# Origin of the Ore Veins in Mátra Mountain after Isotope Investigations

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## Introduction

During the last twenty years the isotope determinations have come into use in a rather wide field of the geological and geochemical research. Beside the composition of lead, the isotopic composition of carbon and oxygen were most frequently determined and used in geological investigations. The authors' work to be reviewed in this paper was carried out in order to elucidate some problems concerning the formation of the ore veins in the Mátra mountain (Hungary) by investigating the oxygen and carbon isotopic composition of the vein carbonate minerals.

## The Geological Environment. Petrography and Mineralogy

The Mátra mountain is a volcanic area of high uniformity. Considering its geological setting and morphology an Eastern and a Western Mátra may be distinguished.

The Tertiary volcanic and sedimentary rocks of the Eastern Mátra are situated on a Mesozoic basement of the Bükk Mountain type. Its volcanic evolution has taken place in two steps, in the Upper Eocene and the Lower Miocene respectively. The magmatic material came to the surface after traversing a Triassic carbonate and pelitoidic stock of about 3000 m thickness, in the lowest layers of which a rich contact metasomatic recrystallization took place.

The Eocene volcanic rocks (200—600 m) appearing as lava shields, veins and pyroclastics consist of amphibole-biotite-andesite, Q-amphibole-biotite-andesite, biotite-amphibole-andesite. The well known enargitic ore deposit (Recsk) is located in the upper level of this volcanic stock, while in the subvolcanic levels Cu-porphyric pyrometasomatic Pb-Zn-Cu ore occurrences are found.

The lava shields, veins and pyroclastics of the Miocene volcanism consist of pyroxene (hypersthene) andesite. In the Miocene volcanic stock only some scattered pyrite and, unsignificantly, pyrrhotite, sphalerite and galena can be found.

The Western Mátra main bulk consists of Miocene (Tortonian-Sarmatian) stratovolcanic rocks, with the Eocene sedimentary and volcanic formations missing. It is adjacent to the Mesozoic carbonate basement, or to the Paleozoic basement consisting of crystalline metamorphic rocks, through the Oligocene sediments.

This Miocene volcanic complex consists of two or three lava beds (augite-hypersthene-andesite, hypersthene-augite-andesite), augite-andesite veins and pyroclastics. In the lower lava bed, in the surroundings of Gyöngyösoroszi and Parádsasvár, a system of hydrothermal veins having significant extension had been formed, mainly in the crack systems NW—SE and NE—SW. The ore of these veins is polymetallic and of the Zn-Pb-Cu type, embedded in quartz-amethyst, barite and calcite matrix.

During the systematic isotopic investigations started two years ago, the carbon and oxygen isotope ratios in the carbonate rocks of the ore deposits in both the Western and Eastern Mátra were measured. In this paper the results obtained for the ore vein near to Parádsasvár (Western Mátra) are briefly summarized. This vein displays a typical periodic texture ("zebraic ore"), changed in some places into the cocade one. The most uniform sections consist of ore ($ZnS$, $PbS$, $CuFeS_2$, $FeS_2$) and calcite zones in a periodical but asymmetric texture. Near to the hanging side rhombohedral calcite druses of about 20—40 cm in diameter were formed, onto which calcite crystals consisting of scalenohedrons and scalenohedral rhombohedrons were superimposed. Formation of $ZnS$, $CuFeS_2$ and $FeS_2$ (galena being mostly missing) has taken place even in this section of the vein.

## Experimental Techniques of the Isotope Investigation

### a) *Collecting of Samples*

The samples for isotope investigation were collected on three different cross sections of the vein, located as shown on the sketch in Fig. 1 from the pure calcite separating the layers of the deposited ore. Besides, samples were taken from a twinned calcite crystal from a calcite druse in which the succeeding steps of mineralization can be followed qualitatively on the basis of mineralogical evidences.

### b) *Sample Chemistry and Mass Spectrometric Isotope Analysis*

Small quantities from all samples, weighing about 0,5 to 1 g were ground to fine powder, 30 mg of which was than used to yield carbon dioxide for oxygen and carbon isotopic ratio measurements, by reacting with the 100 % phosporic acid. If control measurements seemed to be necessary, another quantity of 30 mg was consumed of the powder sample in question. The isotope analyses were carried out by a VARIAN MAT M 86 type mass spectrometer, having a double collector and a dual inlet system. Both the oxygen and carbon isotope ratios reported in this paper present $\delta$-values relative to the PDB standard. In the course of this work the samples of "Stryngocephalenkalk from Rübeland" were used as working standards, having $\delta$-values relative to PDB standard —6,8 and +2,0, for oxygen and carbon respectively. The precision of the data is better than ± 0,3.

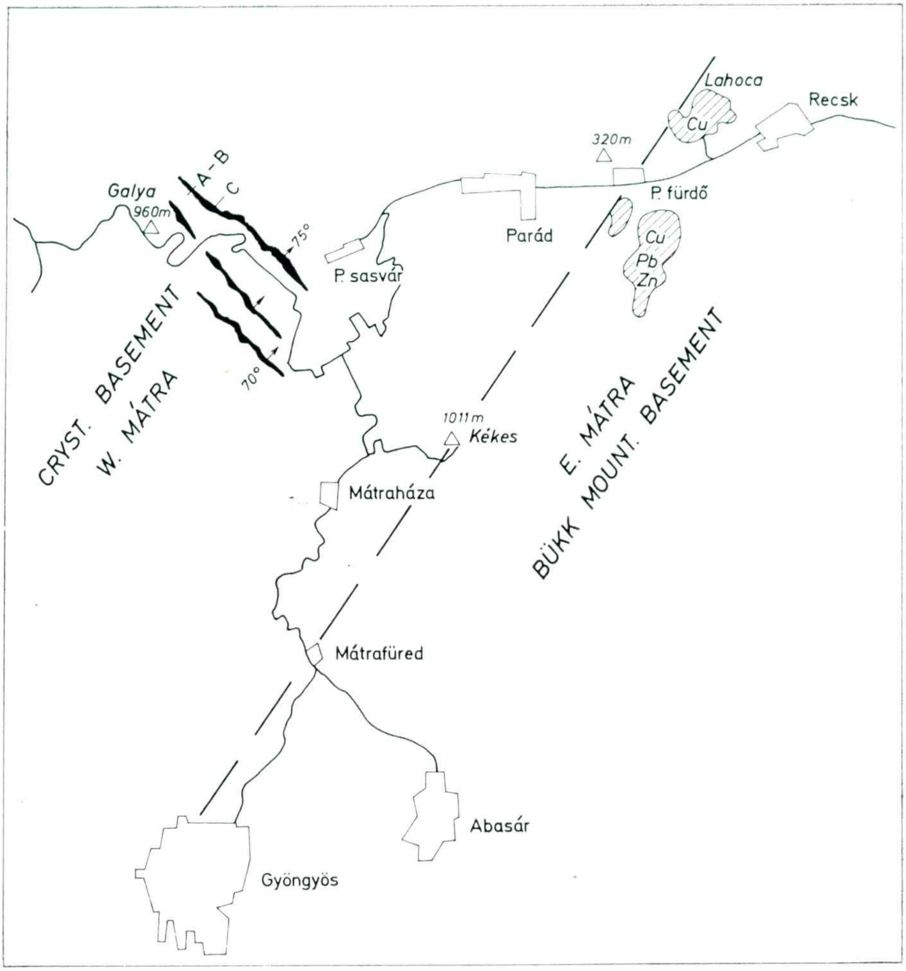

Fig. 1

## Results of the Isotope Investigations

The results of the mass spectrometric isotope analyses are summarized in the tables 1 and 2. Table 1 contains the $\delta_O$ and $\delta_C$ values of the samples No 1 to 7 of the cross section A, the samples No 1 to 4 of the cross section B, and the samples No. 1 to 3 of the cross section C. The numbering of the samples follows in each case their order of succession from the lying towards the hanging side.

Table 2 presents the $\delta_O$ and $\delta_C$ data obtained for the samples taken from the twinned calcite crystal. Samples No. I (1, 2, 3) belong to the central part of the crystal, while samples No. II. (4, 5, 6) have been taken from a twin crystal grown onto it. The scalenohedral outer part is represented by samples No. III. (7, 8) and, finally, the samples 9 and 10 were taken from zones consisting mainly of clay minerals, which were deposited onto the central and the twin crystal, respectively.

**Table 1**

| Cross section | Sample | $\delta_O$ | $\delta_C$ |
|---|---|---|---|
| A<br>(Fig. 2) | No. 1 | —16,3 | —2,1 |
| | 2 | —16,9 | —2,3 |
| | 3 | —15,0 | —2,9 |
| | 4 | —17,1 | —2,1 |
| | 5 | —10,8 | —4,8 |
| | 6 | —16,0 | —3,7 |
| | 7 | —16,5 | —2,2 |
| B<br>(Fig. 3) | No. 1 | —12,5 | —2,9 |
| | 2 | —18,2 | —2,7 |
| | 3 | —14,5 | —2,8 |
| | 4 | —16,9 | —2,8 |
| C<br>(Fig. 4) | No. 1 | —14,8 | —1,4 |
| | 2 | —12,8 | —4,5 |
| | 3 | —18,3 | —2,9 |

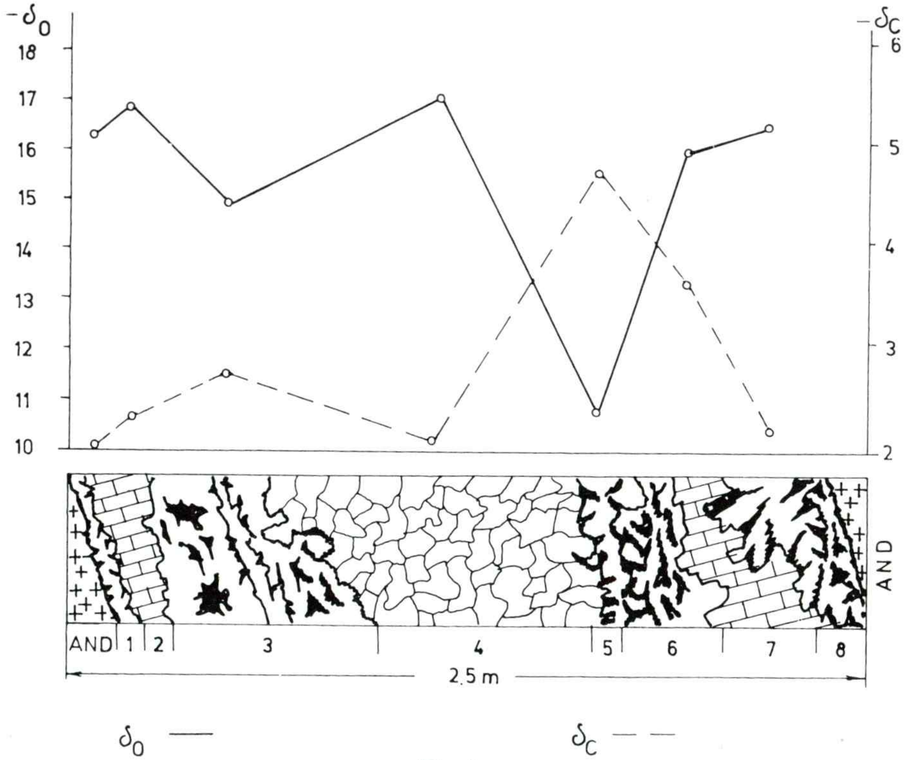

Fig. 2

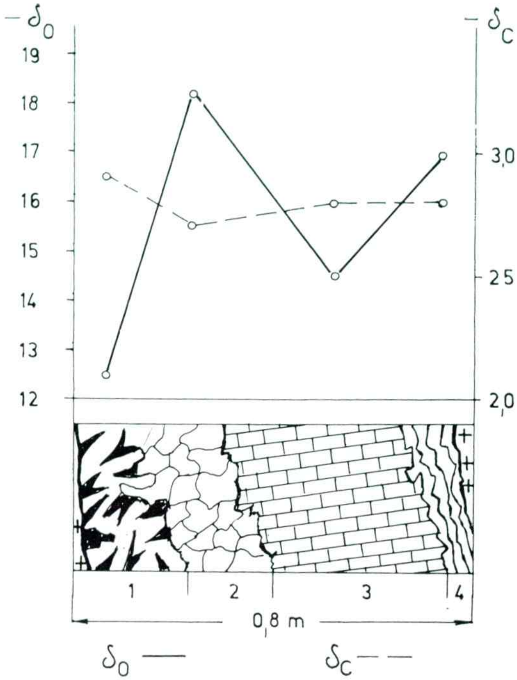

Fig. 3

**Table 2**

| Sample | | $\delta_O$ | $\delta_C$ |
|---|---|---|---|
| No. I. | 1 | —19,0 | —2,8 |
| | 2 | —21,8 | —3,8 |
| | 3 | —21,2 | —3,9 |
| No. II. | 4 | —14,7 | —0,47 |
| | 5 | —16,7 | —2,6 |
| | 6 | —16,7 | —1,6 |
| No. III. | 7 | —16,5 | —2,5 |
| | 8 | —19,0 | —4,3 |
| No. | 9 | —21,1 | —3,5 |
| | 10 | —14,3 | —1,8 |

## Discussion of the Results

Some preliminary measurements performed in the year 1965 indicated a distribution of the $^{16}O$ and $^{18}O$ isotopes along a cross section of the vein in question, characterized by two maxima of the $^{16}O$ concentration (Cornides, Kiss and Szeredai, 1966). The present more detailed and accurate isotopic investigation has reaffirmed this finding for three other cross sections of the same vein. As shown by the diagrams of Figures 2, 3, and 4 the values of $\delta_O$ display two negative maxima along

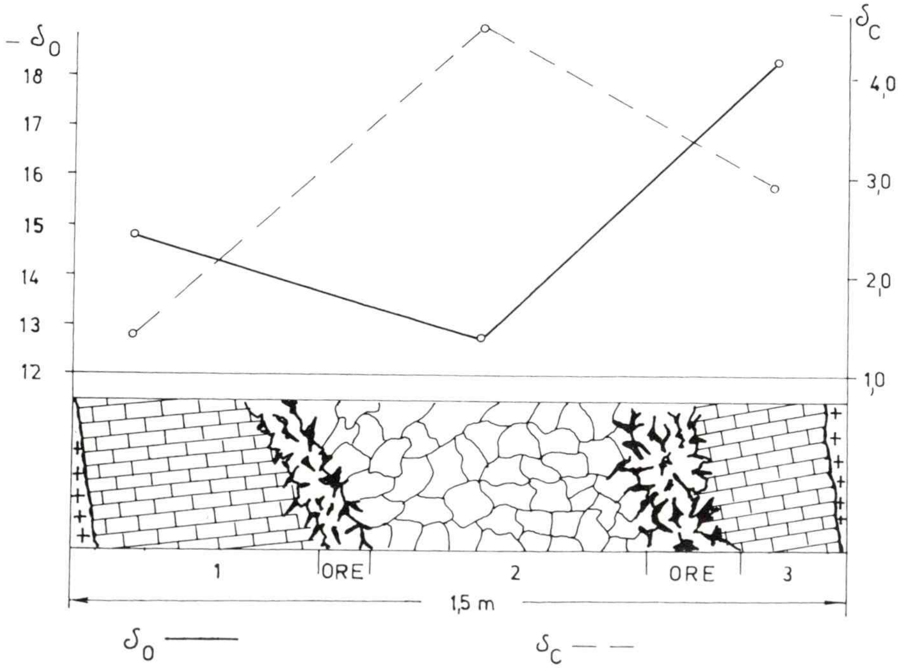

Fig. 4

each cross section investigated, corresponding to two maxima of the temperature of formation.

Considering both the results of the isotope investigation and all geological evidences, the most probable mechanism of the formation of this vein may be described as follows.

When the crevice first opened, the ascending hydrothermal solution was cooled down by the mother rocks and the formation of the minerals started at a moderate temperature. At the same time, however, the side walls were heated up, their cooling effect decreased and, therefore, the crystallization from the newly ascended solutions having followed the gradual dilatation of the hanging side took place at an increasing temperature. Later the cooling effect due to heat conduction etc. predominated again, causing the temperature to reach a maximum and then to decrease to a much lower value. The temperatures calculated from the isotopic data show a maximum as high as $280^0$ C, and a minimum at about $140^0$ C.

Accordingly, both the asymmetrical structure of the vein and the temperature variation found can be understood; the dilatational movement being evident by the general geological setting of this area as well. The second temperature maximum near to the hanging side can be explained by an abrupt increase of the dilatational velocity, a fact rendered probable also by the presence of the druses in this section. Due to the consequent reopening of the crevice a considerable quantity of high temperature

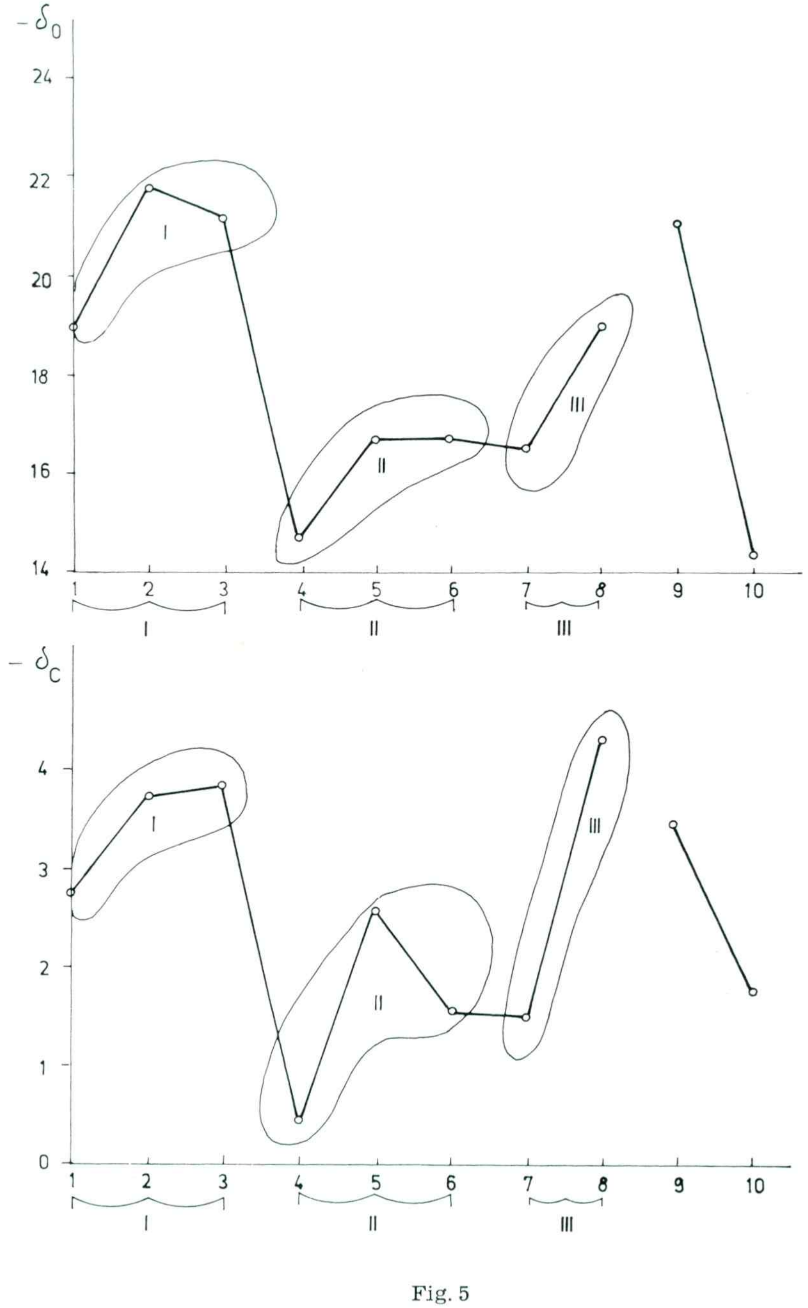
$-\delta_0$
24
22
20
18
16
14
I
II
III
1
2
3
4
5
6
7
8
9
10
I
II
III
$-\delta_C$
4
3
2
1
0
I
II
III
1
2
3
4
5
6
7
8
9
10
I
II
III

Fig. 5

hydrothermal solution rose up again and phenomena similar to those of the first period of the vein formation were repeated.

It is remarkable, that the variation of the isotopic composition of the carbon, i. e. the $\delta_C$ values, follow consistently a trend opposite to that displayed by the $\delta_O$ data, though, due to the same formation temperatures, qualitatively no difference could be expected. The data obtained for the big twinned crystal on the other hand, actually show a qualitative agreement between the trends of the change of the $\delta_C$ and $\delta_O$ values, respectively. This fact may reflect the apparent difference between the quiet conditions of formation of the big crystals of the druses and the conditions governing the formation of the main body of the vein. It may be mentioned that Schoell and Stahl obtained a similar agreement, when they measured the oxygen and carbon isotopic composition of a big single crystal (Schoell and Stahl, 1969). Another remarkable finding, namely the quantitative difference found between the isotopic data of the central part and the twin crystal, respectively (see Fig. 5), and some more detail problems of the vein formation process, deserve further attention.

## References

Cornides, I., Kiss, J., Szeredai, L., 1966, Températures de formation d'un filon de minerai dans la Mátra centrale d'après la fréquence relative de l'isotope $^{18}O$. Bulletin of the Hungarian Geological Society, 96.

Schoell, M., Stahl, W., 1969, »C- und O-Isotopenanalysen an hydrothermalen Kalkspäten aus St. Andreasberg, Harz«. Conference on stable isotopes, Leipzig.

## SUMMARY

During the last twenty years the isotope determinations have come into use in a rather wide field of geological and geochemical problems. Beside lead, the isotopic composition of carbon and oxygen was most frequently determined and used in geological research. The authors' work to be reviewed in this lecture was carried out in order to elucidate some problems concerning the formation of the ore veins in the Mátra mountain (Hungary) by the use of the investigation of the oxygen and carbon isotopic composition of the vein carbonate minerals.

At first the variation of the oxygen isotope ratio of vein calcites was investigated along different cross sections of the vein. The oxygen isotope ratio profiles obtained display two characteristic maxima, corresponding to maxima of the temperature of formation. This result strongly supports the hypothesis according to which the formation of the vein has taken place in two steps with an intervening dilatation of the hanging side. The C isotope ratio changes have shown an opposite, but less expressed tendency, that could not yet be explained.

As the second part of the work a systematic investigation of a mineral assemblage from the same vein was carried out to correlate the succeeding phases of minerogenesis with the variation of the isotopic composition of the carbonate minerals present and the process parameters deducible therefrom.