the most important factor of influence is the structure itself and its features.

Favourable conditions for crystal growth are conditions when the crystal grows slowly, without a large number of defects, and the crystallization environment is relatively stable and homogeneous. At the same time, the main condition for the growth of polyhedra is the presence of free space in the mineral-forming environment (veins, cracks), that is, it must also be easily perceptive for fluids.

Native copper crystallizes in the hexoctahedral class (cubic system) and seven types of simple forms (octahedron, cube, rhombic dodecahedron, trisoctahedron, trapezohedron, tetrahexahedron and hexoctahedron) and their combinations can be manifested on its polyhedra. In the structure of native copper (lattice type - cubic face-centered), copper atoms are almost exclusively present, only a very

small number of them can be replaced by atoms of other elements - Ag, As, Au, Zn .... So, the appearance of possible ideal polyhedra of copper is due primarily to the structure of the mineral.
Information on the crystal morphology of native copper is found in the works of many crystallographers and mineralogists of the 19th century - Haüy (1822), Mohs (1822), Phillips (1823), Haidinger (1826), Rose (1837), Levy (1837), Presley (1837), Chapman (1849), Miller (1852), Schrauf (1872, 1873), Kokscharov (1876), Zadebek (1876), Seligman (1876), Eremeev (1877), Fletcher (1880), Hintze (1898), etc. In addition to the most structurally important simple forms (octahedron, cube and rhombic dodecahedron) copper crystals contain more 13 tetrahexahedrons, 7 trapezohedrons and 9 hexoctahedrons. Until now, not one of the possible trisoctahedrons has been instrumentally recorded on copper crystals, although visually this form was observed by us and other researchers.

More than 30 simple forms characteristic of native copper crystals are known today (Dana, 1886, 1899; Goldschmidt, 1918; Dana et al.,1951; Chukhrov (Eds.), 1960; ets). On polyhedra of native copper from the ore occurrence of Ukraine, goniometric studies revealed such simple forms as {100}, {110}, {111}, {210}, {311}, {322}, {320}, {520}, {740},{750}, as well as new simple forms of copper crystals {940}, {950}, {980} and {259}.

**Results.** The richness of simple forms and habitus is characteristic of native copper crystals from the Vendian volcanic rocks of Volyn' (Figure 1) (Kvasnytsya et al., 2001, 2002; Kvasnytsia et al., 2009). These are rhombic dodecahedron, tetrahexahedrons, transitional forms {110}-{hk0}, octahedron, cube, cube-octahedron. The last two habitus types of crystals are more frequent among on the formations of copper in tuffs; the first three types are found in the breccias of Volyn' basalts.

A simpler morphology is characteristic of native copper crystals from the oxidation zones of ultrabasic rocks of the Zhdanivka intrusion at the Berdychiv block and the Chemerpil ore occurrence of the Pobuzhzhya block of the Ukrainian Shield (Kvasnytsya et al., 2002; Kvasnytsia et al., 2009). Cubes, cube-octahedrons and, less often, octahedrons are quite common among the copper of the Zhdanivka intrusion and octahedrons are among the formations of copper of the Chemerpil ore occurrence.

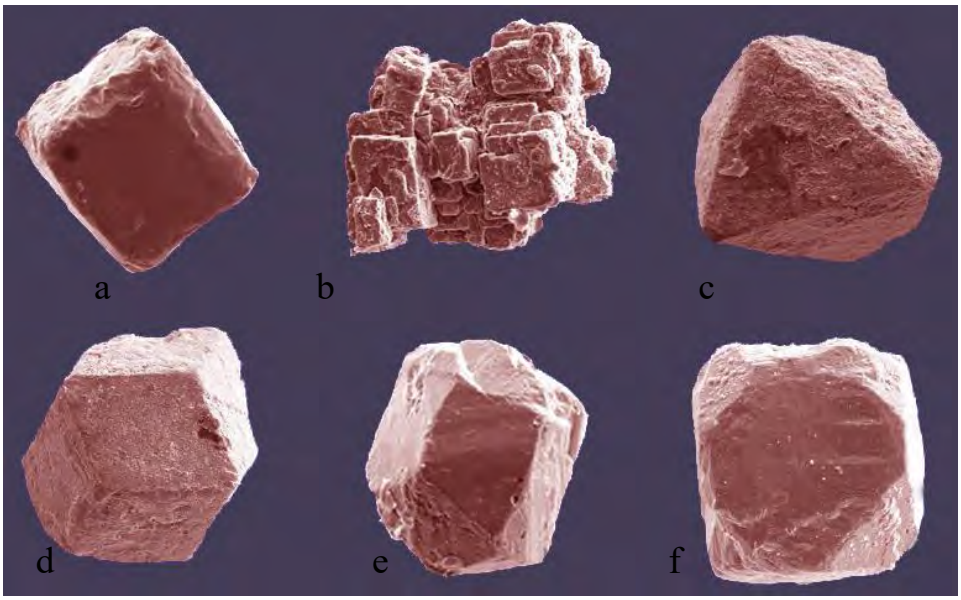


**Figure 1** *Morphology of native copper crystals from volcanic rocks of Volyn' (a - cube; c - octahedron; d - rhombic dodecahedron; e - tetrahexahedron; f - cube-octahedron) and the oxidation zones of ultrabasic rocks of the Zhdanivka intrusion (b –intergrowth of cubes). SEM images.*

Native copper from the oxidation zone of the Chemerpil ore occurrence is represented by simple and more complex (four- and fivefold) twins of octahedrons by spinel law - along the plane (111) (Figure 2) (Kvasnytsya et al., 2002; Kvasnytsia et al., 2009). The regular intergrowths of native copper from

the oxidation zone of the Zhdanivka intrusion are parallel intergrowths and complex three-, four- and fivefold twins of cubes. Parallel intergrowths are the uniformly sized crystals of cubes and cube-octahedrons which have grown on each other. Three- and fourfold twins of cubes by spinel law are elongated pseudotrigonal or pseudotetragonal prisms with input angles. The fivefold twins of cubes by spinel law are represented by well-shaped elongated crystals of pseudopentagonal shape with barely noticeable incoming angles and similar formations, but overgrown incoming angles. Sometimes the top of the cube are blunted by the tiny faces of the octahedron. There are also perfectly formed twins of cube-octahedrons by spinel law. The twins of Volyn' native copper are also simple twins of octahedrons, cubes, rhombic dodecahedrons and tetrahexahedrons, as well as complex twins - fivefold twins of cube-octahedrons rhombic dodecahedrons and tetrahexahedrons by spinel law. The latter are observed more often; they occur both in parallel intergrowths and single. According to goniometric studies, tetrahexahedron of fivefold twins is a simple form close to {650}.

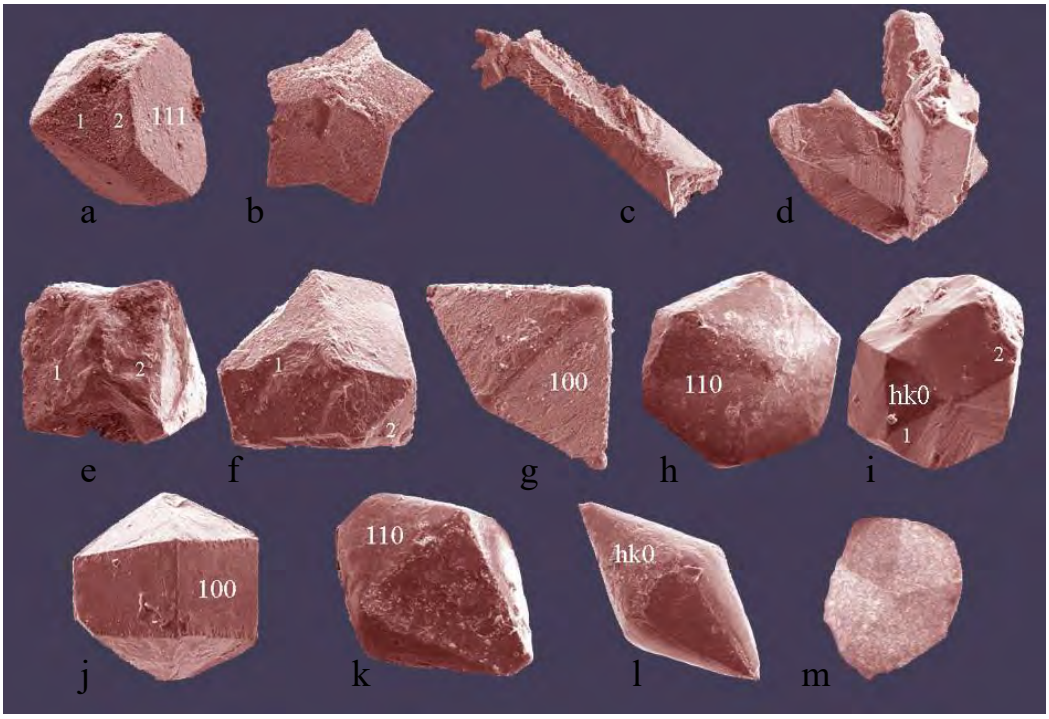


**Figure 2** *Morphology of native copper twins crystals by spinel law: from the oxidation zone of the Chemerpil ore occurrence (a - twins of octahedrons; b - fivefold twins of octahedrons), from the oxidation zone of the Zhdanivka intrusion (c - threefold twins of cubes; d - fivefold twins of cubes), from the Vendian volcanic rocks of Volyn'(e - twins of octahedrons; f - twins of cube-octahedrons; g - twins of cubes; h - twins of rhombic dodecahedrons; i - twins of tetrahexahedrons; j - fivefold twins of cube-octahedrons; k - fivefold twins of rhombic dodecahedrons; l - fivefold twins of tetrahexahedrons; m - section of fivefold twins of tetrahexahedrons in the plane perpendicular to the fifth order pseudo-axis. SEM images.*

**Conclusions.** The morphology of native copper from the ores of Ukraine is due to the nature of the mineral-forming environment in most cases. The free growth of very small copper crystals occurred in cracks, cavities, and other permeable environment, so perfect copper polyhedra grew. A wide range of habitus types of copper polyhedra with a predominance of rhombic dodecahedrons, tetrahexahedron and their combinations is formed under conditions of endogenous crystallization in volcanic rocks of Volyn'. Under exogenous crystallization in oxidation zones (Zhdanivka intrusion, Chemerpil ore occurrence), cubes, octahedron, their combinations and dendrites probably grow out of saturated viscous solutions.

These ores of native copper of Ukraine also revealed a significant diversity of its twin formations, including, apparently, previously unknown to the mineral in the world at all: twins of cubes and rhombic dodecahedrons, fivefold twins of rhombic dodecahedrons and tetrahexahedrons. Although simple and complex twins of native copper crystals are relatively rare formations among polyhedra of Volyn' copper (not more than 1-2%), they, like the single crystals themselves, are peculiar indicators of copper ores, since they are most often found in the horizons rich in native copper mineralization. In

the zones of oxidation of the Zhdanivka intrusion and Chemerpil ore occurrence, the twins of native copper are recorded much more frequently, the latter being dominant. Twins in the Zhdanivka intrusion are associated with different dendritic formations of native copper.

Finally, there are reasons to argue that if the appearance on crystals of the most structurally important forms (octahedron, cube, rhombic dodecahedrons) indicates the optimal growth conditions of native copper, then the presence of simple and complex twins among polyhedra of native copper in the studied ores of Ukraine indicates that in the early stages of their formation, the mineral environment was supersaturated in terms of copper concentration.

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