Study of vein carbonates and notes to the genesis of the hydrothermal mineralization in the Moravo-Silesian Culm

Studium žilných karbonátů a poznámky ke genezi hydrotermálních mineralizací v moravskoslezském kulmu

(6 figs, 6 tabs)

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Hydrothermal mineralizations of Variscan and Post-Variscan ages with high proportion of carbonates (calcite, dolomite-ankerite, siderite), are widespread in the Moravo-Silesian Culm (Lower Carboniferous clastic flysch) formations at the north-eastern margin of the Bohemian Massif. Results of a detailed study (chemistry, isotopic composition, fluid inclusions) of vein carbonates are presented in this work.
Two basic types of hydrothermal vein mineralization were distinguished. Older Variscan epithermal (to mesothermal ?) syntectonic mineralization is represented by quartz-calcite veins with clinochlore-chamosite chlorite, rare pyrite. Younger hydrothermal mineralization is formed mainly by carbonates (calcite, subordinate dolomite-ankerite series, rare siderite) and quartz. Sulphides are represented by galena, sphalerite, chalcopyrite, pyrite and locally marcasite. Both types of mineralization often occur in one vein.
Oxygen and carbon isotopic composition of carbonates of the two types of hydrothermal mineralization ($\delta^{13}C$ between –1.4 and –9.7 ‰ PDB, $\delta^{18}O$ usually between –12.8 and –19.2 ‰ PDB) is probably indicative of formation of the hydrothermal solutions from meteoric waters during their circulation in the Culm sedimentary formations. A strong dependence between mineral composition and the character of the surrounding sediments is typical for the studied mineralizations.

Key words: Moravo-Silesian Culm, hydrothermal mineralization, carbonates, chemistry, carbon isotopes, oxygen isotopes, fluid inclusions

Introduction

The Upper Devonian-Lower Carboniferous siliciclastic flysch formations called the Moravo-Silesian Culm (named after the English attribution Culm Measures) are widespread at the northeastern margin of the Bohemian Massif. The Moravo-Silesian Culm belongs to the Rhenohercynian belt of the Central European Variscides, it forms an accretion wedge developed as a result of a collision of two blocks of continental crust – the inner parts of the Bohemian Massif and the Bruno-Vistulicum (see, e.g., Kumpera – Martinec 1995). The Culm sediments are underlain by an incomplete sequence of pre-Variscan sedimentary rocks and by the crystalline basement of the Proterozoic Bruno-Vistulicum. The Culm sequences are covered by the Upper Carboniferous molasse in the northeast as well as by the younger sediments, especially by autochtone cover and nappes of the Outer Western Carpathians.

The Variscan flysch sequences of the Low Jeseník Uplands and Odra Hills are formed by various types of psammites (mainly graywackes), conglomerates, clay shales to siltstones and locally also by carbonate rocks. Quartz and quartz-carbonate veins of the Alpine type are common in this rock environment.

Generally, the origin of hydrothermal veins of the Alpine type is believed to relate to a process of intraformational redistribution or lateral secretion, i.e., the components that we see in the ore minerals and gangue may have been extracted by a circulating fluid from the immediately adjacent wall-rocks themselves or from a larger volume of wall-rocks generally lateral to and below the veins. It is noteworthy that psammites and aleuropelites of the Moravo-Silesian Culm contain for example 56 and 72 ppm Cu, 71 and 126 ppm Zn, 20 and 29 ppm Pb, 490 and 648 ppm Ba, respectively (see René 1996).

In this paper we present a detailed characteristics of the vein carbonates (calcite, dolomite, Fe-dolomite, Mg-ankerite and siderite).

Types of hydrothermal veins, their position and mineralogy

In the Moravo-Silesian Culm, two major and very common types of the hydrothermal mineralization can be distinguished according to their relation to the Variscan deformational processes. Syn-tectonic quartz or quartz-calcite veins commonly with a distinct fibrous structure represent the first type. Chlorite of green to black-green colour, forming finely flaky aggregates or worm-like inclusions in quartz or in calcite, represents a common component of these veins. Albite can be abundant, too. Pyrite is present in minor amounts. When also other sulphides and locally carbonates of the dolomite-ankerite series occur in these veins, these minerals are present in the fracture filling in the gangue. In such a case it is a younger mineralization, which probably belongs to the following type.

The second type of the mineralization can be called post-tectonic. Veins of this type have a massive, banded, breccia or even druse structure. They are formed mainly by carbonates (calcite or dolomite-ankerite) and also by quartz (missing in some veins). Chlorite occurs in much lower amounts than in the syn-tectonic veins. Albite is common locally, apatite is a typical accessory mineral, barite and siderite are rare phases. REE-minerals and minerals of the TiO_2 group were found at some localities. Sulphides are represented mainly by galena, sphalerite, chalcopyrite and pyrite. These sulphides occur in higher amounts mainly at localities where carbonates of the dolomite-ankerite series are more abundant. This dependency is very remarkable especially in case of galena. The character of this type of the hydrothermal mineralization in the Moravo-Silesian Culm is strongly dependent on the character of the rock environment. Hydrothermal mineralization in clay shales (and aleuropelites) is formed mainly by calcite and quartz. In graywackes (and also conglomerates), carbonates of the dolomite-ankerite series, albite and locally also barite and relatively abundant sulphides occur in addition to calcite and quartz. The carbonates can pre-dominate in some cases, as for instance at Hrabůvka and Bohučovice localities.

Apart from the numerous ore occurrences with no economic importance, this mineralization is present in four historical ore districts, in which mainly silver and lead ores were mined (deposit Franz near Olověná until 1918). This concerns the following historical ore districts: Bystřice Valley ore district (Lošov, Hlubočky, Hrubá Voda, Domašov nad Bystřicí, Velká Bystřice), Fulnek ore district (Jerlochovice, Fulnek, Kletné Pohoř, Veselí, Nejdek), Budišov ore district (Olověná, Staré Oldřůvky, Budišov nad Budišovkou, Rudoltovice) and Podhoří ore district (Podhoří, Uhřínov). Mineralization is of the vein type in all the four districts. Width of the mined veins was of the order of decimetres and locally reached up to 2 m. Some parts of the ore veins were very rich. According to the data from the second half of the 19th century, for instance the Franz deposit yielded ore grades of 10 % Pb and 30 ppm Ag during that time.

Relative proportion of the gangue minerals and hypogene sulphides in the mentioned districts and also at Hrabůvka and Bohučovice localities is presented in Table 1. All these occurrences of the hydrothermal mineralization in the Moravo-Silesian Culm belong to the late Variscan Fe sulphide-poor base metal association based on metallogenetic models of the Bohemian Massif (e.g. Bernard 1967, 1991).

More detailed data and new findings on the character of the hydrothermal mineralization in the Culm of the Low Jeseník Uplands and Odra Hills give for instance Losert (1957, 1962), Čermák et al. (1986), Zimák – Večeřa (1991), Zimák (1999a,b, 2000, 2002), Novotný – Zimák (2001), Losos et al. (2002a,b), Zimák et al. (2002) and Kučera – Slobodník (2002a).

Studied material and methods of study

Samples from 31 localities from the Culm formations of the Low Jeseník Uplands and Odra Hills were used (Fig. 1) for the study of chemistry and isotopic composition of the vein carbonates as well as study of fluid inclusions. The country rocks containing the studied hydrothermal mineralization are characterized in Table 2. The studied localities include quarries, galleries and also waste dumps after the exploitation of roofing slates or ores. Individual types of mineralization for localities Domašov nad Bystřicí and Hrabůvka are shown in Table 2. Sample numbers are given only in cases that respective data are included in the text or tables. Sample numbers bearing the prefix MZM denote samples loaned from the Moravian Museum in Brno. The wall-rock type given in Table 6 represents always the rock in the closest surroundings of the hydrothermal vein.

Data on chemistry of the studied carbonates were acquired using partial chemical analyses and first of all the

Table 1 Relative proportion of gangue minerals and hypogene sulphides in ore deposits and occurrences in the Moravo-Silesian Culm.

	Bystřice Valley ore district	Fulnek ore district	Budišov ore district	Podhoří ore district	Hrabůvka quarry	Bohučovice quarry
Quartz	+++	+++	+++	+++	++	++
Calcite	+++	+++	+	+++	+	++
Dolomite-ankerite	++	+++	+	++	+++	+++
Siderite	+	+				
Chlorite	+	+	+	+	+	+
Albite	+			+	+	
Barite			+	+		+
Galena	+++	+++	+++	+++	++	+
Sphalerite	++	++	+	+	+++	+
Chalcopyrite	+++	+	+	+	+	++
Pyrite	+	+	+	++	+	+++
Marcasite					+	+++
Arsenopyrite				+	+	
Tetrahedrite	?		?			
Pyrargyrite			?			
Strike of veins	130°	0–40°	130°	unknown	355 ± 15°	various

Explanation: +++ = major component; ++ = minor component; + = rare component; ? = questionable presence; in case of sulphides, the table gives only their mutual proportions.

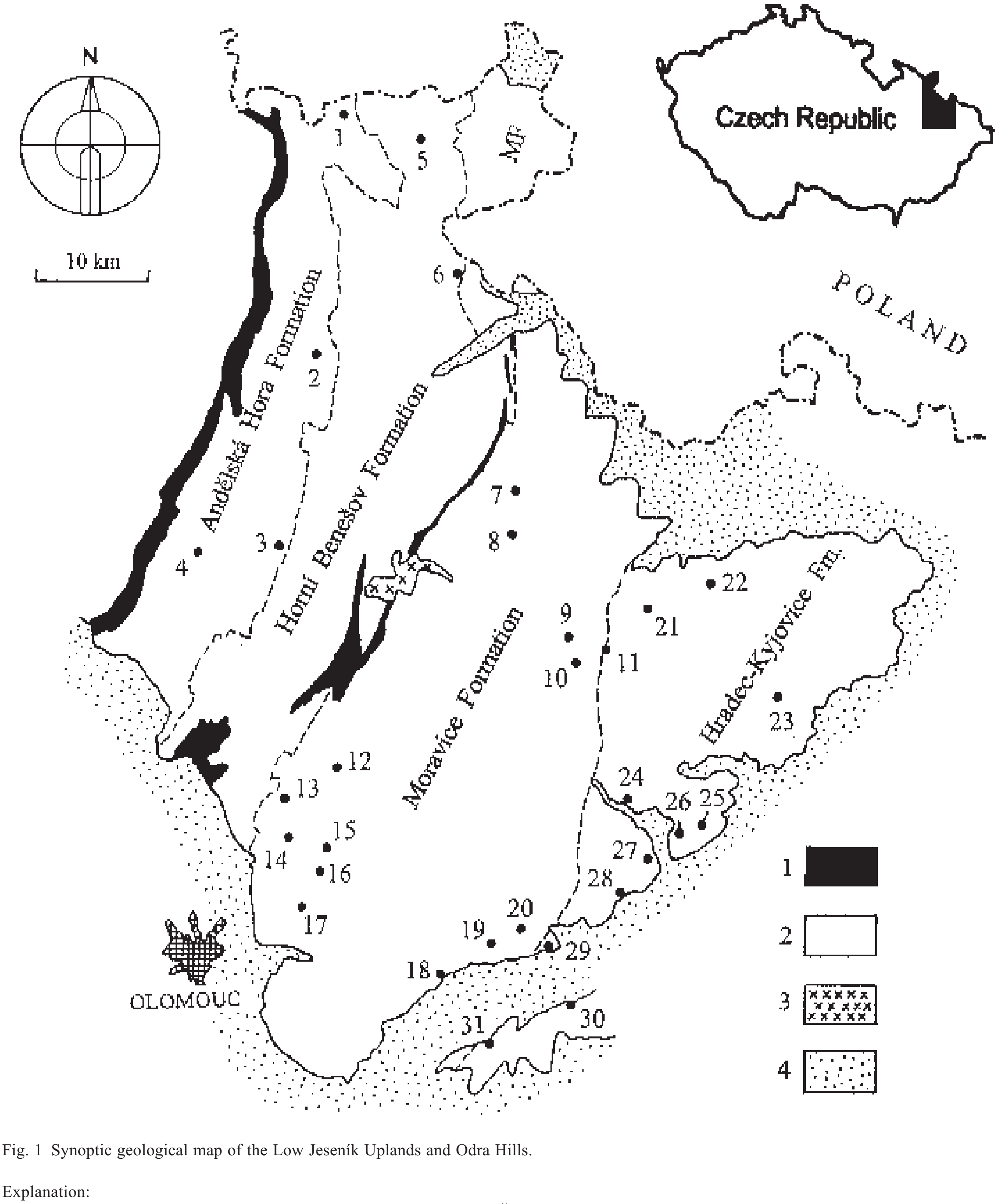

Fig. 1 Synoptic geological map of the Low Jeseník Uplands and Odra Hills.

Explanation:
1 – pre-flysch formations and Devonian volcanics of the Vrbno and Šternberk-Horní Benešov zones; 2 – Variscan flysch sequences of the Famennian to Namurian ages; 3 – neovolcanics; 4 – Neogene sediments.

Localities:
1 – Janov; 2 – Dětřichovice; 3 – Břidličná; 4 – Ondřejov; 5 – Pitárné; 6 – Krásné Loučky; 7 – Svobodné Heřmanice; 8 – Jakartovice; 9 – Zálužné; 10 – Lhotka; 11 – Dubová; 12 – Domašov nad Bystřicí; 13 – Bělkovice; 14 – Pohořany; 15 – Hrubá Voda; 16 – Hlubočky; 17 – Lošov; 18 – Bohuslávky; 19 – Podhoří; 20 – Uhřínov; 21 – Domoradovice; 22 – Bohučovice; 23 – Stará Ves; 24 – Jakubčovice; 25 – Pohoř; 26 – Odry; 27 – Veselí; 28 – Nejdek; 29 – Hrabůvka; 30 – Rybáře; 31 – Pod Hůrou.

Table 2 Description of the studied occurrences, composition of hydrothermal mineralizations.

Locality	Wall rock	Main minerals	Minor and scarce minerals	Samples
Andělská Hora Formation				
Janov – d., Malá Stříbrná Hill [O]	grw.	Qtz, Cal	Py, Chl, Apy, Ccp, Gn	MZM-14285
Dětřichovice – d., Veik Quarry [S]	sh., ap.	Qtz, Cal	Chl	
Břidličná – q., 1.5 km ENE of B. [M]	grw., ap., sh.	Cal, Qtz	Chl	
Ondřejov – d., 1 km S of O. [S]	sh., ap.	Qtz, Cal	Chl	
Horní Benešov Formation				
Pitárné – q., 2 km SW of P. [M]	grw.	Cal, Qtz	Fl	
Krásné Loučky – q., Kobylí [M]	grw.	Cal, Qtz	Brt, Chl, Py, Ccp, Gn	KO-1
Moravice Formation				
Svobodné Heřmanice – d., 1 km W of S.H. [RS]	sh.	Cal, Qtz	Chl, Py	
Jakartovice – d., 1.5 km W of J. [RS]	sh.	Cal	Qtz, Chl, Py, Ccp	JAK-1, 2
Zálužné – d., 1 km SW of Z.	sh., grw.	Cal, Qtz	Gn, Py, Sp, Ccp	
Lhotka – d., 0.5 km NE of L. [RS]	sl	Cal, Qtz	Chl, Py	
Dubová – d., 0.7 km ESE of D.	grw.	Cal, Qtz	Ab, Py, Ccp, Gn, Sp	
Domašov nad Bystřicí – q., 1 km S of D. [M]	grw., cong.	Qtz, Cal	Chl, Ab, Py	DOM-41
Dtto	cong., grw.	Qtz, Cal, Dol	Ank, Py, Ccp, Gn, Sp, TR	DOM-6, 8, 20, 31, 39, 42, 43
Dtto	grw., cong.	Qtz, Cal	Sp, Ccp, Gn, Py	
Bělkovice – q., Tepenec [M]	grw.	Qtz, Cal	Ab, Chl, Py	TEP-1
Pohořany – d., 1 km NW of P. [RS]	sh.	Cal, Qtz	Chl, Py, Gn	POH-1, 2
Hrubá Voda – q., W of H.V. [M]	grw.	Cal, Qtz	Chl, Ccp, Py, Sp, Gn	HRV-12, 13, 15
Hlubočky – g., "Schusterloch" [O]	grw.	Cal, Qtz	Gn, Ccp, Py	HLU-1, 2, 5
Lošov – d., 1km E of L. [O]	grw.	Qtz, Cal, Dol	Ccp, Gn, Sp, Py, Ank, Ant, TR	MÚ-1/1, 1/8, 32, 36/4, 36/5, 100/2, 102
Bohuslávky – q., 0.7 km W of B. [M]	grw.	Cal, Qtz, Dol	Sp, Gn, Ank	
Podhoří – d., 2 km NW of P. [O]	grw.	Qtz, Cal	Dol, Chl, Py	
Uhřínov – deluvium, 1 km E of U.	grw.	Qtz, Cal	Brt, Ab, Gn, Py, Chl	
Hradec-Kyjovice Formation				
Domoradovice – d., 0.5 km SE of D.	grw.	Dol, Qtz	Ccp, Sp, Gn, Py, Ab, Chl	
Bohučovice – q., 1 km SSE of B. [M]	grw.	Cal, Qtz	Ab, Brt, Py, Mrc, Ccp, Gn, Sp, Chl	BOH-1, 11, 13, 14
Stará Ves – q., 0.3 km E of S.V. [M]	grw.	Qtz, Cal	Dol, Py, Ccp, Sp	
Jakubčovice – q., 1 km NW of J. [M]	grw.	Cal, Qtz	Dol, Py, Sp, Brt, Chl	MZM-352
Pohoř – d., 1 km SW of P. [O]	ap., sh.	Qtz, Cal	Ab, Gn, Ccp, Sp, Py	
Odry – d., 2 km WSW of O.[O]	grw.	Qtz, Cal	Gn	
Veselí – d., 1 km SE of V. [O]	grw.	Qtz, Dol, Cal	Gn, Sp, Py, Ccp	
Nejdek – q., 0.3 km W of N. [M]	grw.	Dol, Cal	Sid, Brt, Ab, Qtz	NEJ-1
Hrabůvka – q., 0.3 km NE of H. [M]	grw.	Dol, Cal	Qtz, Sp, Gn, Py, Ccp, Apy, Chl	HR-5, 8, 9, 11, 12, 13, 15
Dtto	grw.	Cal	Mrc	HR-4
Dtto	lmst.	Cal	Mrc	HR-18
Rybáře – q., 0.5 km S of R. [M]	grw.	Cal, Qtz	Ccp, Py	
Pod Hůrou – q., 0.5 km WSW of P.H. [M]	grw.	Cal, Qtz	Ab, Chl, Ap, TR, Ant or Rt	PH-1, 2, 3, 4

Explanation: d. = dump(s); q. = quarry; g. = gallery; [RS] = roofing slates are or were exploited at the locality; [O] = ores (Au, Ag, Pb) were mined at the locality; alternatively, dumps and adits from exploration works exist; [M] = quarry stone is or was exploited at the locality; congl. = conglomerate (mainly gravelite); grw. = graywacke; ap. = aleuropelite (siltstone + slate); sh. = shale; lmst. = limestone.
Symbols for minerals: Ab = albite; Ank = ankerite; Ant = anatase; Ap = apatite; Apy = arsenopyrite; Brt = barite; Cal = calcite; Ccp = chalcopyrite; Chl = chlorite; Dol = dolomite; Fl = fluorite; Gn = galena; Mrc = marcasite; Py = pyrite; Qtz = quartz; Rt = rutile; Sd = siderite; Sp = sphalerite; TR = REE-minerals.

EDX method. Contents of CaO, MgO, FeO, MnO and in some calcite samples also SrO (analysed by P. Kadlec, Masaryk University, Brno) were determined. EDX – spot analyses were acquired using electron microscope CamScan equipped with EDX – analyser Link AN 10 000 (accelerating voltage 20kV, ZAF-4 corrections, analyst V. Vávra, Masaryk University, Brno).

Fluid inclusions were studied by optical microthermometry using Chaixmeca apparatus (Poty et al. 1976) by one of the authors (P. D.). The apparatus was calibrated for temperatures from –100 °C to 400 °C using chemical standards of the Merck Company, temperature of the melting point of distilled water and phase transitions in inclusions with pure CO_2. The apparatus had reproducibility of ± 0.2 °C at temperatures lower than 0 °C and ± 3 °C at temperature to 200 °C. Fluid salinity was calculated according to Bodnar (1993).

For the isotopic study of C and O, the carbonate sample was decomposed in the vacuum by 100% H_3PO_4 at 25 °C (after McCrea 1950). The liberated carbon dioxide was measured using the Finnigan MAT 251 spectrometer (analysed by J. Hladíková and I. Jačková). The results are given in δ values (‰) and they are related to the standard V-PDB. Recalculation of the $\delta^{18}O$ values on

Table 3 Representative analyses of carbonates of the dolomite-ankerite series (numbers of cations calculated on the basis of $Ca^{2+} + Fe^{2+} + Mg^{2+} + Mn^{2+} = 2$).

Sample	Locality	CaO wt. %	MgO wt. %	FeO wt. %	MnO wt. %	Ins.res. wt. %	Ca^{2+} at. %	Mg^{2+} at. %	Fe^{2+} at. %	Mn^{2+} at. %	Method
MZM14285	Janov	28.25	10.75	16.40	1.25	–	0.99	0.52	0.45	0.04	EDA
DOM-31	Domašov n.B.	29.89	10.33	15.06	0.96	–	1.05	0.51	0.41	0.03	EDA
DOM-39	Domašov n.B.	28.94	8.29	18.87	0.50	–	1.04	0.42	0.53	0.01	EDA
DOM-39	Domašov n.B.	29.98	8.40	17.32	1.18	–	1.07	0.42	0.48	0.03	EDA
DOM-39	Domašov n.B.	30.48	8.73	16.75	1.60	–	1.07	0.43	0.46	0.04	EDA
MÚ-1/8	Lošov	30.23	19.11	2.62	0.83	–	1.02	0.89	0.07	0.02	EDA
MU-36/5	Lošov	28.69	12.25	13.90	0.50	–	1.01	0.60	0.38	0.01	EDA
MÚ-32	Lošov	29.75	10.66	15.50	0.48	–	1.04	0.52	0.43	0.01	EDA
MÚ-32	Lošov	28.34	8.33	19.35	0.69	–	1.02	0.42	0.54	0.02	EDA
MÚ-32	Lošov	29.73	9.14	17.44	0.64	–	1.05	0.45	0.48	0.02	EDA
MÚ-36/4	Lošov	31.53	18.00	2.52	0.60	n.a.	1.06	0.85	0.07	0.02	WA
MÚ-100/2	Lošov	27.35	10.36	13.32	0.52	n.a.	1.04	0.55	0.39	0.02	WA
BOH-1	Bohučovice	30.24	10.31	13.23	1.05	1.05	1.08	0.52	0.37	0.03	WA
BOH-11	Bohučovice	30.03	15.18	8.14	0.70	–	1.03	0.73	0.22	0.02	EDA
BOH-13	Bohučovice	30.29	19.30	3.22	0.80	–	1.01	0.89	0.08	0.02	EDA
BOH-14	Bohučovice	29.16	10.68	14.20	1.70	–	1.03	0.53	0.39	0.05	EDA
MZM352	Jakubčovice	29.46	14.47	9.58	1.25	–	1.02	0.69	0.26	0.03	EDA
NEJ-1	Nejdek	28.71	9.64	15.25	1.23	–	1.04	0.49	0.43	0.04	EDA
NEJ-1	Nejdek	29.87	13.06	12.77	0.65	–	1.02	0.62	0.34	0.02	EDA
NEJ-1	Nejdek	29.61	14.39	12.11	0.54	–	1.00	0.67	0.32	0.01	EDA
HR-5	Hrabůvka	31.03	14.45	7.39	1.32	0.32	1.07	0.69	0.20	0.04	WA
HR-8	Hrabůvka	30.08	19.99	1.80	0.37	1.24	1.01	0.93	0.05	0.01	WA
HR-11	Hrabůvka	30.45	15.99	5.96	1.15	0.44	1.05	0.76	0.16	0.03	WA
HR-13	Hrabůvka	32.37	15.38	4.18	1.31	0.85	1.11	0.74	0.11	0.04	WA
HR-15	Hrabůvka	30.50	16.94	4.74	0.98	0.61	1.04	0.80	0.13	0.03	WA

WA = wet analysis; EDA = energy dispersive analysis; n.a. = not analysed

standard V-SMOW is given, too. The following equation for calculation of isotopic composition of hydrothermal solutions was used (Hoefs 1997):

$$1000 \ln a_{c-w} = 2.78 \times 10^6 / T^2 - 3.40$$

Chemistry of the vein carbonates

Detailed evaluation of the chemistry of vein carbonates from the Low Jeseník Uplands and Odra Hills has been presented by Zimák (1999b). His work contains results of 97 carbonate analyses. Carbonates are represented mainly by calcite, presence of which was confirmed at all studied localities. In addition to the dominant $CaCO_3$, the analysed calcites (EDX) usually contain up to 0.6 wt. % FeO. Higher Fe content was found only at some localities: Jakubčovice (0.81–2.54 wt. % FeO, Kučera – Slobodník 2002), Podhoří (up to 1.25 wt. % FeO) and Bohučovice (1.66–1.95 wt. % FeO). MgO content in the set of the calcite samples is usually below 0.4 wt. %. Calcite from Jakubčovice contains up to 0.94 wt. % MgO (Kučera – Slobodník 2002), from Bohučovice 0.47–0.68 wt. % MgO and from Hrabůvka up to 0.53 wt. % MgO. Our set of data clearly shows that calcite from veins in pelites (aleuropelites) has always relatively low contents of Fe and Mg. Higher contents of the two elements appear only at some localities, where the hydrothermal mineralization is located in graywackes and/or conglomerates or where these rocks represent the prevailing rock types. MnO content in calcite usually ranges between 0.4 and 1.2 wt. %, at some localities it is slightly higher: Čermná up to 1.42 wt. % MnO, Jakubčovice up to 1.77 wt. % MnO (data from both localities from Kučera – Slobodník 2002).

At some localities, calcite is associated with carbonates of the dolomite-ankerite series. Hydrothermal veins with carbonates of the dolomite-ankerite series occur in graywackes or conglomerates. They can be located also in aleuropelites, but just in case that these make part of a sedimentary complex with a considerable proportion of graywackes and/or conglomerates. Results of the analyses (Table 3) show that these carbonates have composition corresponding to dolomite or Fe-dolomite, just occasionally to Mg-ankerite with a slight prevalence of Fe over Mg (Fig. 2). "Ankerites" described in literature (e.g., Kruťa 1966, 1973) correspond to one of the members of the dolomite-ankerite series mentioned above or (very often) to calcite. This conclusion is based on the results of chemical analyses of "ankerite" samples collected mainly by T. Kruťa and deposited in the mineralogical collections of the Moravian Museum in Brno.

Siderite has been found only at Nejdek and Lošov localities up to now. It represents the oldest vein carbonate (succession of the carbonates: siderite → Fe-dolomite → calcite). Data on chemistry of siderite are presented in Table. 4.

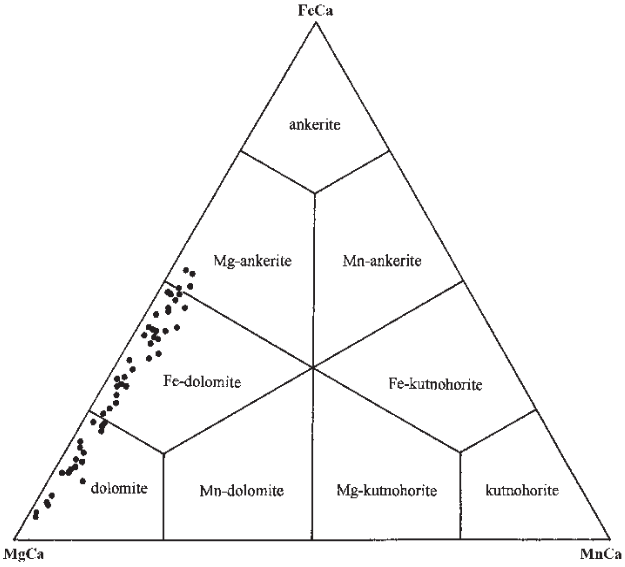

Fig. 2 The $FeCO_3$-$MgCO_3$-$MnCO_3$ triangular classification diagram of Trdlička – Hoffman (1976) showing the compositions of carbonates of the dolomite-ankerite series from the studied veins and inluding data of Zimák (1999b, 2002) and Kučera – Slobodník (2002a).

Fluid inclusion study

Fluid inclusions in calcite and quartz from five localities were studied. The localities are as follows: Krásné Loučky (active quarry Kobylí), Domašov nad Bystřicí (abandoned quarry, Kupka Hill), Hrabůvka (active quarry), Pod Hůrou (active quarry "Podhůra") and Lošov (waste dumps after ore mining at the historical locality "Goldgrund" – this locality is commonly called Mariánské Údolí). Both the material from syn-tectonic veins and from the younger mineralization (for detailed characteristics see Novotný – Zimák 2001) is represented in the set of the analysed samples.

Krásné Loučky

The sample KO-1 from a veinlet formed by quartz (locally with worm-like chlorite inclusions) and calcite was used for the fluid inclusion study. Quartz contains primary inclusions with very variable liquid to vapour ratio (L-only, V-only, L+V). The inclusions enclose H_2O–CH_4 mixture trapped under heterogeneous conditions $ThCH_4^V = -82.5$ °C, CH_4 density about 0.006 gcm^{-3}, Th of H_2O-rich inclusions are falling in a large range of 128 to 236 °C, which is caused by a variable CH_4 admixture and these values cannot be considered as reliable.

Domašov nad Bystřicí

Quartz-calcite veins with chlorite of the clinochlore-chamosite series and in places also albite (An_{00-01}) and pyrite represent probably the oldest type of the hydrothermal mineralization at Domašov nad Bystřicí locality. These are largely 30–40 cm wide steep veins of the E–W strike, strongly tectonized. Smaller veins show some signs of the coarse fibrous structure, characteristic of syn-tectonic veins, formed by crack-seal mechanism. Homogenization temperature of the primary L+V inclusions in calcite from this type of mineralization is 65–80 °C; relatively low temperature of ice melting of these inclusions is indicative of a relatively high salinity ranging from 14.6 to 23.2 wt. % equiv. NaCl (see Table 5, Sample DOM-41). Determined Te around –50 °C corresponds probably to the system NaCl–KCl–$CaCl_2$±$MgCl_2$–H_2O in enclosed solution. Veins of this type have been studied already by Slobodník et al. (1995). These authors found L+V inclusions in quartz and calcite of unclear origin with homogenisation temperatures ranging between 50 and 140 °C and with Tm falling in the range –23 to –33 °C, which indicates very high salinity. Based on the distribution of the primary L-inclusions parallel to the growth zones of quartz, Slobodník et al. (1995) assumed that they were formed at temperatures around 50 °C.

Hydrothermal mineralization of the stockwork character is associated with a steep dislocation of S–N strike, observable from the second to the fourth quarry level. Individual veins and veinlets of this stockwork consist of quartz, calcite, carbonate of dolomite-ankerite series and locally abundant sulphides. A part of the hydrothermal mineralization of this stockwork is probably of Variscan age and syn-tectonic (quartz, calcite, chlorite, pyrite), a part is apparently younger (quartz, calcite, dolomite-ankerite, chalcopyrite, sphalerite, galena, pyrite) – see Zimák et al. (2002) for details. Three types of fluids were distinguished in primary fluid inclusions in samples from this stockwork (Samples DOM-42 and 43, see Tab. 5): a) fluids with salinity of 17.0 to 21.5 wt. % equiv. NaCl, enclosed in probably the oldest generation of the hydro-

Table 4 Representative analyses of siderite (numbers of cations calculated on the basis of $Fe^{2+} + Ca^{2+} + Mg^{2+} + Mn^{2+} + Zn^{2+}=1$).

Sample	Locality	FeO wt. %	CaO wt. %	MgO wt. %	MnO wt. %	ZnO wt. %	Fe^{2+} at. %	Ca^{2+} at. %	Mg^{2+} at. %	Mn^{2+} at. %	Zn^{2+} at. %	Method
MÚ-32	Lošov	53.14	1.80	2.55	1.01	–	0.870	0.038	0.075	0.017	–	EDA
MÚ-102	Lošov	49.46	6.27	2.51	0.59	–	0.790	0.128	0.072	0.010	–	EDA
MÚ-102	Lošov	51.65	6.12	2.63	0.53	–	0.799	0.121	0.072	0.008	–	EDA
NEJ-1	Nejdek	43.24	7.53	5.10	1.32	0.65	0.677	0.151	0.142	0.021	0.009	EDA
NEJ-1	Nejdek	43.31	7.25	4.78	1.33	0.78	0.686	0.147	0.135	0.021	0.011	EDA
NEJ-1	Nejdek	41.52	7.34	5.42	1.16	0.36	0.669	0.151	0.156	0.019	0.005	EDA
NEJ-1	Nejdek	41.52	7.09	5.79	1.16	0.76	0.661	0.145	0.164	0.019	0.011	EDA
NEJ-1	Nejdek	41.09	6.78	7.67	0.69	0.44	0.636	0.135	0.212	0.011	0.006	EDA

Table 5 Microthermometric data of primary fluid inclusions (Domašov nad Bystřicí).

Sample	Mineralization	Mineral	Tm (°C)	Salinity (wt. % NaCl equiv.)	Te (°C)	Th (°C)
DOM-41	syn-tectonic	calcite	–10.6 to –24.6	14.6 to 23.2	–50.0 to –50.5	65 to 80
DOM-42	syn-tectonic?	quartz	–13.1 to –21.2	17.0 to 21.5	–50.2 to –56.0	70 to 90
DOM-42	younger	quartz	–0.3 to –2.6	0.5 to 4.3	–35.0 to –37.5	
DOM-42	younger	quartz	–5.3 to –7.2	8.3 to 10.7	–37.0	
DOM-43	younger	quartz	–0.2 to –0.5	0.4 to 0.9		
DOM-43	younger	calcite	–0.2 to –0.7	0.4 to 1.2		

Tm = temperature of melting of the last ice crystal; Te = eutectic temperature; Th = homogenization temperature

thermal quartz at the locality, with homogenization temperature of 70–90 °C. These parameters are similar to those for fluids from primary inclusions in syn-tectonic quartz-calcite veins with chlorite; b) fluids with salinity of 8.3 to 10.7 wt. % equiv. NaCl; c) fluids with salinity 0.4–4.3 wt. % equiv. NaCl enclosed in the youngest quartz and in calcite in veinlets from the dislocation zones filling; these are veinlets with sulphide mineralization and rare chlorite. Te and Tm values were measured only in the two-phase inclusions; one-phase liquid inclusions showed metastable behaviour after freezing. Based on the Tm a Te, 2–3 types of enclosed fluids of different salinity and composition (see Table 5) were distinguished in the studied quartz. Te around –37 °C corresponds to the system $NaCl–KCl–MgCl_2–H_2O$; Te around –50 °C to the system $NaCl–KCl–CaCl_2±MgCl_2–H_2O$.

Hrabůvka

Fluid inclusions in two samples were studied. The first one (Sample HR-9) represents the most common type of the hydrothermal mineralization at the locality. These are post-tectonic veins of a pinkish dolomite, associated with younger white calcite, which commonly crystallizes in cavities or it forms fine veinlets cutting through the dolomite. Primary inclusions in calcites are of the H_2O type and they have a very variable LVR. For this reason, Th were not measured. Tm of the ice corresponds to –0.7 to –1.4 °C, salinity ranges between 1.2 and 2.4 wt. % NaCl equiv. Primary inclusions in the older dolomite are of irregular shape, they are of the H_2O type and they also feature variable LVR, therefore, Th were not measured either. Tm of ice corresponds to –0.5 to –1.2 °C, salinity ranges between 0.9–2.1 wt. % NaCl equiv. Irregular shape and a variable degree of filling of the inclusions in both minerals indicate rather low temperature of inclusion trapping, probably much lower than 200 °C. Material from veins of the corresponding type was studied already by Dolníček et al. (2001) and Slobodník – Dolníček (2001). These authors give homogenization temperatures of the two-phase (L+V) inclusions in dolomite in the range 123 to 133 °C (fluid salinity 14.9 to 17.3 wt. % equiv. NaCl). They report mainly single-phase (L-only) inclusions in calcite, two-phase (L+V) inclusions being less common. The presence of the L-only inclusions corresponds to temperature of trapping of inclusions below +50 °C.

The second studied sample (HR-18) represents hydrothermal calcite, which forms veinlets crosscutting neptunian veins of limestone of probably Mesozoic or Tertiary age (see Dolníček – Zimák – Slobodník 2002). Very few primary inclusions were found in this calcite. These inclusions are of the H_2O type, with LVR ranging from 0.9 to 0.95, Th = 135–140 °C, Tm of ice = –1.2 °C and salinity of 2 wt. % NaCl equiv. Also, a trail of secondary or primary-secondary inclusions with Th from 129 to 138 °C has been found.

Pod Hůrou

The sample PH-1, collected from about 20 cm thick vein consisting of coarsely fissile calcite of grey-white, locally slightly yellowish or pinkish colour with relatively abundant chalcopyrite grains, was studied as fluid inclusions concerns. Primary inclusions of the H_2O type present in the described calcite feature very variable LVR. Therefore, Th were not measured. Calcite probably contains inclusions of two types of solutions: a) Tm of ice = –23.1 °C, salinity = about 23 wt. % NaCl equiv.; b) Tm of ice = –0.7 °C, salinity = 1.2 wt. % NaCl equiv. A fine trail of pseudosecondary inclusions with a regular LVR = 0.9 was also measured: Th = 132 to 140 °C, Tm of ice = –19.4 to –21.6 °C, salinity from 21.9 to 23 wt. % NaCl equiv.

Lošov

Fluid inclusions study on fine quartz crystals, about 1 cm in size, forming druses covering the walls of cavities in the quartz gangue (Sample MÚ-1/1) was carried out. Secondary inclusions occurring along healed fractures are of the H_2O single-phase liquid (L-only) type. Temperature of trapping of inclusions is supposed to be very low, below 50 °C. Primary inclusions are of the H_2O type, with variable liquid to vapour ratio. Tm of ice corresponds to –21.8 to –20.4 °C, salinity fluctuates around 23 wt. % NaCl equiv.; Th = 114–132 °C (for inclusions with LVR = 0.95).

Fig. 3 A part of the Domašov nad Bystřicí quarry; the state in 2001.

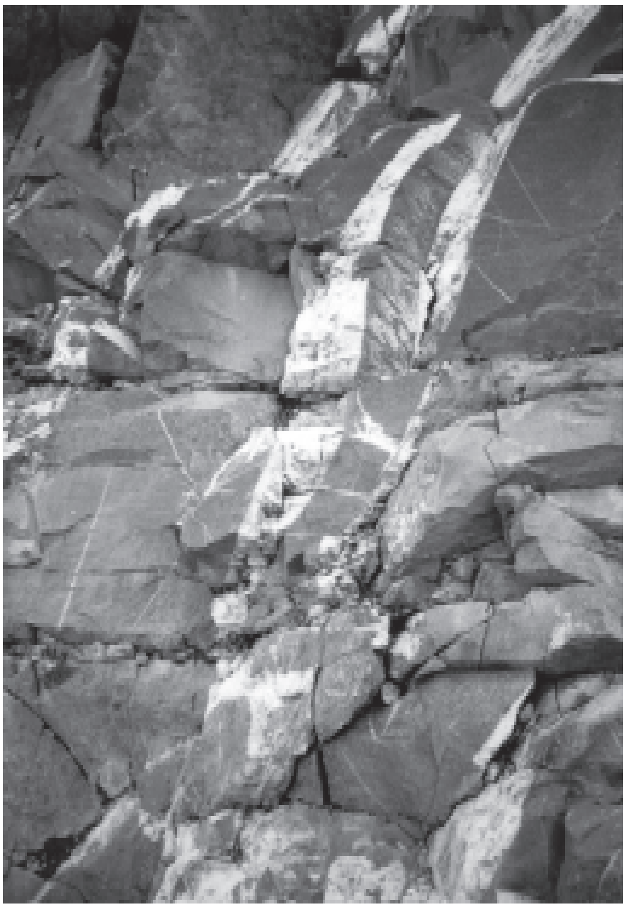

Fig. 4 Up to 20 cm wide syntectonic quartz-calcite veins with chlorite in graywacke in the Domašov nad Bystřicí quarry.

Isotopic composition of C and O of the vein carbonates

Published data on the C and O isotopic composition of vein carbonates come from two localities. Slobodník – Dolníček (2001) and Dolníček et al. (2001) studied vein carbonates from the Culm siliciclastic sediments (graywackes, gravellites) at Hrabůvka locality. Hydrothermal mineralization in the Lower Carboniferous coral reefs, encountered in several boreholes SE of Frýdek-Místek (Dolníček et al. 2001; Slobodník et al. 2001a,b), represent the second studied material. The authors reported relatively homogeneous isotopic composition of the vein dolomites s.l. from Hrabůvka: $\delta^{13}C$ ranging between –1.4 and –5.0 ‰ PDB, $\delta^{18}O$ between –12.8 and –13.1 ‰ PDB; isotopic analyses of one calcite sample yielded following values: $\delta^{13}C$ = –5.7 ‰ PDB and $\delta^{18}O$ = –16.3 ‰ PDB. Isotopic composition of calcite from the hydrothermal mineralization from the boreholes SE from Frýdek-Místek (e.g. Dobratice, Janovice) was determined as $\delta^{13}C$ = –0.5 to –2.1 ‰ PDB and $\delta^{18}O$ = –8.2 to –11.3 ‰ PDB.

Isotopic composition of hydrothermal carbonates from our new set of 25 samples from the veins in the Culm sediments (Tab. 6) ranges in a rather narrow interval (Losos et al. 2002a,b). $\delta^{13}C$ values correspond to –9 to –4 ‰ V-PDB, $\delta^{18}O$ values to –19 to –13 ‰ V-PDB, with the exception of one calcite sample from Hrabůvka (sample HR-4, see below).

Calcite from HR-18 sample, representative of calcite veins with minor marcasite, crosscutting neptunian veins

Fig. 5 Pyrite crystal, 2 mm long, in assemblage with quartz and calcite. Domašov nad Bystřicí quarry.

of limestone of uncertain age (Lower Mesozoic or rather Tertiary?), features very contrasting isotopic composition. This sample yielded the following values: $\delta^{13}C$ = –30.5 to –33.1 ‰ V-PDB, $\delta^{18}O$ = –5.1 to –5.6 V-PDB. This anomalous isotopic composition (Fig. 6) corresponds roughly to the limestone from HR-18 sample (Dolníček et al. 2002).

The isotopic composition of carbonates from hydrothermal mineralizations in the Culm sediments display some spatial dependence. Vein carbonates from the Bystřice River valley (localities Domašov nad Bystřicí, Hrubá Voda and Hlubočky) are characterized by lower $\delta^{13}C$ values compared to the other studied localities (except the sample HR-4) – see Table 5. This fact can be related to the higher proportion of clay shales, relatively rich in the organic material, in the Culm sediments at the Bystřice River valley localities.

Isotopic composition of oxygen and carbon of the hydrothermal solution from which calcite crystallized can be calculated using published equations (Hoefs 1997), when the temperature of calcite crystallization and its isotopic composition are known. Results of our fluid inclusion study by optical microthermometry method on samples from Krásné Loučky, Domašov nad Bystřicí, Lošov, Hrabůvka and Pod Hůrou are consistent with the vein carbonate crystallization at epithermal conditions. For the following calculations, temperatures of 70 and 130 °C were used.

i) Oxygen isotopic composition of the water from the hydrothermal solution

Theoretically, at 70 °C, calcites with $\delta^{18}O$ = 11 ‰ V-SMOW would crystallize from a solution containing water with $\delta^{18}O$ = –9 ‰ V-SMOW; those with $\delta^{18}O$ = 14 ‰ V-SMOW from water with $\delta^{18}O$ = –6 ‰, and those with $\delta^{18}O$ = 15 ‰ V-SMOW from water with $\delta^{18}O$ = –5 ‰ V-SMOW.

At temperature of 130 °C, the same calcites would crystallize from a hydrothermal solution with oxygen isotopic composition of water $\delta^{18}O$ = –2 ‰ V-SMOW, $\delta^{18}O$ = 0 ‰ V-SMOW and +1 ‰ V-SMOW, respectively.

Similarly, dolomite from Hrabůvka with $\delta^{18}O$ = 17 ‰ was formed at temperature of 100 °C from water with the oxygen isotopic composition of $\delta^{18}O$ = –4 ‰ V-SMOW, and dolomite with $\delta^{18}O$ =18 ‰ crystallized from water with $\delta^{18}O$ = –3 ‰ V-SMOW.

At the temperature of 130 °C, these dolomites would crystallize from a hydrothermal solution with oxygen isotopic composition of $\delta^{18}O$ = –1 ‰ V-SMOW and $\delta^{18}O$ = 0 ‰ V-SMOW, respectively.

Low $\delta^{18}O$ values calculated for the hydrothermal solutions indicate that the water was very probably of a meteoric origin (Hoefs 1997). The interaction of the meteoric water with surrounding rocks resulted in the isotopic exchange of oxygen between the water and the rocks and in this way also in the increase of $\delta^{18}O$ of the water in the hydrothermal solution. An alternative theoretical interpretation of $\delta^{18}O$ values close to 0 ‰ V-SMOW as fossil marine water is improbable, according to our results.

ii) Carbon isotopic composition of the hydrothermal solution

HCO_3^- represents a dominant oxidized carbon component of the solution at temperature around 100 °C at pH conditions, where carbonates are stable. Carbon isotopic composition of the precipitating calcite is by about 3 ‰ higher than the carbon isotopic composition of HCO_3^- in the solution (Hoefs 1997). This means, that calcites from localities in the Bystřice River valley with $\delta^{13}C$ in the

Table 6 Isotopic composition of vein carbonates.

Sample	Locality	Wall-rock	Vein carbonate ‰ PDB	$d^{13}C$ ‰ PDB	$d^{18}O$ ‰ SMOW	$d^{18}O$
JAK-1	Jakartovice	shale	calcite	–5.7	–17.7	12.7
JAK-2	Jakartovice	shale	calcite	–6.0	–15.2	15.2
DOM-6	Domašov n.Bystř.	conglomerate	calcite	–7.5	–16.6	13.8
DOM-8	Domašov n.Bystř.	conglomerate, graywacke	calcite	–7.0	–18.1	12.3
DOM-20	Domašov n.Bystř.	shale, graywacke	calcite	–6.8	–19.1	11.2
TEP-1	Bělkovice	graywacke	calcite	–4.6	–19.2	11.1
POH-1	Pohořany	shale	calcite	–5.3	–18.2	12.1
POH-2	Pohořany	shale	calcite	–3.1	–17.9	12.5
HRV-12	Hrubá Voda	graywacke	calcite	–8.9	–19.2	11.1
HRV-13	Hrubá Voda	graywacke	calcite	–9.7	–19.1	11.2
HRV-15	Hrubá Voda	graywacke	calcite	–8.2	–18.3	12.0
HLU-1	Hlubočky	graywacke	calcite	–7.9	–16.9	13.5
HLU-2	Hlubočky	graywacke	calcite	–7.5	–18.6	11.7
HLU-5	Hlubočky	graywacke	calcite	–8.6	–18.7	11.6
BOH-1	Bohučovice	graywacke	Fe–dolomite	–4.5	–7.9	22.8
HR-12	Hrabůvka	graywacke	calcite	–5.7	–16.3	14.1
HR-11	Hrabůvka	graywacke	dolomite s.s.	–5.0	–13.0	17.5
HR-13	Hrabůvka	graywacke	dolomite s.s.	–1.4	–13.1	17.4
HR-15	Hrabůvka	graywacke	dolomite s.s.	–4.7	–12.8	17.7
HR-4	Hrabůvka	graywacke	calcite	–15.3	–6.2	24.5
HR-18b	Hrabůvka	limestone (Cretaceous?)	calcite	–33.1	–5.1	25.7
HR-18c	Hrabůvka	limestone (Cretaceous?)	calcite	–30.5	–5.6	25.1
PH-2	Pod Hůrou	graywacke	calcite	–5.2	–18.8	11.5
PH-3	Pod Hůrou	graywacke	calcite	–4.2	–16.7	13.7
PH-4	Pod Hůrou	graywacke	calcite	–4.8	–17.4	13.0

range from –7 to –10 ‰ V-PDB formed from a solution containing HCO_3 with $\delta^{13}C$ between –10 and –13 ‰ V-PDB. These low values indicate, that the hydrothermal solution contained HCO_3^-, which originated mainly from the oxidized organic material.

The presence of the carbon of hydrocarbons (oil hydrocarbons, gas, biogenic methane) in hydrothermal calcite is evident in case of the sample HR-18 discussed above (calcite veinlets in isotopically anomalous limestone). Sample HR-4 from Hrabůvka with $\delta^{13}C$ = –15.3 ‰ V-PDB (see Tab. 5) is considered interesting, too. It strongly smelled after carbohydrates during the spreading and its isotopic composition is indicative of a presence of carbon of organic origin. Hydrothermal mineralization of the HR-4 and HR-18 samples is of a similar character based on the microscopic and macroscopic evaluation. However, the surrounding rocks are different – for the HR-4 sample they are represented by a Culm graywacke; this sample was taken about 1m from a neptunian vein of limestone. It is evident, that the isotopic composition of hydrothermal fluids was in this case also strongly influenced by the isotopically anomalous limestone.

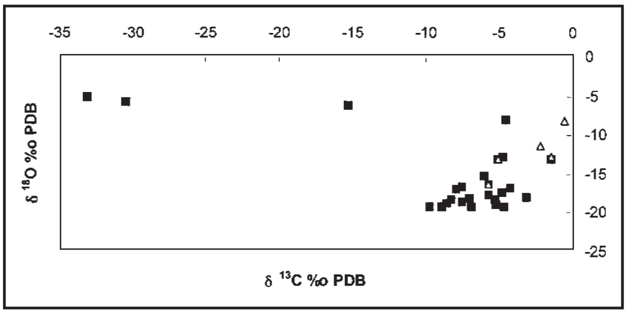

Fig. 6 Isotopic composition of C and O of the vein carbonates. The △ symbols are used for published analyses of Slobodník – Dolníček (2001), Dolníček et al. (2001), Dolníček et al. (2001) and Slobodník et al. (2001a, b).

Discussion and conclusions

• Two widely distributed types of hydrothermal vein mineralization can be distinguished in the Culm formations at the NE margin of the Bohemian Massif:

(1) Variscan syntectonic mineralization, typically represented by quartz-calcite veins with chlorite of the clinochlor-chamosite series. Sulphide minerals are represented only by a rare pyrite. Homogenization temperature of the primary L+V inclusions in calcite and quartz are falling in the range about 60–90 °C, indicative of epithermal conditions. The enclosed solutions are characterized by a high salinity (around 20 wt. % NaCl equiv.). Mineralization of such type occurs mainly in the Andělská Hora, Horní Benešov and Moravice Formations. It is less common in the Hradec-Kyjovice Formation.

(2) Younger hydrothermal mineralization is formed mainly by carbonates, which are represented largely by calcite. Carbonates of the dolomite-ankerite series (dolomite s.s., Fe-dolomite, Mg-ankerite) are abundant or prevailing carbonates at some localities, siderite is present exceptionally. Crystallization sequence of carbonates is as follows: siderite → dolomite-ankerite → calcite. Quartz occurs in variable amounts and it can be even missing. Sulphides represented by galena,

sphalerite, chalcopyrite, pyrite and locally abundant marcasite are rather common. Homogenization temperatures of the primary L+V inclusions in carbonates and quartz are falling in the range 110–140 °C; presence of the L-only inclusions in some calcite samples is indicative of the temperature of the solution below 50 °C. Enclosed solutions have variable salinity (0.4 to 23 wt. % NaCl equiv.) and several types of fluids within one mineral in a single sample can be commonly distinguished. Mineralization of this type occurs first of all in the southern part of the Moravice and Hradec-Kyjovice Formations, for instance in the Bystřice River valley, in the surroundings of Budišov nad Budišovkou and Fulnek, at Hrabůvka and Bohučovice localities.

Both types of mineralization can occur in one vein. Such a feature is common at localities in the Bystřice River valley, where several decimetres thick syntectonic quartz-calcite veins with chlorite are crosscut by fractures filled with younger carbonate of dolomite-ankerite series, quartz, calcite and commonly also sulphides.

• Oxygen and carbon isotopic composition of carbonates of the two types of hydrothermal mineralization (δ^{13}C between –1.4 and –9.7 ‰ PDB, δ^{18}O usually between –12.8 and –19.2 ‰ PDB) is indicative of formation of the hydrothermal solutions in the thick Culm sedimentary formations. The water of the hydrothermal solutions was largely of meteoric (vadose) character. In case of the younger mineralization, there is a strong dependence between its mineral composition and the character of the surrounding Culm sediments. Veins located in clay shales and aleuropelites are formed mainly by calcite and quartz. Veins in graywackes and conglomerates commonly contain carbonates of the dolomite-ankerite series, which can predominate in the veins, sulphide minerals, albite and sometimes also barite in addition to calcite and quartz.

• The age of the younger hydrothermal mineralization is still unclear. According to Bernard (1967, 1991), the hydrothermal veins with base metal assemblage in the Low Jeseník Uplands and Odra Hills Culm formations should be of the late Variscan age. There is probably no doubt about the late Variscan age in case of the hydrothermal filling of the "old" dislocation zone of the NW-SE strike in the Budišov ore district (e.g. deposit of the rich Pb-Ag ores Franz by Olověná).

On the other hand, at least some of the veins and veinlets in the southern part of the Moravice and Hradec-Kyjovice Formations (e.g. Hrubá Voda, Hrabůvka and Bohučovice), consisting largely of carbonate (calcite and/or dolomite-ankerite), cannot be considered as late Variscan. These veins and veinlets occur both in old fracture systems and in younger extensional structures. Degree of deformation of the vein filling is variable, often the deformation is very weak or missing, as in case of the large grains of quartz displaying no granulation and no undulose extinction and undeformed grains of carbonates. It is therefore possible, that at least in some cases this mineralization is Neoidic. Based on the study of the orientation of hydrothermal veins in the E part of the Moravo-Silesian Culm, Kučera – Slobodník (2002b) concluded that regional distribution of the studied hydrothermal mineralization points to more extensive migration of fluids along fractures originated in consequence of regional stress field, perhaps developed by movement of large crustal blocks during a certain phase of the Alpine tectogenesis.

Clear evidence for presence of the Neoidic mineralization in the Moravo-Silesian Culm comes from the locality Hrabůvka. Neptunian veins of the isotopically anomalous fossiliferous limestone of the Mesozoic age (Dolníček et al. 2002) are crosscut by calcite veinlets. Isotopic composition of calcite from these veinlets (δ^{13}C = –30.5 to –33.1 ‰ PDB, δ^{18}O = –5.1 to –5.6 ‰ PDB) is very similar to the isotopic composition of the surrounding carbonate. Similar veinlets with isotopic composition influenced by limestone of the Mesozoic or Tertiary age were found also in the Culm graywackes close to the limestone bodies.

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Studium žilných karbonátů a poznámky ke genezi hydrotermálních mineralizací v moravskoslezském kulmu

Variské flyšové sekvence Nízkého Jeseníku a Oderských vrchů na SV okraji Českého masivu jsou tvořeny různými typy pískovců (hlavně drobami), konglomeráty, jílovými břidlicemi, siltovci a lokálně také karbonátovými horninami. V tomto horninovém prostředí se hojně vyskytuje hydrotermální mineralizace dvou typů (oba typy mineralizace se mohou podílet na stavbě jedné žíly):

1. Variská syntektonická mineralizace, jejímž typickým reprezentantem jsou křemen-kalcitové žíly s chloritem klinochlor-chamositové řady. Sulfidické minerály jsou zastoupeny pouze ojedinělým pyritem. Teplota homogenizace primárních L+V inkluzí v kalcitu a křemeni se pohybuje zhruba v intervalu 60–90 °C; pro inkludované roztoky je charakteristická vysoká salinita (kolem 20 hm. % NaCl ekv.). Mineralizace tohoto typu je běžná v andělskohorském, hornobenešovském a moravickém souvrství; méně častá je v souvrství hradecko-kyjovickém.

2. Mladší mineralizace je tvořena hlavně karbonáty, které jsou zastoupeny zejména kalcitem, na některých lokalitách hojnými nebo zcela převládajícími karbonáty dolomit-ankeritové řady (dolomit s.s., Fe-dolomit, Mg-ankerit); výjimečně je přítomen siderit. Posloupnost vzniku karbonátů: siderit → dolomit-ankerit → kalcit. Křemen se vyskytuje ve variabilním množství, někdy chybí. Poměrně časté jsou sulfidy, zastoupené galenitem, sfaleritem, chalkopyritem, pyritem a lokálně hojným markazitem. Lze konstatovat výraznou závislost mezi nerostným složením mineralizace a charakterem okolních kulmských sedimentů: žíly v jílových břidlicích a aleuropelitech jsou tvořeny hlavně kalcitem a křemenem, žíly v drobách a slepencích kromě kalcitu a křemene často obsahují karbonáty dolomit-ankeritové řady, sulfidické minerály, albit a někdy také baryt a siderit. Teploty homogenizace primárních L+V inkluzí v karbonátech a křemeni jsou v intervalu zhruba 110 - 140 °C; přítomnost inkluzí vyplněných pouze kapalinou v některých vzorcích kalcitu ukazuje na teploty roztoku pod 50 °C. Inkludované roztoky mají rozdílnou salinitu (0,4 až 23 hm. % NaCl eq.) a často lze rozlišit několik typů fluid v rámci jednoho vzorku a jednoho minerálu. Mineralizace tohoto typu se vyskytuje především v jižní části moravického souvrství a hradecko-kyjovického souvrství.

Izotopické složení uhlíku a kyslíku karbonátů z obou typů hydrotermální mineralizace (d^{13}C mezi –1,4 a –9,7 ‰ PDB, d^{18}O obvykle mezi –12,8 a –19,2 ‰ PDB) ukazuje na formování hydroterm v mohutných souvrstvích kulmských sedimentů.

Časové zařazení mladší hydrotermální mineralizace je dosud nejasné. Podle Bernarda (1967, 1991) by hydrotermální žíly s polymetalickou asociací v kulmu Nízkého Jeseníku a Oderských vrchů měly být pozdně variské. Za pozdně variské rozhodně nelze považovat alespoň některé převážně karbonátové (kalcit nebo dolomit-ankerit) žíly a žilky v jižní části moravického souvrství a hradecko-kyjovického souvrství, které se vyskytují jak na starších puklinových systémech, tak i na zjevně mladších extenzních strukturách. Zcela jasný důkaz přítomnosti neoidní mineralizace v moravskoslezském kulmu byl získán na lokalitě Hrabůvka. Kromě pro tuto lokalitu typických Fe-dolomitových žil se sulfidy zde byly zjištěny drobné kalcitové žilky s markazitem, probíhající neptunickými žilami fosiliferního vápence (křídového nebo terciérního stáří) a okolními drobami. Izotopické složení kalcitu z těchto žilek (d^{13}C = –30,5 až –33,1 ‰ PDB, d^{18}O = –5,1 až –5,6 ‰ PDB) je v zásadě shodné s izotopickým složení zmíněného vápence.