STRUCTURE AND MINERAL ASSOCIATION OF THE VEINS OF THE MINE OF GYÖNGYÖSOROSZI

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In the western part of the Mátra Mountains, in the northern vicinity of the village Gyöngyösoroszi there occur volcanic rocks of a strato-volcanic structure consisting of pyroxene andesites and agglomerated andesite tuffs. The mining exploration of the hydrothermal veins enclosed by same had been begun in the 1750's already. The prospecting and exploration of the mine on a large scale has started however only in 1949. In the course of the mining operations there had up to now been detected about 15 hydrothermal veins. Most important among them is the Károly vein, which is opened up in a length of almost 900 m. The total length of the vein workings of the mine exceeds 16 km.

According to the classification of Schneiderhöhn and Cloos the gold- and silverbearing lead and zinc ore veins of Gyöngyösoroszi represent sub-volcanic hydrothermal veins, containing in their greater part epithermal and in their lesser part mesothermal mineral associations.

By the assistance of the investigation of the vein structure we endeavoured to get answers to the following questions: 1. what were the succession and the phases of the mineral filling up of the veins, 2. which were the productive ore bringing phases and finally, 3. what variations can be observed horizontally and vertically in the association of vein minerals and what regularities may be deduced from same.

In the formation of the ore bearing veins of the Gyöngyösoroszi mine there can generally be observed with the unaided eye or a magnifying glass six ore minerals (pyrite, galenite, chalcopyrite, sphalerite, wurtzite and marcasite) as well as more than ten varieties of barren minerals (quartzite, rock crystal, chalcedony, opal, jasper, amethyst, calcite, dolomite, manganocalcite, chlorite, baryte, celestite, fluorite, gypsum). In addition to these minerals, by microscopic examinations or chemical analyses there can be detected at least fifteen vein minerals, occurring in small quantities (tetrahedrite, arsenopyrite, gold, stannite, bournonite, jamesonite, semseyite, antimonite, chalcocite, covellite, cerussite, boulangerite, chabasite, laumontite, adular). The veins are banded, the individual bands (layers) are formed of the substance of not more than one to three different minerals, the banded elements extend along long stretches of the vein in a parallel arrangement and are easily distinguishable one from the other. Even in cases when the vein had been crushed by a tectonical force working along the vein, the latter is generally not smashed to such a degree, that the mineral associations forming the different bands were mixed and the homogeneous bands could not be recognized. In case of the development of a brecciated structure the cements of the vein rubble are fairly homogeneous and the original vein structure, that existed before the tectonical process, may easily be reconstructed. From the foregoing it seams to be easy to determine the order of deposition of the vein minerals. In reality, however, it represents a rather difficult task. The bands forming the veins, mainly just the ore interstices, are very thin; their thickness equals some centimetres and frequently only some millimetres, thus they can sooner be called stringers. These stringers are frequently recurring: proceeding towards the younger vein fillings the succession of identical vein fillings repeats itself several times. Thus the mineral generations of decreasing temperatures were followed again and again by generations of higher temperatures. It is a matter of course that such recurrences have partly or totally reabsorbed or redissolved certain former mineral generations or replaced them by younger ones. Thus the first generation of galenite is intermixed to a various degree with sphalerite and in most places of the ore stringer driven out, replaced by it, consequently in the middle section of the Károly vein smashed pieces only of the galenite can be observed under the magnifying glass. Exemples of a similar phenomenon can be observed also in relation of first generation galenite and quartz, the latter bringing about the subsequent displacement of the former. In the Péter-Pál vein of Bikkszél sphalerite is partly replaced by chalcopyrite. In the vein No. 1 of Bikkszél calcite is sometimes replaced by quartz and chalcedony. So the recurrences, rejuvenations are manifold and are packed in the vein structure spatially also into a small space. It is particulary the sphalerite, which presumably took its place by resolution. After they had been smashed up or become friable, the same mineral generations show in accordance with the space in question various degrees of recrystallization: the imperfect recrystallization of the gel-like silica can only arbitrarily be distinguished from the finely brecciated cryptocrystalline variety of quartz, which was subsequently cemented by silica gel. The regressions in temperature, respectively the rhytmical recurrences (pulsations) of the geochemical conditions of the parent solution succeed one another in certain sections of the Károly and Péter-Pál veins 12 to 18 times, their product is the closestriped so-called »zebra ore«. The variousness is crowned by the fact that the opening up of the veins did not occur simultaneously but intermittently. The opening up, viz. the widening of the vein cracks sometimes took place by five to six subsequent splittings. Although the vein structure is generally symmetrical, this symmetry is disturbed just by these recurrent openings up. For the cracking up did not occur unfailingly along the youngest mineral filling of the vein, viz. along the genetical medium plane, but asymmetrically or in a zigzag line or even by laminar loosening. In consequence thereof even if in such vein sections the whole succession is at hand, its deciphering proves in most cases to be dubious: the vein structure reminds a shuffled pack of cards.

In attempting the determination of genetical phases and, within their limits, of generations first of all it must be pointed out that the results obtained have to be considered for the time being as a supposition based upon the structural observations executed in certain intact vein sections. It is the task of the future to execute upon the individual veins detailed ore microscopical investigations and trace element analyses, which in all probability will bring us nearer to the solution of the genetic problems. The investigations executed by *Sándor Koch*[8] provide an exceedingly suitable basis for the detailed investigation of the locality in question and the results reported must be taken into consideration in an increased degree all the more because they were almost wholly verified by the observations executed in the course of the geological survey of the mine.

It is an undeniable fact that the *first phase* of the vein formations is represented by *veins of barren dykes.* It could be ascertained that they represented the first fissures of the cooling lava. They appear in different workings of the mine with thicknesses of 5 to 40 cm and a variable strike. They are cut by the ore bearing quartz veins. It is possible that certain veins of this vein system of barren rocks existed also along the strike of productive veins and preceded the ore bringing quartz veins, however, the vein filling was absorbed, sucked up by the material of the later vein and thus the pre-existence of such a barren vein could not be ascertained. The filling of such barren veins shows a bluish-grey, greenish-grey or reddish-grey colour. Its material consist in most cases of sparse angular and pointed rock fragments with diameters of from 0,5 to 3 cm, reminding a fine-grained sandstone or a quartzite with cryptocrystalline structure, cemented by a fine-grained silicified homogeneous vein substance. On basis of its petrographical character the always prevailing cementing material probably consist of a tuff washed in into the fissures and permeated by hydrothermal solutions rich in silica. Its exceedingly fine-grained silt-like structure has been conserved, but its material is sometimes almost entirely replaced by silica. This seems to demonstrate the influence of the first hydrotherms ascending through the fissures of the barren veins, confirmed also by the fact that on their borders these veins are often accompanied by a zone of caolinic decomposition.

The *second phase* of vein formation probably generated the thick-banded massy cryptocrystalline vein quartzite, simultaneously with which there began the deposition of the first pyrite generation as well as that of an older galenite. The mineralization of this phase is poor and therefore in itself not minable. The first galenite, appearing in a limited quantity and in the form of isolated grains, is displaced by a silica, that in the course of later movements along the veins permeated the fissured or even brecciated thick-banked quartz. In consequence of a powerful crushing the fragments of the country rocks sometimes got into this section of the vein, too. The permeating and recementing silica solution enhanced the decomposition of the older galenite by segregating also chalcopyrite and sphalerite, partly taking the place of the crushed and dissolved galenite. On account of its strong ferrous pigmentation and its dark colour the sphalerite of the first generation proves to be easily discernible.

As a product of the *third phase* may be considered the fine-banded, densely striated complex formed by quartz, chalcedony, opal as well as minute quartz druses and visible in almost every vein of undisturbed development; simultaneously with it there appears in the lower horizons of the mine wurtzite and in general the second generation of galenite. Most of the galenite stocks of the mine were provided by the phase in question, namely directly at its beginning in the form of uninterrupted high grade ore bands or densely dispersed nests. Later on there appear thin stringers of alternating rhythmic galenite and sphalerite generations, their series are characterized by the gradual relative increase of the sphalerite. At the end of the phase the sudden enrichment of sphalerite can be observed. This second sphalerite generation, the colour of wich is light-brown or resinous-yellow, represents most of the ore quantity found in the present mine workings. The ore in question produces in some places — mainly in the vicinity of the points of ramification or juncture of the veins — a considerable tenor of ore in the form of zonal twin crystals with sizes of 1 to 3 cm or segregations gathering in a thicker vein. To the final stage of this phase there sometimes attaches a kaolinic phase. The kaolinic ore bearing rock contains similarly galenite and sphalerite in the form of a spotty sprinkling, but in smaller concentrations and with the peculiar deviation that the enrichment concluding the phase in question is provided not by sphalerite, but again by galenite.

The *fourth phase* once more produces a massive cryptocrystalline quartzite but in a smaller quantity and with an ore that does not attain the stage of workability (sphalerite, chalcopyrite, pyrite and traces of galenite). In investigating the product of this phase the impression is gained that the quartzite may have come into being by means of the subsequent recrystallization of the gel-like silica hydrate. This massive silica variety, which shows in many cases a hair's-breadth thin and indistinct reticulated design, is often tinted red by a finely dispersed iron compound (hematite?). This vein constituent reminds the vein rock called »zinopel« in the workings of Selmecbánya and Hodrusbánya.

In the *fifth phase* probably arose the carbonate vein rocks. The filling up regularly started by a thick, coarse-crystalline calcite, upon which deposited a black-tinted (manganiferous) thin layer of calcite. These two calcite varieties of different colours cover each-other in 4 to 5 or more thin layers, but in such a way that the individual incrustations are interwoven by lace-like bulges or cocarde figures; in the older generations the black-tinted variety gains the upper hand. After that the design is edged by some chalcopyrite and pyrite, followed by a larger mass of uniformly brown-tinted calcite or occasionally manganocalcite, showing similarly a coarse-crystalline structure. After the phase providing black and white calcites there sometimes follows a coarsely brecciated crushing, among the fragments of the calcite vein in certain veins there may be found fragments of the country rock, too (*e. g.* in the vein »1600-as«), then the fragments are imbedded once more in a black and white fine-crystalline calcite substance. In other cases the black and white calcite fragments are united into a homogeneous block by the ultimately deposited brown-tinted calcite. At the end of the phase, especially on the higher levels of the mine and in the eastern veins, in addition to pyrite there appears also marcasite, whilst the innermost crust of the hollow druses is often formed by a fine-crystalline dolomite with a yellowish lustre. In the company of dolomite there can also be found baryte, occurring occasionally in the mine workings. The phase in question can hardly be considered as significant from the point of view of the mining operations.

The sixth phase starts by the slight splitting of the already established vein fillings in consequence of which there opens for the amethyst deposited in same a rather capriciously meandering aperture, which oversteps even the vein borders and returns to the vein in an arched form. The amethyst filled veins, come into being in this manner, mark only approximately the strike of the vein and it may be said that they move only in the vicinity of the latter. It seems that the typomorphic mineral connected with the amethyst phase proves to be the chalcopyrite, although beside it there appear in this phase also pyrite, marcasite and more rarely sphalerite, namely its peculiar honey-coloured youngest variety, developing in most cases as a thin, stringer-like series of grains. On the other hand, amethyst could be observed only in the Károly and Bikkszéli veins, running along the strike and filled up in the course of their widening, whilst in the crushed or compressed vein fissures (*e. g.* in the vein »1600-as«) it does not occur. Amethyst never occurs together with galenite or carbonates aside from the case that they are traversed by the leading fissure of the amethyst. Hydrothermal decomposition and kaolinization are never connected with an amethyst stringer, the vicinity of the latter almost always consists of a silicified compact country rock, impregnated by silica. Amethyst always represents the final phase of mineralization and lies for itself far below the limit of workability, although its occurrence is so to say a complement of the fully developed rich vein sections. It richly permeates the brecciated or ruptured rock zones, that are independent of the ore bearing veins, cements the brecciated fragments and forms exceedingly beautiful druses. Its tributary minerals are celestite and gypsum.

As a seventh phase mention must finally made of the antimonite filled stringers occurring in some places of the mine, especially on its highest level and in a very scarce quantity, accompanied by low-temperature quartz, gypsum and calcite. Their occurrence in the mine is only of mineralogical interest.

The genetic order described in the foregoing cannot be observed in its entirety in the same vein section. In the vein structures some mineral generations are missing, others are mixed with each-other and this represents the biggest factor of uncertainty. The whole system of phases could be constructed only by inferences drawn on basis of the investigation and comparison of selected sections of various veins. In relation of this operation the only reassuring phenomenon consists in the fact that in the veins of identical origin of the occurrence there can nowhere be found dissimilar mineral associations or conspicuous differences. It seems, on the other hand, that this genetic order can fundamentally be compared with the results of the above mentioned investigations of *Sándor Koch,* in which the individual mineral generations of the ore bearing veins of Gyöngyösoroszi are given in the following order:

Ores: pyrite I, galenite I, gold, chalcopyrite I, sphalerite I, wurtzite, stannite, bournonite, galenite II, sphalerite II, chalcopyrite II, marcasite, pyrite II, jamesonite, semseyite, arsenopyrite, tetrahedrite, antimonite.

Non-ores: quartz varieties (quartzite, chalcedony, jasper, rock crystal, amethyst), opal, calcite, dolomite, fluorite, pennine, baryte, celestine, gypsum I, laumontite. In agglomerated tuffs: adular.

In the oxide zone: chalcocite, covellite, cerussite, sulphur, gypsum II.

In opposition to several authors, in respect of the ore occurrence of Gyöngyösoroszi there cannot be attached great importance to such a genetic classification from the point of view of mine working as *e. g.* in the course of the driving of opening drifts the generation representing the productive phase of the vein may be interrupted or — in case of its lack — reappear. At any rate the process in question can successfully be applied to avoid serious errors in prospecting as *e. g.* a low-grade vein, the structure of which fits into the formations of the third phase, may further be prospected with good hope, whilst the following by a drift advance of an independently occurring amethyst bearing seam filling or of a brecciated trend cemented by amethyst will most assuredly prove to be unsuccessful.

In respect of the last question propounded at the beginning of the discussion, viz. the horizontal and vertical variations of the mineral association, the mine workings executed up to now do not offer limiting experiences, although it is indisputable that in the course of the last few years the extension of mineralization could be determined with a much greater approximation than during the previous decades. It appears that in the underground mine workings the horizontal extension of the productivity of the present mining centre at the level of the adit (400 m above sea-level) has roughly been cleared by extensive prospecting. At this level there is not much to be looked for, the straight front entry of the adit extends northwards already towards a further mineralized region that is not cleared up yet; towards NW the prospecting activity should similarly be developed in the direction of the nearest ore bearing region.

The length along the strike of the most important ore bearing veins, disclosed at the adit level, varies from 400 to 800 m, beyond that distance the veins become barren, ramify and pinch out. Approximately only half of the above mentioned strike lengths is workable however. Progressing, towards the flat terminations of the veins, the products of the third (fine-banded) and at the same time most valuable genetic phase terminate earliest of all, whilst the final veinlets of the fifth and sixth (carbonate and amethyst bearing) phases extend farthest. This can be observed best of all at the northern and western borders of the centre of mineralization. The southern boundary of the natural, undisturbed pinch-outs and ramifications is not known. At the level of the adit, near the intersection of the Károly vein with the straight front entry of the adit, there can be observed a rather considerable tectonic dislocation, which has displaced the Károly vein from its crossing with the straight front entry of the adit eastwards to a distance of approximately 15 m. The strike of this dislocation is 305°, its dip 80° to SSW. On basis of the vein structure and the fault relations as well as of the structural comparison of the vein section lying north of the fault with its southern section it seems probable that in the gallery lying north of the fault the Károly vein will be detected — in accordance with the situation existing before the dislocation — on a deeper section. This means that along the great fault of the Károly vein there occurred not only a horizontal, but chiefly a vertical displacement. The great fault striking from WNW to ESE cannot be followed in the vicinity as there are no mine openings here. It seems, however, that in the southern section of the Péter-Pál vein-working (in the former »180°« shoot) the fractured and disturbed zone, lying at a distance of about 150 m from the Arany-Péter vein-working, as well as the interruption of the vein, connected with its displacement, lie in the strike of the great fault. It these two facts are really in connection, then it follows that the eastern part of the southwestern block, situated below the slip plane, was downcast by a rotary motion to a greater extent and its western part to a lesser extent. The slip planes of the above mentioned great fault of the Károly vein indicate the downcasting of the southwestern block. The centre of rotation of this motion must have lain somewhere in the Péter-Pál (180°) vein. The downcasting of the above mentioned block gives an obvious explanation of the structure of the Péter-Pál vein, showing near its juncture with the Bikkszéli front entry the downfall of the opening and loosening vein matter, as well as of the rich, virtually »comfortable« development of the amethyst, deriving from a late phase. This means that in the vein workings lying southwest of the fault line the veins are situated in a higher genetic zone. This may serve as an explanation of the above mentioned fact that in consequence of tectonic phenomena and owing to the lack of adequate development works we are not acquainted with the natural original terminations of the veins. In consequence thereof the undisturbed original workable strike lengths cannot be determined either. This circumstance serves also as an explanation of the fact that below the adit the exploration of the whole vein group seems to be most promising in a souther direction.

As regards the vertical development of mineralization some data are provided by the peripheral prospecting activity preceding the establishment of the Gyöngyös Ore Mine and to some extent extending into the time, when the Mine was working already. On basis of the data obtained it could be ascertained that the oxidation, the leaching, affects the veins to a sub-surface depth of 20 to 25 m. This action is so strong to a depth of 6 to 10 m that even if the vein contained an appreciable quantity of primary ore, most of the latter has been removed and thus at this level the vein is not productive any more. The vein matter shows only skip pockets as well as a discolouration, indicating the former presence of the ore. It is a well known fact that in consequence of the massive structure of the vein matter, the substances dissolved near the surface could not reach a deeper level and thus a cementation zone could not come into being. Leaching ensued only to a depth to which external disintegrating forces could penetrate and disaggregated or crushed the vein matter. The solutions formed in the course of leaching reached the surface upon the lower plane of the disaggregated and crushed section.

The data obtained from the present, but mainly from the former prospecting indicate that the veins occurring in the wider region of the ore mine are poor in ore in the vicinity of the surface, whilst at lower levels their ore content increases. It seems that the height of 400 m above sea-level, representing the level of the adit, proves to be the optimum zone, within whose limits, in consequence of tectonic movements, the optimum mineralization occurs in the southern part of the territory at a relatively lower and in its norther and northwestern parts at a higher level. In addition to this it can be ascertained with great probability that along the strike of a vein the optimum zone has to be looked for by proceeding from the rich middle section of the vein towards its pinches and terminations, at an increasingly lower level.

With respect to the mineral composition of the veins towards the depth information can be obtained only from the Károly vein, this being the only one that had been prospected and developed at five levels and some intermediate levels of lesser extent with a pillar height of 260 m (between 460 and 200 m above sea-level). The mineral composition of the said vein does not show any marked zonation, there can sooner be observed a gradual alternation, which is hardly perceptible from one level to the other. This alternation manifests itself in the fact that the quantity of galenite decreases and that of the sphalerite increases with the depth. Towards the lower levels the quantity of chalcopyrite and pyrite gradually also increases. Such a change is a well-known phenomenon in ore veins of a similar type. It seems that the thickness of the veins decreases to some extent towards the depth. It may be surmised that in addition to the further decrease of galenite further development works will bring to light also decrease of sphalerite and in a greater depth that of chalcopyrite as well as a quantitative increase of pyrite, viz. a gradual impoverishment of the veins. In spite of all this it seems to be absolutely justified that some veins, the development of which in the present centre of mining, at the level of the adit does not prove to be workable, should be prospected at lower levels.

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