Crystal-morphological evolution of minerals
(4th scientific discovery in Bulgaria)

A scientific regularity along the applied line of crystal morphology is: “Establishing the change of the morphology of mineral individuals in space and time in the processes of natural crystal formation, including paragenetically, morphologically and anatomically related evolutionary habit trends of minerals, running through a maximum to minimum reticular density of the crystal faces and demonstrating itself in a crystal-morphological zonality of the natural crystals in mineral bodies, deposits and ore fields” (from Bulgaria – I. Kostov, M. Maleev and B. Zidarova, and deom Russia – D. P. Grigoriev, N. Z. Evzikova, S. K. Kuznetzov, D. A. Mineev, V. A. Popov, B. V. Chesnokov, I. I. Shafranovskii and N. P. Yushkin, 1983). The essential ideas of the regularity has been reported at the IMA'82 General Meeting in Varna, Bulgaria (Grigoriev et al., 1981).

As shown by crystallomorphological prospecting and ontogenetic studies, the crystal forms of a mineral change in time and space. This has been illustrated for example on the zonality of the crystals in cassiterite (Evzikova, 1972; 1976), fluorite (Zidarova et al., 1978), pyrite (Evzikova, Belen'kaya, 1980) or rock-crystal (Korago, 1968; Kuznetzov, Yukhtanov, 1981) deposits (see also Povarennykh, 1965). These examples underline the changes in morphology of individual mineral in time and space as a rule and not as a phenomenon of chance. This rule is directed towards the evolution of stable morphological rows. It displays itself also in crystallomorphological zonality of mineral deposits and aureoles. In the case on anatase and cassiterite crystals, it has been shown, that the change of morphology runs at the beggining with increase of the reticular density, and at the end with a decrease of their reticular density of the corresponding crystal forms (Evzikova, 1958; 1965; 1966; 1976; 1979; 1983; Schneer, 1970; 1971; Shafranovskii, Evzikova, 1976). A new scientific branch defined as 'evolutionary crystallomorphology' has been suggested (Grigoriev et al., 1986).

The change of the habits of two or more paragenetic minerals simultaneously grown is also considered to be morphologicaly coinciding or corresponding. This has been demonstrated by the morphological evolutionary rows on co-grown paragenetic crystals of cassiterite and anatase as well as on other minerals (Popov, 1976b; Shafranovskii, Evzikova, 1976; Evzikova, 1979). The platy anatase crystals are related to isometric cassiterite of the early generations, the barrel-type anatase crystals correspond to prismatic cassiterite crystals of later generations, and acute pyramidal anatase crystals to long prismatic cassiterite, latest in time. The crystal habits of co-grown minerals coincide according to crystallochemical resemblance, supposed to be with no difference among isostructural and especially among isomorphous minerals. This is described as “paragenesis of forms” (Grigoriev et al., 1986).

Studies of different minerals showed, that morphological sequences coincide with change of the internal (“anatomical”) morphology of the minerals, thus a synchronization of both processes could be established (Mineev, Rozenkova, 1962; Grigoriev, Zhabin, 1975; Popov, 1976b).

The crystallomorphological evolution of minerals seems to contradict the Bravais principle, but the observed “exceptions” are explained in terms of the densest faces appearing as habit faces only in a deffinite stage of the process of crystallization, near its begginning or its end, the crystal forms according to the Bravais principle appearing inbetween, in the central richer zones of the ore or vein bodies.

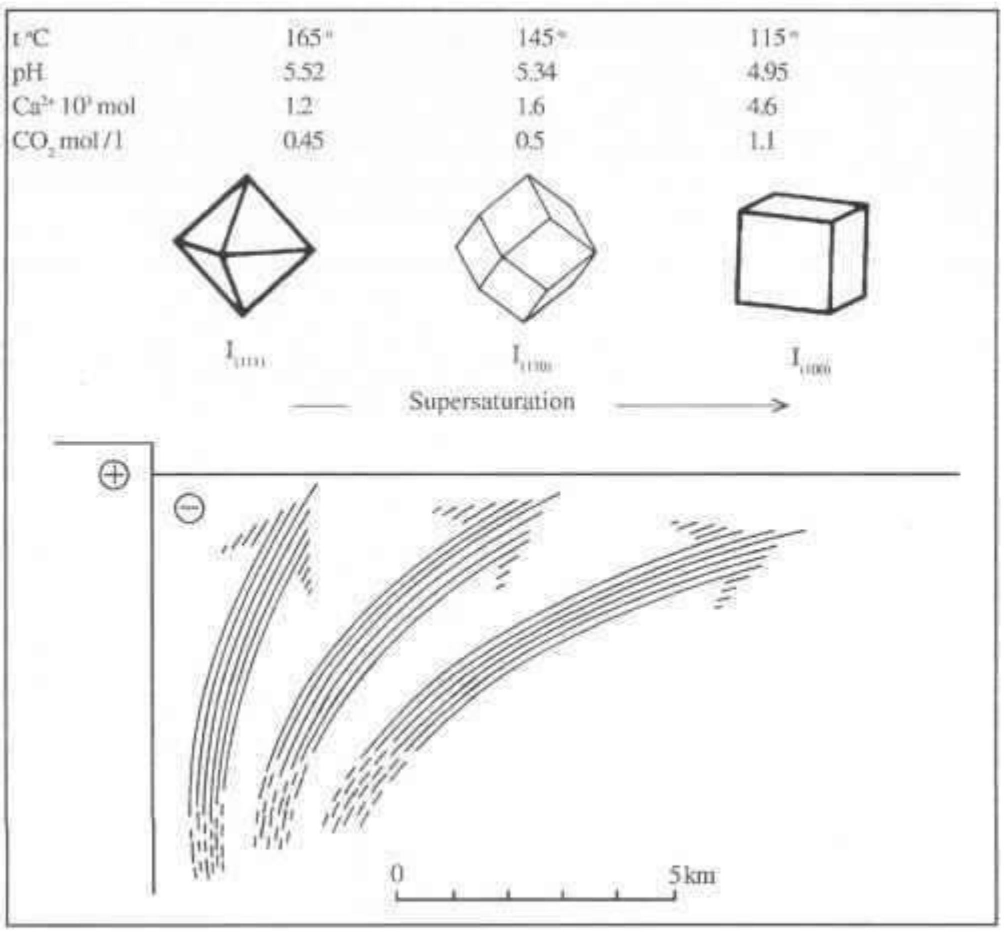
The development of the crystal forms of minerals in space and time is depending on the evolution of the mineralforming environment, viz. physico-chemical parameters (temperature, pressure, supersaturation, pH etc.), and symmetry of environment leading to additional local variability (Yushkin, 1980; Grigoriev et al., 1981; 1986). In certain cases crystallomorphological schemes of habit variations can violate the classical sequences, resulting in “forbidden” morphological combinations. Therefore a statistical approach of crystallomorphological studies is recomended.

The importance of the crystal morphology for geological prospecting and exploration has been stresses by many authors (Kostov, 1975; 1983; 1987; Shafranovskii, Evzikova, 1976; Velikoboretz, 1977; Evzikova, 1980; 1981; Ginzburg et al., 1981; Grigoriev et al., 1981; 1986; Popov, 1984; 1986; see also Petrov, 1959; Lazarenko, Bartoshinskii, 1966; Lazarenko, 1967; Kostov, Kostov, 1999). Two main applications can be underlined: direct observation of crystal morphology of economically important mineral (habit type corresponding to the productive zone or to stages of deposition; important trace elements and impurity phases in different generations of the mineral, zonality in mineral deposits with a supposed sorting of grades of the raw mineral; rate of erosion level in different type deposits; aureoles of distribution of certain minerals; technological grades, etc.

The establishment of crystallomorphological zonality consists of: 1 - differentiation of habit types of different age according to the zonal growth of the mineral individuals and building a morphological sequence; 2 - systematic separation of samples in the ore body or aureole of mineralization and determining the percentage of crystals with different morphological habits; 3 - obtained data are displayed on maps, projections etc., corresponding morphologically zonality being outlined with dominating morphological types; 4 - prognosis and estimation of regularities 5 - checking morphological anomalies (Evzikova, 1980; Grigoriev et al., 1981; 1986). The crystallomorphological zonality of *in situ* deposits is considered copied by placer deposits in a reverse manner. A basic scheme of determination of erosional level of a definite deposit according to the habit variation of amineral has been suggested, illustrating normal and reverse morphological zonality (Kostov, 1975). The crystallomorphological method of prospecting is considered secure, easily dealt with, reliable, cheap, express (it can be used in field or underground work).

Fine zonality in the distribution of fluorite crystal habits is illustarated in the Mikhalkovo deposit, Bulgaria (Fig. 1). Two principal types of morphological zonalities are there recognized: 1 - within individual crystals, and 2 - local or regional zonalities, when individual crystals are bodily homogeneous or nearly so, but spacially vary in habits (Kostov, 1975). The first type is presented in the zoned crystals (the shortest range zonality), with gradual or abrupt change of habits. In both such cases the trend could be “normal” or “reverse” depending on the increase or decrease of the influence of the acepted factors of habit modification. As 'normal' is considered zonality in which the habit modification runs from such formed under higher temperature and lower supersaturation to lower temperature and higher supersaturation, respectively from lower to higher rate of crystallization. The importance of adsorbed elements or other factor of crystallization should be suitably added, as done in the previous chapter of the book for the important minerals.

Fig. 1. Distribution of the fluorite crystal habits in the Mikhalkovo deposit, Rhodope Mountain, Bulgaria, as dependent on tempeature, pH, Ca/CO_2 composition of the solutions and supersaturation (data of B. Zidarova et al. 1978, B. Zidarova, 1989).



Two or more generations of crystal habits are not rare on composite crystals as shown in Fig. 1 for fluorite. Recurrences of habit variation indicate pulsatory crystallization. The long range zonalities are operative in space, found in or around regular or irregular magmatic bodies, or around source of mineralizing solutions, and linear along faults, fissures and dyke rocks. The importance of all these types of zonalities of a mineral or associated minerals stands out clearly not only when genesis of a mineral (ore) deposit is interpreted, but also when evaluation of the deposit from an economic point of view is aimed.