Gas flux distribution in mineral springs and tectonic structure in the western Eger Rift

Distribuce výronů plynů v minerálních pramenech a tektonická struktura západní části ohareckého riftu (Czech summary)

(8 text-figs.)

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The gases of more than 70 mineral springs and mofettes (cold dry CO_2 gas vents) were investigated for gas flux, gas composition and $^3He/^4He$ ratios in the western part of the Eger Rift. Both regional gas flux and gas composition pattern are controlled by the tectonic structure.
Four separate main gas escape centres could be detected, partly with gas fluxes of more than 150 m^3/hr of free gas: Františkovy Lázně/Cheb Basin, Mariánské Lázně, Konstantinovy Lázně and Karlovy Vary. The very similar gases of the gas escape centres are > 99 vol. % CO_2-rich. Isotopically heavy CO_2 and high mantle derived helium proportions indicate the magmatic origin of these CO_2 rich gases. As a result of gas fractionation by CO_2 solution and HCO_3^- formation the N_2 contents in the gas phase increase in the margin areas with lower gas flux. According to a first estimation, the entire gas flux (natural flux) in the western part of the Eger Rift lies around a minimum of 5.31 million m^3/a free gas, including dissolved CO_2 and HCO_3^- of 8.13 million m^3/a.
The opposite dip of the main faults of the Eger Rift forms a Y-shaped structure and splits the gas flux about 15 km below the surface, forming a CO_2-free zone between them. The borders of this zone correspond to the position of the Eger Rift main fault, the southern border to the Litoměřice deep fault. The Eger Rift is shifted on younger NNW-SSE striking faults and narrows to the west.
The migration of the magmatic gases is mainly bound to the WSW-ENE striking Eger Rift main faults, while the younger NNW-SSE striking faults only have a distributive function. Southerly directed gas migration along the Horní Slavkov deep fault formed the small gas escape centre of Konstantinovy Lázně in the area of intersection with the Bezdružice deep fault.

Key words: gas flux, gas composition, He isotopes and gas fractionation, mineral springs and mofettes, tectonics, faults, Ohře (Eger) rift, Czech Republic

1. Introduction

Intensive basaltic volcanism and an increased gas flux of magmatic CO_2-rich gases in a large number of mineral springs and mofettes (cold dry gas vents) are connected with the post Alpidian crustal extension in the Eger Rift. Released gas volumes of almost pure CO_2 reach several m^3/hr in some springs in the spas of Mariánské Lázně, Františkovy Lázně and Karlovy Vary (e.g. Pačes 1974, Kolářová - Myslil 1979, Tesař 1986). The presence of high proportions of mantle derived helium with corresponding isotopically heavy CO_2 demonstrates the magmatic origin of the CO_2-rich gases (Polyak et al. 1985, Pačes 1974, 1987, D'Amore et al. 1989, O'Nions et al. 1989, Weinlich et al. 1998).

The distribution of the CO_2-rich mineral springs in north-west Bohemia has been linked for a long time to the tectonic structure of the Eger Rift (e.g. Kolářová 1965, Egerter et al. 1984). Thus the term "Bohemian thermal water line" by Jokély (1857) and Laube (1884) is the historical forerunner of the Eger Rift. However, the subject of the investigations was mainly the occurrence of mineral waters and not the distribution of the gas flux.

The ascent of gases mostly depends on the existence of paths of higher permeability, i.e. like fractures of the fault zones in compact igneous and metamorphic rocks. Therefore, it is possible to map out these fault zones by means of the gas distribution on the surface. For this purpose noble gases are normally used (Dikun 1975, Sugisaki 1980), however CO_2 can also be applied (Ernst 1968, Duddridge et al. 1991).

New facts and possibilities for tectonic interpretation are gathered by the measuring of gas fluxes in combination with chemical composition of the gases. Both the course of the main faults and the tectonic structure in the western part of the Eger Rift become apparent by the regional distribution pattern of the gas flux and the chemical characteristics of the gases.

2. Geological settings

The lithospheric extension in the Bohemian massif followed the Alpine orogeny in the late Eocene-Oligocene and resulted in the WSW-ENE striking North Bohemian Tertiary Basins (Malkovský 1980, 1987). This evolution was accompanied by extensive Oligocene-Miocene alkaline basaltic volcanism, e.g., Doupovské hory Mts. (Kopecký 1979). In a further tectonic phase, NNW-SSE striking deep faults were reactivated from Pliocene to Pleistocene (and present). The change of the extension direction led in the Cheb Basin to the sedimentation of an up to 300 m thick Pliocene-Pleistocene sequence with a basin axis striking parallel to the Mariánské Lázně deep fault. This latest phase was also accompanied by volcanism (olivine nephelinite-olivine melilithite) in the area of the Eger Rift (Šibrava - Havlíček 1980). The youngest eruptions formed two quaternary volcanoes (Komorní Hůrka, Železná Hůrka, cf. Fig. 1). Recent swarm earthquake activities provide evidence for contemporary tectonic activity of the faults (Grünthal et al. 1990).

Dominating tectonic elements of the Eger Rift are the WSW-ENE striking fault zones of the Ore Mountains fault, which forms a Y-shaped structure, the Central fault (of the Bohemian středohoří Mts.) and the Litoměřice deep fault (Kopecký 1979, Šťovíčková 1980, Conrad et al. 1983). Within the investigation area, the Eger Rift is crossed by the younger NNW-SSE striking deep fault zones of Mariánské Lázně and Horní Slavkov and a few secondary NNE-SSW striking faults (Fig. 1).

In the eastern part of the Eger Rift, the course of the Litoměřice deep fault is indicated by geophysical data up to the area south of Karlovy Vary by the use of gravity gradients (Šťovíčková 1980, Conrad et al. 1983). In the area of Mariánské Lázně, the gravity pattern is disturbed by

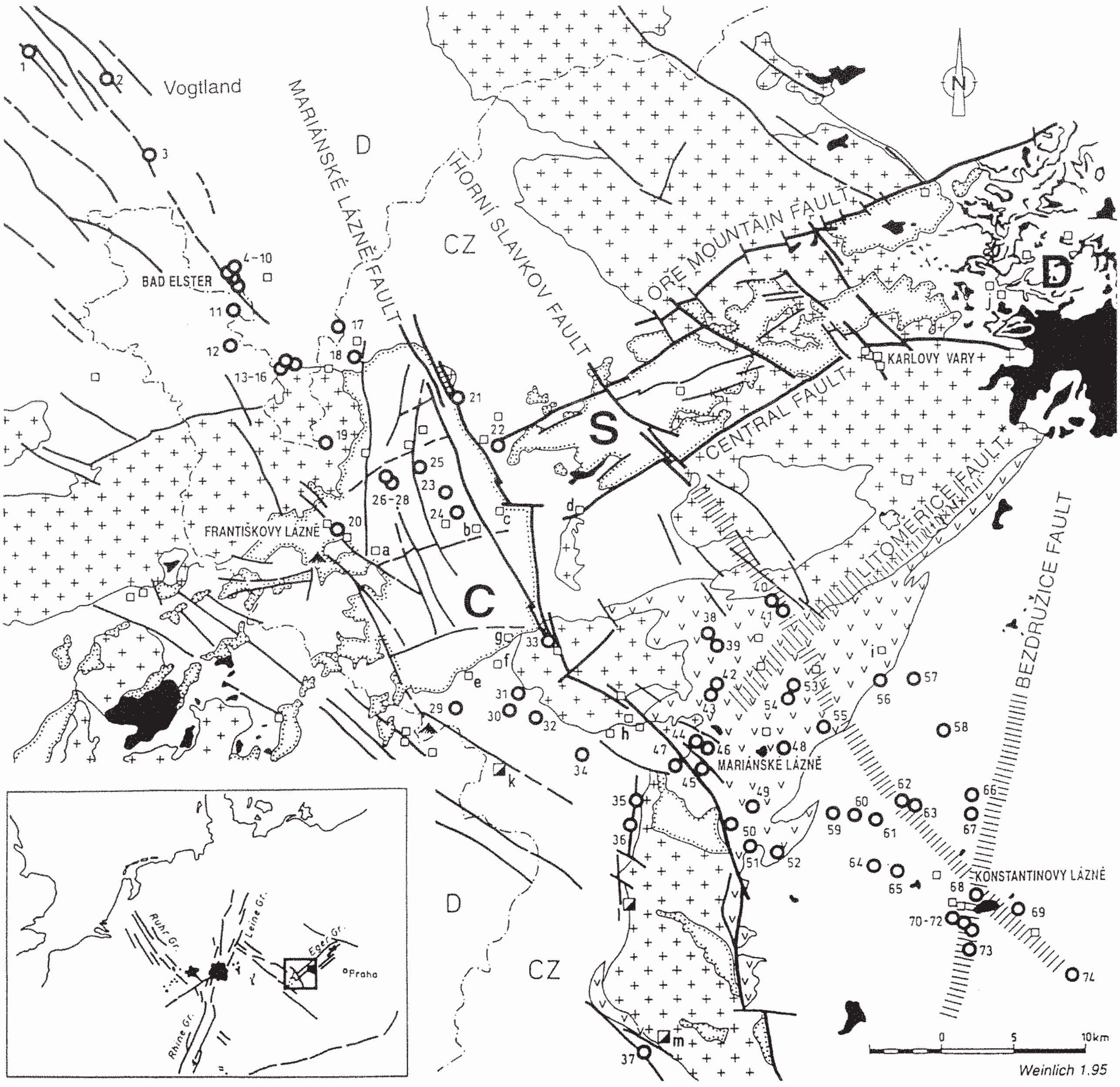

Fig. 1. General map of the western part of the Eger Rift with the position of the sampled gas-bearing springs
C - Cheb (Eger) - Basin; S - Sokolov Basin; D - Doupovské hory;
+ - Variscian granite; v - Proterozoic Mariánské Lázně Amphibolite Complex; *dotted lines* - Tertiary extension basin; *black* - Tertiary volcanite; *cones* - Quaternary volcanoes (north: Komorní Hůrka; south: Železná Hůrka), Litoměřice deep fault according to geophysical mapping (Conrad et al. 1983) *circles* - sampled springs with numbers in tables 1 to 3; *squares* - not investigated, dried up or inaccessible mineral springs: *a* - Tršnice, *b* - Nebanice, *c* - Pochlovice, *d* - Šabina, *e* - Palič, *f* - Salajna, *g* - Ždírnice, *h* - Lázně Kynžvart, *i* - Brť, *j* - Kyselka; half-filled squares - uranium mines with gas blowouts and water inflow: *k* - Dyleň, *l* - Zadni Chodov, *m* - Vítkov II, Tachov

granite intrusions at the margin of the Mariánské Lázně Amphibolite Complex, rendering an exact localization of the Litoměřice deep fault impossible (Conrad 1995). Due to the disturbing effect of the Kynžvart granite even the course of the Mariánské Lázně deep fault is not to be distinguished by gravimetrical means. However it is detectable on the surface. In the geological surface picture the course of the Litoměřice deep fault zone is not visible because of the presence of similar rock complexes.

The total dissolved solids (TDS) in the waters of the mineral springs range from 70 to 23500 mg/l (Dietl 1942, Myslil - Václ 1966, Pačes 1974, Carlé 1975, Kolářová - Myslil 1979, Egerter et al. 1984). Higher concentrations of TDS from 2000 to 23500 mg/l are mostly in the Na-SO_4-Cl-HCO_3 waters in the spas Karlovy Vary, Mariánské Lázně and the surroundings of Františkovy Lázně. The Na-SO_4-Cl mineral waters are interpreted as Tertiary relict waters (Myslil and Václ 1966, Pačes 1974, Dvořák 1990). Pačes (1987) suggests an additional volcanic sulphur input, based on the $\delta^{34}S$ values. Outside these areas there exist for the most part only low mineralized Ca-Mg-HCO_3 waters with 70-1000 mg/l TDS and 1200-2000 mg/l of dissolved CO_2. Due to their high CO_2 contents, the waters dissolve cations, mainly Ca^{2+} and Mg^{2+}, out of the adjacent rock, which leads to the formation of Ca-Mg-HCO_3 waters. The petrographic composition of the adjacent rock is indicated by the Ca^{2+}/Mg^{2+} ratio (Pačes 1974, Dvořák 1990).

3. Methods of investigation

The area of investigation (Fig. 1) extends from Vogtland in the north-west via the Cheb Basin in an approximately 25 km wide area to Konstantinovy Lázně (Czech Republic), 40 km south of the Eger Rift. From the approximately 140 mineral springs described in this area (Laube 1884, Jahnel 1937, Dietl 1942, Kolářová - Myslil 1979, Egerter et al. 1984, Kolářová - Hrkal 1986), 74 gas bearing springs were selected for sampling. Almost all the mineral springs at the margin of the investigated area were sampled. Not investigated, however, was the mineral spring of Karlovy Vary.

3.1. *Gas sampling and gas flux measurements of free gas*

Between CO_2 and N_2, noble gases and hydrocarbons exist large solubility differences in water. Due to their essentially lower solubility, inert and rare gases are enriched in the gas phase. Accordingly, in order to obtain comparable results of the gas composition, only free gas at atmospheric pressure was collected. The gas was trapped by a funnel and led to gas vessels made of highly helium impermeable glass. The vessels were filled with water from the sampled spring prior to gas collection. Because the water in the gas vessels was saturated with the gas of the respective spring, solubility effects between the gas and aqueous phases during sampling could so be kept to a minimum. The sample volumes were between 0.5 and 1 l, and 2.5 l in the case of the CO_2-rich gas samples. Gas chromatography was used to analyse the gas composition and the isotopic composition of the He determined.

At each of the sampled mineral springs and mofettes, the gas flux was measured. Funnels with a diameter of 0.6 to 1 m, made from a 1 mm thick flexible polythene sheet, covered the springs. The gas flux was measured using gas flow meters with varying ranges (drum gas counters for 5 to 750 l/hr; dry gas counters for 60 l/hr to 12000 l/hr). The smallest gas fluxes were measured with a scaled measuring cylinder placed above the funnel. Reproducible readings of gas flux were achieved in 10 to 15 minutes of measuring in springs and mofettes with large gas flux (more than 50 l/hr). Measurement times partly of up to 2 hr were necessary in springs with very low gas fluxes in which the gas often ascends sporadically. The errors of the gas flux measurements is ± 10-20 %.

In the mofette fields, for instance in Soos, Bublák or Smrad'och, as many as 50-500 gas exhalations exist. In these cases, all the larger and a selection of the smaller gas vents were measured. The total gas flux was estimated in accordance with these measurement values and the number of the gas exhalations (Table 3).

3.2. *Sampling preparation and He isotope analysis*

In order to analyse the N_2 and trace gas components, firstly CO_2 was scrubbed out with KOH-solution according to Weinlich (1989) in the case of CO_2-rich gases. Contamination with dissolved air in the saturated KOH solution can be excluded because of the negligibly small solubility of air components. The possible effect is lower than the analytical errors.

The error in the reported CO_2 contents lies within the precision of readout of ± 0.1 ml per 1 to 2.5 l gas vessel. The error of the gas GC analyses of the other gas components, after parallel analyses in two laboratories (GSF Munich: Shimadzu GC-9A and the Františkovy Lázně Reference Laboratory: Laboratorní Přistroje Praha, Chrom 5), along with double sampling dependent on concentration, is ± 3 % for N_2 and O_2 and ± 10 to 40 % for He, Ar and hydrocarbons). Results of the analyses are listed in Table 1.

Most of the gas samples contain small contents of O_2, and thus atmospheric proportions, which must be corrected for calculating purposes. In several CO_2-rich gases the O_2 and/or Ar contents were partly higher than expected due to contaminations with atmospheric air (N_2/Ar ratio = 83.97 and N_2/O_2 ratio = 3.73). This is a result of exsolution of dissolved air in the ground waters during the CO_2 transport through the ground waters (stripping effect). A recalculation of the analyses of the O_2 concentrations in dissolved air (N_2/O_2 ratio dependent on temperature 1.81...1.85) leads to N_2/Ar ratios being too low compared with those of magmatic gases (Matsuo et al. 1978, Kita et al. 1993). As shown in the plot of O_2 vs. Ar content - in the CO_2-free proportion - (Fig. 2), a variable O_2 reduction occurs. The Ar isotope ratios of the spring gases of the Vogtland (Jordan et al. 1979) show no essential divergences from the atmospheric ratios. Therefore Ar contents were used to correct for atmosphere derived contributions. The air-free proportions of the investigated gases, listed in Table 2, form the basis of further considerations.

The gas composition (air-free part) does not change significantly with time, as established with multiple samplings during 1992-1994. The gas composition of the CO_2-rich gases is very constant. Variations in the N_2 content between 3 and 5 vol. % were observed only in some springs with gases containing less CO_2.

The gas samples were analysed for their ^4He and ^{20}Ne content, and the $^3He/^4He$ ratio was measured. Both sample purification and measurement procedure on a mass spectrometer VG MM 3000 are given by Weise - Moser (1987). The precision of the helium isotope measurements is generally ± 2 %. The precision of ^4He- and ^{20}Ne concentration ratios is ± 10 %, depending on the quantity of the samples. The measured $^3He/^4He$ ratios, R, must also be corrected for atmospheric contributions. Here, it is assumed that ^{20}Ne is completely atmospheric in origin and the value R was corrected following Craig et al. (1978) with the $^4He/^{20}Ne$ ratio of dissolved air. The helium isotope ratio values are given as air corrected R/R_a values. In relation to $R_{MORB} \approx 8 \cdot R_a$ and $R/R_{a\ crust} \approx 0.02$ (Ozima - Podosek 1983), a mantle derived proportion can be given.

4. Results

4.1. *Gas flux distribution*

The gas fluxes ranged between 30 ml/hr and > 30 m^3/hr of free gas (Table 3) in the mineral springs and mofettes of the investigated area. Four separate major gas escape centres are apparent in the western Eger Rift (Fig. 3):

1. Františkovy Lázně/Cheb Basin: a minimum of 85 m^3/hr of free gas escapes from the main mofettes and springs of the Cheb Basin in the Soos (# 26-28), Bublák (# 23), Hartoušov (# 24) and Františkovy Lázně (# 20). In the Soos moor, gas flux measurements were carried out in the main gas escape areas on 25 gas exhalation points in total and estimates were made on a further 15 smaller gas exhalations. The well scattered smaller gas exhalations in the Soos only slightly increase the total value to 35 m^3/hr. In Bublák, the CO_2 escape is also concentrated in a small area of ~ 3000 m^2, so that, at 15 measuring points, the dominant part of the gas volume stream could be determined at 28 m^3/hr in total. Repeated measuring confirmed the values shown in Table 3. In the case of Františkovy Lázně, determinations of the dissolved gases are available (Myslil - Václ 1966, Kolářová - Myslil 1979). Access to the springs to measure the free gas was however not available. The gas flux of the free gases can therefore only be estimated at > 16 m^3/hr, compared to those of Soos and Bublák.

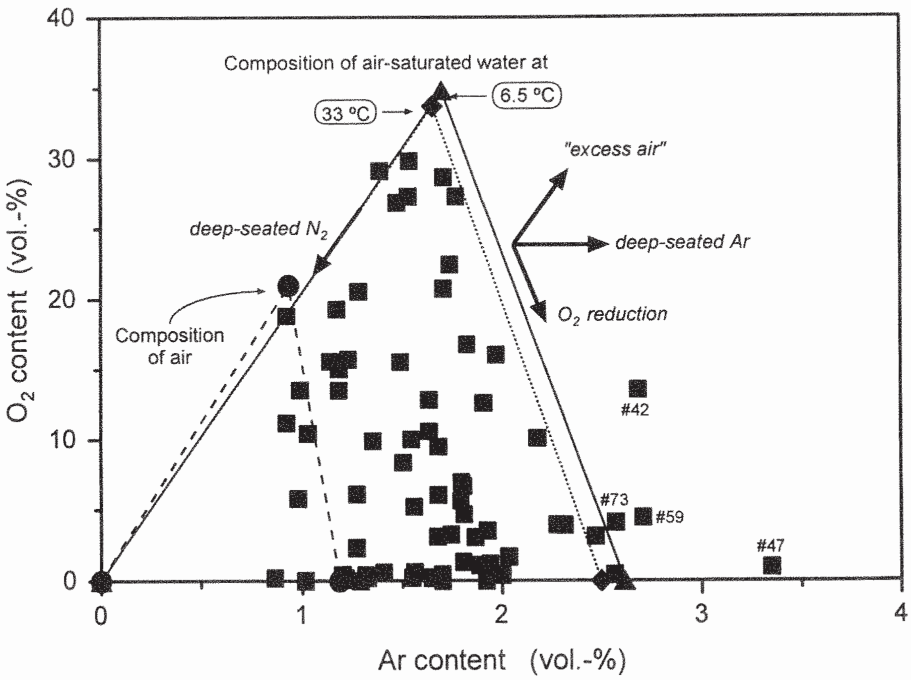

Fig. 2. Concentrations of O_2 and Ar in the CO_2-free proportions of the gas samples due to contamination by dissolved air
squares - measured Ar and O_2 contents in the gas samples; *triangular field between the circles* - contamination with atmospheric air and O_2 reduction; *triangular field between the triangle and diamond symbols* - contamination by dissolved air at the range of measured water temperature (6.5 to 33 °C) and bacterial and/or chemical O_2 reduction in the waters

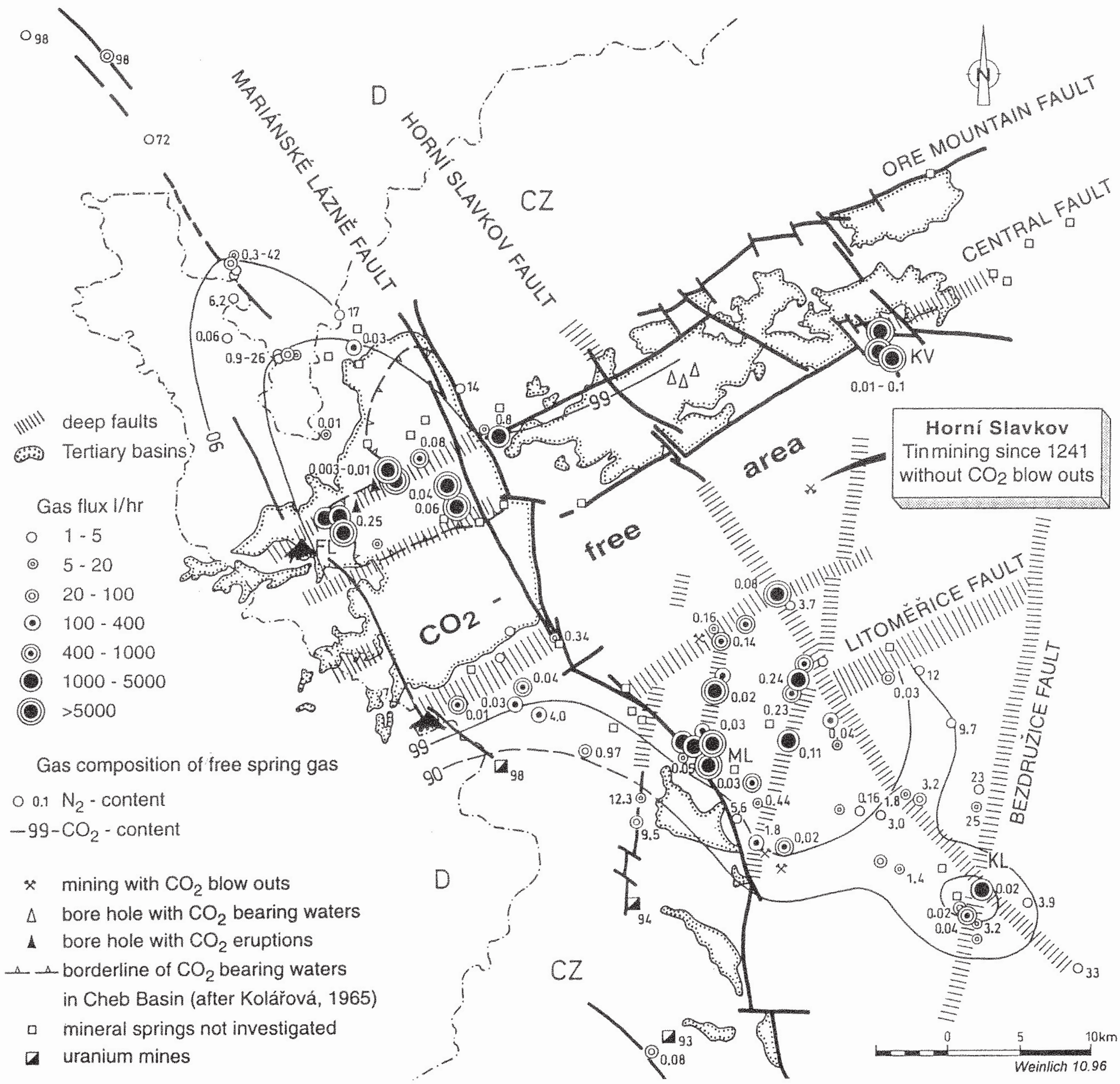

Fig. 3. Distribution pattern of gas flux and composition (air-free) of the gases in mineral springs and mofettes in the surrounding area of the western Eger Rift
Gas escape centres: Františkovy Lázně (FL)/Cheb Basin, Mariánské Lázně (ML), Konstantinovy Lázně (KL) and Karlovy Vary (KV)

2. The region east of Mariánské Lázně: The free gas escaping in mineral springs of Mariánské Lázně could be estimated as a gas flux of over 100 m³/hr for the 15 springs; 90 m³/hr of which was measured in 4 springs (# 44-47). The mofettes of Smraďoch, Prameny, Sirňak at Podhorní vrch and the mineral springs of Nová Ves and Čihaná in the area NE of Mariánské Lázně additionally produce approximately 20 m³/hr of free gas.

3. The region surrounding Konstantinovy Lázně: The gas flux decreases rapidly to the SE of Mariánské Lázně. However, it increases again in a small area surrounding Konstantinovy Lázně to approximately 2 m³/hr in the Prusíkův spring in Konstantinovy Lázně, and to 0.43 m³/hr in a gas spurt in the Čelivský creek at Břetislav (# 72). There is no mofette formation.

4. Karlovy Vary region: The thermal water and CO_2 ascent is bound to the NNW-SSE striking "Thermal zone" parallel to the Teplá river. In the Vřídlo and the Tržní springs approximately 266 m³/hr of gas is liberated alone. The entire CO_2 gas flux of the main springs is 356 m³/hr (Vylita et al. 1991). Mofettes have existed in the prolongation of the Thermal zone between the Vřídlo and the Dorotka and Štěpánka springs (Gromes 1940). The CO_2-bearing waters in the basal sediments of the Sokolov

Table 1. Composition of the gases of mineral springs and mofettes in the western Eger Rift, north-west Bohemia and Vogtland

#	Locality, spring	Sampling date	Gas composition									
			CO_2 vol.%	N_2 vol.%	O_2 vol.%	Ar vol.%	He vol.%	H_2 vol.%	CH_4 vol.%	C_2H_6 vpm	C_3H_8 vpm	C_4H_{10} vpm
1	Neumühle, well	28.4.92	0.0	97.50	0.19	0.8640	1.347		0.101	1.90		
2	Schönbrunn, Flour. mine	28.4.92	0.41	97.85	0.0	1.012	0.459		0.273	5.03		
3	Ebersbach	4.10.93	17.20	72.80	9.23	0.765	0.0	tr.	0.0047			
4	BE Marienquelle I	28.4.92	92.90	6.94	0.0	0.121	0.0272		0.0111	1.11		
5	Mariemquelle III	28.4.92	46.38	52.70	0.102	0.650	0.1409		0.028	1.40		
6	Moritzquelle	27.4.92	91.38	8.32	0.110	0.156	0.0230		0.015	0.699		
7	Sprudel I	23.4.92	41.00	58.08	0.0	0.760	0.131		0.027	0.40		
8	Sprudel II	23.4.92	89.12	9.25	1.47	0.129	0.012		0.0259	1.10	0.105	
9	Sprudel III	23.4.92	83.82	15.05	0.746	0.293	0.0329		0.0628	3.09		
10	Sprudel IV	20.10.92	98.70	1.18	0.0895	0.0234	0.00247	tr.	0.0010	0.441	0.0779	tr.
11	Doubrava	5.6.92	85.48	14.15	0.0813	0.226	0.0331	tr.	0.0289	0.566		
12	Dolni Paseky	25.4.92	90.55	9.12	0.0390	0.242	0.0290		0.0180	1.00		
13	BB Schillerquelle	21.11.85	98.00	1.60	0.376	0.0185	0.00139	0.00002	0.0022	0.020	0.0597	
14	Eisenquelle	21.11.85	98.10	1.49	0.390	0.0177	0.00013		0.00067			
15	Unt. Grenzquelle	29.4.92	56.18	42.72	0.233	0.615	0.116	tr.	0.140	0.801		
16	Ob. Grenzquelle	29.4.92	93.30	6.54	0.0	0.129	0.0188		0.0139	4.95	<0.1	<0.1
17	Hennebach	5.5.93	65.60	33.22	0.0711	0.533	0.135	tr.	0.441	1.07		
18	Plesná, Smrčina	4.5.93	99.42	0.403	0.166	0.0099	0.00012	tr.	0.00027			
19	Schönberg	4.5.93	99.89	0.090	0.0187	0.0020	<0.00001	<0.00001	0.00093	0.129	0.0043	tr.
20	Františkovy Lázně, Kostelní	6.5.93	99.02	0.869	0.0929	0.0165	0.00217	tr.	0.0023	tr.		
21	Kopanina	5.5.93	74.00	24.71	0.0530	0.345	0.0742	tr.	0.819	1.33	0.265	
22	Dolní Častkov	4.5.93	98.09	1.59	0.297	0.0218	0.00595	tr.	0.00135	2.58	0.0198	
23	Bublák/Vackovec, mofettes	29.9.93	99.844	0.127	0.0241	0.0023	0.00188	tr.	0.00020	0.68	0.0092	
24	Hartoušov, mofettes	5.5.93	99.826	0.142	0.0272	0.0021	0.00220	tr.	0.00037	0.073	0.0124	
25	Děvín, mofettes	5.5.93	99.643	0.322	0.0237	0.0065	0.00154	tr.	0.0032	0.072	0.0108	
26	Soos, mofettes	5.5.93	99.947	0.0429	0.00856	0.0011	0.00087	tr.	0.00010	0.026	0.0017	
27	Soos, Císařský pramen	5.5.93	99.941	0.0407	0.0173	0.00083	0.000094	0.00031	0.00021	0.021	0.0030	tr.
28	Soos, Vera		5.5.93	99.940	strongly air contaminated, no He data							
29	Kyselecký Hamr	7.5.93	99.767	0.165	0.0637	0.0041	0.000046	0.00005	0.00013	0.060	0.0023	
30	Brtná, village	6.5.93	99.823	0.127	0.0475	0.0026	0.000035	tr.	0.00023	0.0017	<0.1	
31	Brtná, viaduct	19.4.94	99.855	0.124	0.0153	0.0024	0.000166	0.00007	0.0031	$<10^{-3}$	$<10^{-3}$	$<10^{-3}$
32	Poustka	6.5.93	89.10	10.11	0.562	0.170	0.0233	tr.	0.0313	1.27	0.106	
33	Podlesí, Radionka	7.5.93	99.10	0.797	0.0885	0.012	0.000434	tr.	0.00002	0.017	0.0260	
34	Jedlová	6.6.92	95.73	4.13	0.0158	0.085	0.0174	<0.00001	0.0203	2.18	0.0427	<0.1
35	Panský vrch	7.5.93	76.00	22.08	1.45	0.305	0.0235	<0.00001	0.139	0.235	<0.1	<0.1
36	Skelné hutě	7.5.93	82.60	15.36	1.81	0.179	0.00179	<0.00001	0.0459	4.30	0.359	
37	Tachov, minerálka	9.6.92	99.82	0.147	0.0103	0.0018	0.00154	tr.	0.0192	0.558	0.0378	
38	Prameny, kyselka	8.5.93	99.524	0.449	0.0145	0.0080	0.000094	0.00011	0.0039	0.005	$<10^{-3}$	
39	Prameny, Mofettes	28.4.94	99.489	0.475	0.0164	0.0089	0.00429	0.00005	0.0071	<0.01	<0.01	<0.01
40	Nová Ves, pond, gas spurts	30.9.93	99.668	0.271	0.0331	0.0051	0.00133	0.00006	0.0214	tr.		
40	Nová Ves, kyselka	25.11.94	99.658	0.296	0.0205	0.0057	0.00220	0.00295	0.0152	0.074	<0.01	<0.01
41	Louka, Grünska kyselka	8.5.93	87.00	12.58	0.136	0.246	0.0136	tr.	0.0286	0.818	0.273	
42	ML-Farská kyselka	10.5.93	99.367	0.524	0.0855	0.0170	0.00013	0.00007	0.0062	0.0065	0.0587	$<10^{-3}$

#	Locality, spring	Sampling date	Gas composition									
			CO_2 vol.%	N_2 vol.%	O_2 vol.%	Ar vol.%	He vol.%	H_2 vol.%	CH_4 vol.%	C_2H_6 vpm	C_3H_8 vpm	C_4H_{10} vpm
43	Smrad'och, Mof.	30.9.93	99.923	0.0633	0.00982	0.0013	0.00062	tr.	0.0018	0.580	0.006	tr.
44	Křížový pramen III	20.4.94	99.625	0.279	0.0840	0.0065	0.000036	0.00433	0.00087	1.31	0.655	0.182
45	Ferdinand	20.4.94	99.963	0.0257	0.0110	0.0	0.000004	0.00010				
46	Mariiny, mofettes	4.6.92	59.99	30.98	8.65	0.376	strongly air contaminated					
47	Vlčí	5.10.93	99.922	0.073	0.000715	0.0026	0.00109	tr.	0.00050	0.047	0.0024	$<10^{-3}$
48	Sirňák, Podh. vrch, Mofettes	30.9.93	99.702	0.257	0.00680	0.0038	0.00376	<0.00001	0.0272	tr.		
49	Martinov, Horká	10.5.93	99.069	0.786	0.126	0.0092	<0.0001	0.00018	0.0098	0.207	0.0366	
50	Chotěnov, Koňský pr.	7.6.92	79.98	19.29	0.232	0.388	0.00380	tr.	0.101	0.200		
51	Dolní Kramolín, Ilsano	10.5.93	95.00	3.93	0.963	0.0586	0.00049	0.00010	0.0489	0.0069	0.0138	
52	Čiperka, Michalovy hory	7.6.92	99.820	0.151	0.0226	0.0034	0.00032	0.00003	0.0023	0.176	0.0036	
53	Čihaná, HJ 3	8.5.93	98.98	0.951	0.0306	0.0190	0.00327	0.00084	0.0136	0.105	0.0211	tr.
54	Čihaná, kyselka	25.11.93	98.93	1.002	0.0371	0.0207	0.00331	<0.00001	0.0099	0.530	0.0318	<0.1
55	Hoštěk	9.5.93	99.905	0.0782	0.0142	0.00112	0.000056	0.0012		tr.	<0.1	
56	Otročin	8.5.93	99.815	0.131	0.0504	0.0028	tr.	0.00018	0.00062	0.049	0.0151	
57	Poseč	18.4.94	69.93	29.09	0.125	0.511	0.0491	<0.00001	0.279	21.20	<0.1	<0.1
58	Dobrá Voda	2.10.93	76.90	22.59	0.0453	0.381	0.0521	tr.	0.0344			
59	Beranovka	10.5.93	99.327	0.611	0.0297	0.0182	0.00027	0.00034	0.0139	0.101	0.0135	
60	Pěkovice	3.10.93	98.00	1.86	0.0777	0.0455	0.00159	tr.	0.0146	7.18	0.0399	
61	Křepkovice	27.4.94	88.200	10.70	0.659	0.212	0.0185	<0.00001	0.213	17.35	0.347	<0.1
62	Nezdice	3.10.93	97.93	1.92	0.0637	0.0512	0.00185	tr.	0.0397	6.16	0.205	
63	Zahrádka	9.5.93	85.00	14.28	0.244	0.305	0.0412	<0.00001	0.125	18.29	0.610	<0.1
64	Hanov	2.10.93	99.045	0.775	0.0959	0.0208	0.00150	tr.	0.0593	22.86	0.480	
65	Zhořec	11.5.93	95.69	3.81	0.358	0.0647	0.0199	tr.	0.0574	0.82	tr.	
66	Úterý	2.10.93	64.30	34.94	0.140	0.428	0.0876	tr.	0.103			
67	Křivce	9.5.93	61.40	37.64	0.0389	0.467	0.163	tr.	0.229	583.32	0.389	
68	Konst. Láz., Prusíkův pr.	4.10.93	99.554	0.405	0.0172	0.0103	0.00068	0.00014	0.0121	2.30	0.0542	tr.
69	Poloučany, Kozi vrch	2.10.93	82.90	15.86	0.0841	0.331	0.0219	tr.	0.786	121.13	3.70	
70	Kokašice, Luční	1.10.93	99.853	0.112	0.0305	0.00251	0.000044	0.00010	0.0019	0.205	0.0044	tr.
71	Břetislav, Čeliv creek	27.4.94	99.650	0.239	0.1044	0.00539	0.000050	0.00010	0.0018	0.174	<0.1	<0.1
72	Břetislav, kyselka	1.10.93	89.90	7.86	2.07	0.129	0.00303	0.00036	0.0377	4.15	0.303	
73	Břetislav, Na Hadovce	11.5.93	89.80	9.07	0.413	0.262	0.00705	0.00038	0.437	95.65	0.503	tr.
74	Horské Domky, Tripisty	11.5.93	49.90	49.16	0.188	0.658	0.09399	tr.	0.0018			

BE - Bad Elster, BB - Bad Brambach, ML - Mariánské Lázně

Table 2. Composition of the air-free fraction and air contents of the gases of mineral springs and mofettes in the western Eger Rift, north-west Bohemia and Vogtland

#	Locality, spring	Gas composition air-free								air
		CO_2 vol.%	N_2 vol.%	He vol.%	H_2 vol.%	CH_4 vol.%	C_2H_6 vpm	C_3H_8 vpm	C_4H_{10} vpm	proportion vol.%
1	Neumühle, well	0.00	97.82	2.023		0.152	2.854	0.0078		33.43
2	Schönbrunn, Flour. mine	0.70	98.08	0.770		0.454	8.2			40.66
3	Ebersbach	28.05	71.94	tr.	tr.	0.00773				38.68
4	BE Marienquelle I	97.44	2.52	0.0285		0.0116	1.16			4.66
5	Marienquelle III	62.00	37.77	0.188		0.0374	1.87			25.19
6	Moritzquelle	97.34	2.62	0.0244		0.0160	0.74			6.12
7	Sprudel I	58.04	41.73	0.185		0.0382	0.57			29.36
8	Sprudel II	95.24	4.72	0.0128		0.0277	1.17	0.11		6.42
9	Sprudel III	95.33	4.56	0.0373		0.0714	3.51			12.07
10	Sprudel IV	99.69	0.31	0.00249	tr.	0.0010	0.45	0.079	tr.	0.99
11	Doubrava	93.72	6.21	0.0363	tr.	0.0317	0.62			8.79
12	Dolní Paseky	99.89	0.062	0.0320		0.0199	1.10			9.35
13	BB Schillerquelle	99.08	0.92	0.00141	0.00002	0.0022	0.020	0.060		1.09
14	Eisenquelle	99.16	0.84	0.00013		0.00067				1.07
15	Unt. Grenzquelle	73.89	25.78	0.153	tr.	0.184	1.05			23.96
16	Ob. Grenzquelle	98.18	1.78	0.0198		0.0146	5.21	<0.1	<0.1	4.97
17	Hennebach	82.59	16.68	0.170	tr.	0.555	1.34			20.57
18	Plesná, Smrčina	99.97	0.032	0.00012	tr.	0.00028				0.55
19	Schönberg	99.99	0.014	<0.00001	<0.00001	0.00093	0.129	0.0043	tr.	0.10
20	Františkovy Lázně, Kostelní	99.75	0.25	0.00218	tr.	0.0023	tr.			0.73
21	Kopanina	85.36	13.60	0.0856	tr.	0.945	1.53	0.31		13.31
22	Dolní Částkov	99.21	0.78	0.00601	tr.	0.0014	2.61	0.020		1.13
23	Bublák/Vackovec, mofettes	99.96	0.039	0.00188	tr.	0.00020	0.68	0.0092		0.11
24	Hartoušov, mofettes	99.94	0.062	0.00221	tr.	0.00037	0.073	0.012		0.11
	Hartoušov, kyselka									
25	Děvín, mofettes	99.92	0.080	0.00155	tr.	0.0033	0.072	0.011		0.27
26	Soos, mofettes	99.99	0.0033	0.00087	tr.	0.00010	0.026	0.0017		0.05
27	Soos, Cisařský Pramen	99.99	0.0093	0.000094	0.00031	0.00021	0.021	0.0030	tr.	0.05
28	Soos, Vera	>99.9	strongly air contaminated							
29	Kyselecký Hamr	99.99	0.010	0.000046	0.00005	0.00013	0.060	0.0023		0.22
30	Brtná, village	99.97	0.029	0.000035	tr.	0.00023	0.0017	<0.1		0.15
31	Brtná, viaduct	99.96	0.035	0.00017	0.00007	0.0031	$<10^{-3}$	$<10^{-3}$	$<10^{-3}$	0.11
32	Poustka	95.91	4.03	0.0251	tr.	0.0337	1.37	0.11		7.10
33	Podlesí, Radionka	99.66	0.34	0.00043	tr.	0.00002	0.017	0.026		0.56
34	Jedlová	98.99	0.97	0.0180	tr.	0.0210	2.25	0.044	<0.1	3.30
35	Panský vrch	87.54	12.28	0.0270	<0.00001	0.160	0.270	<0.1	<0.1	13.18
36	Skelné hutě	90.49	9.46	0.00194	<0.00001	0.0503	4.71	0.39		8.72
37	Tachov, mineralka	99.90	0.081	0.00154	tr.	0.0192	0.56	0.038		0.08
38	Prameny, kyselka	99.84	0.152	0.000093	0.00011	0.0039	0.0047	$<10^{-3}$		0.32
39	Prameny, mofettes	99.85	0.141	0.00430	0.00005	0.0071	<0.1	<0.01	<0.01	0.36
40	Nová Ves, gas spurts, pond	99.90	0.079	0.00133	0.00007	0.0215	tr.			0.23
	Nová Ves, kyselka	99.90	0.081	0.00220	0.00295	0.0153	0.074	<0.01	<0.01	0.24
41	Louka, Grünska kyselka	96.22	3.73	0.0151	tr.	0.0317	0.91	0.30		9.58

#	Locality, spring	Gas composition air-free								air
		CO_2 vol.%	N_2 vol.%	He vol.%	H_2 vol.%	CH_4 vol.%	C_2H_6 vpm	C_3H_8 vpm	C_4H_{10} vpm	proportion vol.%
42	ML Farská kyselka	99.99	0.000	0.00013	0.00007	0.0062	0.007	0.059	<10-3	0.74
43	Smraďoch mofettes	99.98	0.016	0.00062	tr.	0.0018	0.58	0.0061	tr.	0.06
44	Křížový pramen III	99.96	0.034	0.000036	0.00435	0.00088	1.32	0.66	0.18	0.33
45	Ferdinand II	99.97	0.026	0.000004	0.00010					0.01
46	Mariiny, mofettes	>99.99	strongly air contaminated							
47	Vlčí	99.99	0.000	0.00109	tr.	0.00050	0.047	0.0024	0.10	
48	Siriňák, Podh. vrch, mofettes	99.85	0.114	0.00376	<0.00001	0.0272	tr.			0.15
49	Martinov, Horká	99.55	0.443	<0.0001	0.00019	0.0098	0.21	0.037		0.48
50	Chotěnov, Koňský pramen	94.28	5.60	0.00443	tr.	0.119	0.24			15.16
51	Dolní Kramolín, Ilsano	98.16	1.79	0.00050	tr.	0.0505	0.0069	0.014		3.22
52	Čiperka, Michalovy Hory	99.98	0.022	0.00032	0.00003	0.0023	0.18	0.0036		0.16
53	Čihaná, HJ 3 a. spring field	99.74	0.24	0.00329	0.00085	0.0137	0.11	0.021	tr.	0.76
54	Čihaná, kyselka a. well	99.76	0.23	0.00333	<0.00001	0.0099	0.53	0.032	<0.1	0.83
55	Hoštěk	99.96	0.036	0.000056		0.0012	tr.	<0.1		0.06
56	Otročin	99.97	0.025	tr.	0.00018	0.00062	0.049	0.015		0.16
57	Poseč	87.16	12.41	0.0612	<0.00001	0.348	26.4	<0.1	<0.1	19.77
58	Dobrá Voda	90.15	9.75	0.0610	tr.	0.0404				14.70
59	Beranovka	99.99	0.000	0.00027	0.00034	0.0140	0.102	0.014		0.73
60	Pěkovice	99.82	0.160	0.00162	tr.	0.0148	7.31	0.041		1.83
61	Křepkovice	96.71	3.04	0.0203	<0.00001	0.233	19.0	0.38	<0.1	8.80
62	Nezdice	99.96	0.00016	0.00188	tr.	0.0405	6.29	0.21		2.03
63	Zahrádka	96.57	3.24	0.0467	<0.00001	0.142	20.8	0.69	<0.1	11.98
64	Hanov	99.94	0.00	0.00152	tr.	0.0599	23.1	0.48		0.90
65	Zhořec	98.50	1.42	0.0204	tr.	0.0591	0.84	tr.		2.85
66	Útery	77.08	22.69	0.105	tr.	0.124				16.58
67	Křivce	74.87	24.58	0.199	tr.	0.280	711.2	0.47		17.99
68	Konst. Láz. Prusíkův pr.	99.97	0.019	0.00068	0.00014	0.0122	2.31	0.054	tr.	0.41
69	Poloučany, Kozi vrch	95.12	3.94	0.025	tr.	0.901	139.0	4.25		12.85
70	Kokašice, Luční	99.98	0.018	0.00004	0.00010	0.0020	0.21	0.0044	tr.	0.13
71	Břetislav, Čeliv creek	99.96	0.037	0.00005	0.00010	0.0018	0.17	<0.1	<0.1	0.31
72	Břetislav, kyselka	96.76	3.19	0.0032	0.00037	0.0406	4.46	0.33		7.09
73	Břetislav, Na Hadovce	99.50	0.000	0.0078	0.00039	0.484	106.0	0.56	tr.	10.48
74	Horské Domky, Tripisty	66.99	32.88	0.126	tr.	0.0024				25.51

BE - Bad Elster, BB - Bad Brambach, ML - Mariánské Lázně

Table 3. Gas flux and He isotopic composition of gases from mineral springs and mofettes in the western part of the Eger Rift, north-west Bohemia and Vogtland

#	Locality, spring	Water			Gas flux				Gas/water	He isotope ratio	
		T	TDS	discharge	dissolved in vater $CO_2+HCO_3^-$	Gaseous phase number of escape points measur.	(estim.)		ratio	$^3He/^4He$ x10^{-6}	R/R_a
		°C	mg/l	l/hr	l/hr			l/hr	l/l		
1	Neumühle		2478	1	0.01	1		0.1	0.1	0.25	0.18
2	Schönbrunn, Flour. mine	32.9	1740.9	72000	3941.2	2		98.5	10^{-5}	0.98	0.71
3	Ebersbach			surface water		1		2			
4	BE Marienquelle I	10.8	3331.1	38.4	53.5	1		6	0.156	2.22	1.61
5	Marienquelle III	10.6	1564.1	504	368.1	1		0.1	0.0002		
6	Moritzquelle	9.9	2373.1	400	410.3	1		34	0.085		
7	Sprudel I	11.0	1169.7	pumped			(1)	0.1		2.31	1.67
8	Sprudel II	8.9	447.3	pumped							
9	Sprudel III	11.35	494.7	pumped		1		1			
10	Sprudel IV	9.1	317.5	pumped		1		0.1		2.88	2.08
11	Doubrava	8.3	3860.9	33.5	207.6	1		0.4	0.0025	1.76	1.27
12	Dolní Paseky	7.8	4290.2	72.0	93.8	1		2.8	0.039	2.30	1.66
13	BB Schillerquelle	12.9	1408.7	75.0	111.3	1		88	1.17		
14	Eisenquelle	7.4	994.9	260.0	431.7	1		24	0.092	2.69	1.94
15	Unt. Grenzquelle	10.2	1150.3	173.6	127.2		(1)	0.05		2.67	1.93
16	Ob. Grenzquelle	9.6	1840.1	347.2	475.1		(1)	0.1		3.19	2.30
17	Hennebach	7.7	1218.4	30.0	23.5	1		0.03	0.001	3.24	2.34
18	Plesná, Smrčina	8.7	228.8	500.0	538.9	12		144	0.29	2.35	1.7
19	Schönberg	6.5	3287.3	35.1	62.3	1		7	0.20	2.54	1.83
20	Frant. Lázně, Kostelní	12.1	3098.5	8600.0	12522.2		(1)	>2500	>0.25	2.99	2.16
21	Kopanina	8.1	126.5	72.0	67.9	1	(1)	0.6	0.0083	5.95	4.30
22	Dolní Částkov	7.3	738.0	gas without water		1	(1)	4000		3.57	2.58
23	Bublák/Vackovec	14.3	77.6	mofettes		15	(22)	28000		6.93	5.01
24	Hartoušov	9.4	285.7	mofettes		2	(6)	6000		3.30	2.38
	Hartoušov, kyselka	8.2				3		425			
25	Děvín	8.7	110.6	mofettes		2		760			
26	Soos, mofettes	13.9	5407.1	mofettes		12	(31)	21100			
27	Soos, Cisařský pramen	17.1	5601.0	2520.0	4566.9	8	(2)	7600	3.02	4.75	3.43
28	Soos, Vera	8.0	184.0			5	(2)	6540			
29	Kyselecký Hamr	8.3	2543.6	290.0	467.9	1		402	1.39	4.77	3.45
30	Brtná, village	8.7	496.6	36.0	47.6	3		123	3.42		
31	Brtná, viaduct	8.4	577.1	72.0	96.4	1		404	5.61	3.33	2.41
32	Poustka	8.8	606.4	360.0	506.0	1	(1)	110	0.31	3.18	2.29
33	Podlesí, Radionka	7.5	4053.7	69.2	138.5	1	(3)	11	0.15	1.51	1.1
34	Jedlová	7.2	2270.9	337.2	664.4	1		36	0.11	2.51	1.82
35	Panský vrch	7.5	177.9	361.9	328.5	1		10.4	0.029	3.34	2.41
36	Skelné hutě	9.3	1224.0	400.0	392.4	14	(4)	84.4	0.21	2.73	1.97
37	Tachov, alej minerálka	7.9	1210.7	pumped		1		60		2.50	1.81
38	Prameny, kyselka	6.9	429.7	810.0	1014.5	1		11.2	0.014		4.87*
39	Prameny, mofettes		241.4	mofettes		6		800			
40	Nová Ves			gas spurts in pond			(>500)	8000		6.37	4.6
	Nová Ves, kyselka	6.8				1		40			

#	Locality, spring	Water			Gas flux				Gas/water	He isotope ratio	
		T	TDS	discharge	Disolved in vater $CO_2+HCO_3^-$	Gaseous phase number of escape points measur.	(estim.)		ratio	$^3He/^4He$ x10^{-6}	R/R_a
		°C	mg/l	l/hr	l/hr			l/hr	l/l		
41	Louka, Grünska kyselka	8.4	1920.1	290.0	476.5	1		0.1		6.18	4.46
42	ML Farská kyselka	6.5	444.4	1166.0	1687.0	6		149	0.128	5.45	3.94
43	Smraďoch	9.3	641.6	mofettes		18	(~170)	5200		4.85	3.51
44	Křížový pramen III	8.8	9487.9	72.0	179.4	1		135.6	1.88		
45	Ferdinand II	10.0	9476.0	1440.0	3196.8	1		8240	5.72	5.25	3.79
46	Mariiny		129.2	mofettes		6		87000		6.54	4.73
47	Vlčí	6.9	1422.6	184.0	274.1	2		11.5	0.063		
48	Sirňák, Podhorní vrch	11.1		mofettes		7	(~190)	3800		4.62	3.34
49	Martinov, Horká	7.0	948.7	90.0	141.9	3	(5)	6.3	0.07		
50	Chotěnov, Koňský pramen	7.6	1153.1	171.1	244.1	1		4.1	0.024	4.53	3.27
51	Dolni Kramolin, Ilsano	7.4	532.7	324.0	461.5	1		164	0.51	3.63	2.63
	Milhostov, mofettes						(5)	1000			
52	Čiperka, Michalovy Hory	9.2	1536.3	663.0	1142.1	2		396	0.60	4.60	3.32
	Čiperka, gas spurts in creek					5	(49)	300			
53	Čihaná, HJ 3 a. spring field	9.4	938.0	445	193	2	(~ 60)	1290	2.9	2.33	1.69
54	Čihaná, kyselka a. well	8.0	1175.3			2	(1)	772			
	Čihaná, HJ 1 a. spring field					6	(~ 40)	801			
55	Hoštěk	7.3	1899.6	1800.0	2759.3	1		210		5.67	4.09
56	Otročin	5.9	1927.7	282.7	533.9	1		72	0.25	6.03	4.36
57	Poseč	6.2	653.9			1		0.5		0.91	0.66
58	Dobra Voda	8.5	1318.0			1		1.2		3.33	2.40
59	Beranovka	9.2	1067.0	360.0	485.1	2		7.1	0.02	3.55	2.56
60	Pěkovice		916.7			1		1			
61	Křepkovice	7.7	405.3	200.7	218.0	1		3.6	0.018	3.24	2.34
62	Nezdice	8.3	634.0	257.4	393.2	1		5.6	0.02		
63	Zahrádka	8.7	766.9	278.2	402.2	1		50.8	0.18		
64	Hanov	8.6	678.7	195.4	203.0	1		24	0.12		
65	Zhořec		724.4	gas spurts in creek		4	(8)	10.2		3.30	2.39
66	Úterý	7.9	665.7	294.5	277.8	1		1.7	0.006		
67	Křivce	7.9	559.1	428.3	457.2	1		10.5	0.025	2.47	1.78
68	Konstantinovy Lázně Prusíkův pr.	9.2	882.1	pumped		1		2130		3.90	2.82
69	Poloučany, Kozi vrch	8.8	1444.7	84.0	157.4	1		0.04	0.0005		
70	Kokašice, Luční	8.1	419.2	108.0	132.8	1		48	0.44	4.03	2.91
71	Břetislav, Čeliv creek	6.1	638.1	gas spurts in creek		11	(7)	430			
72	Břetislav, kyselka.	13.0	872.5	163.9	204.8	1		6.5	0.04	3.88	2.80
73	Břetislav, Na Hadovce	7.7	945.4	43.2	64.2	5	(6)	12	0.28	2.63	1.90
74	Horské Domky, Tripisty	8.4	943.8			1		0.03		1.82	1.31

BE - Bad Elster, BB - Bad Brambach, ML - Mariánské Lázně
* data from O'Nions et al. (1989); TDS after Kolářová and Myslil (1979) and own data

Basin, which were discovered in 1898 (Kolářová - Myslil 1979), are pumped to the surface by brown coal mining. Initiated by the pressure release of these waters, the CO_2 liberation in bore holes in the brown coal mines is 360 m^3/hr (T. Vylita 1997). Natural mineral springs have not existed (Laube 1884).

The greater the distance from the gas escape centres, the lower the liberated quantities of free gas. The gas flux remove is about 1 l/hr, and in some cases is as low as 30-40 ml/hr in the springs of the margin areas around the centres.

In the southern part of the Cheb Basin and to the south of the Sokolov Basin, a zone without CO_2 escaping and also without mineral springs can be established between two WSW-ENE striking lines (Fig. 3). There are no known occurrences of mineral springs south of the Tršnice-Nebanice-Pochlovice line. South of the Cheb Basin, this CO_2-free zone is restricted by the reoccurrence of mineral springs with gas flux mostly of 400-8000 l/hr. The southern limit of the CO_2-free zone shifts and therefore widens this zone to the east of the Mariánské Lázně deep fault and the Horní Slavkov deep fault in a southerly and south-easterly direction respectively.

The gas flux measured in these four gas escape centres and estimated for the inaccessible springs in the spas (Table 4) amounts to more than 606 m^3/hr of free gas. Including the dissolved CO_2 and the CO_2 fixed as HCO_3^- - and including the data of non-investigated mineral springs and springs without gaseous CO_2 (Myslil - Václ 1966, Kolářová - Myslil 1979, Egerter et al. 1984, Nevoral et al. 1989, Vylita 1997) - the entire CO_2 flux (natural flux) is recorded at approximately 928 m^3/hr (Table 5). These are the minimal estimates. By pressure release caused by bore holes or mining, as for example in the Sokolov Basin (360 m^3/hr free gas and 180 m^3/hr dissolved CO_2, Vylita 1997) these values can increase.

Table 4. Estimations of gas flux (gaseous phase) of inaccessible mineral springs in north-west Bohemia and Vogtland

Locality, spring	(estimations)	Gasflux gaseous phase l/hr
Sohl,	Hofquelle	60
	Urquelle	80
	Sachsenquelle	60
Plesná,	Smrčina II	30
Františkovy Lázně,	Sluneční pramen	50
	Františkův pramen	2000
	Glauber III	2000
	Glauber IV	500
	Nový pramen	100
	Adlerův pramen	8000
	Luční pramen	150
	Cartellieri	100
	gas spurts in Slatinný creek	500
Tršnice		0.5
Hluboká		20
Mariánské Lázně,	Lesní pramen	2000
	Balbínův pramen	3000
	Křížový pramen IV	140
	Ambrož pramen II	150
	Ferdinand I	2000
Hoštěk, II		30
Jankovice,	Orioha	60

Table 5. Estimation of the total CO_2 flux (natural flux) in the western part of the Eger Rift (gaseous phase, dissolved CO_2 and fixed HCO_3^- discharged in water)
Minimal values, including estimations of free gases and data of dissolved and fixed CO_2 in all mineral springs in the spas of Františkovy Lázně, Mariánské Lázně and Karlovy Vary (not listed in Table 3), and including the mineral springs without free gases; data from Myslil - Václ (1966), Kolářová - Myslil (1979), Egerter et al. (1984), Nevoral et al. (1989), B. Vylita (1991) and T. Vylita (1997)

Region	CO_2 Gas flux		
	free CO_2 (l/hr)	CO_2 in water (l/hr)	total (l/hr)
South Vogtland	360	5 980	6 340
Cheb Basin	90 720	69 020	159 740
only Františkovy Lázně	*15 900*	*62 850*	*78 750*
Mariánské Lázně-Teplá region	156 240	69 900	226 140
only Mariánské Lázně	*109 130*	*47 460*	*156 590*
west Mariánské Lázně fault	*1 190*	*6 900*	*8 090*
Čihaná	*2 690*	*1 660*	*4 350*
Konstantinovy Lázně region	2 670	2 050	4 720
Karlovy Vary region	356 400	174 760	531 160
only Kyselka		*6 820*	*6 820*
total (l/hr)	606 390	321 710	928 100
total (m^3/a)	5 311 980	2 818 210	8 130 190

A complete measuring of the liberated gas flux in the investigation area (mainly CO_2) is not possible due to the large amount of gas spurts and lack of access to the balneologically used mineral springs in the spas. Furthermore, gas liberation is not connected exclusively to mineral springs. The measurement and estimation of the gas flux is only possible in the presence of water. Without water and vegetation cover, small gas spurts cannot be located. Therefore no measurements can be made on dry gas vents in forest soil, e.g. the mofettes of Milhostov (Wieser 1990).

Deep-seated gases are, however, to be expected generally in the soil air above faults (Ernst 1968, Dikun et al. 1975, Sugisaki et al. 1980). Further gas spurts are expected in the surrounding area of the gas-rich mineral springs and mofettes. These become visible at higher water levels, e.g. in the Soos and Bad Brambach (Witte 1926). At mineral springs situated in close proximity to creeks, the gas spurts can be observed along the creeks or faults, often for a distance of 50 m (e.g. in Slatinný creek, Vonšovský creek, Plesná river in the Cheb Basin; Kosí creek at Dolní Kramolín, Pramenský creek near Mariánské Lázně, Hadovka and Čelivský creek near Konstantinovy Lázně). The CO_2 discharge in the ground waters (subsurface and in creeks and rivers) is impossible to be measured and cannot even be estimated.

4.2. *Distribution pattern of gas composition*

The highest CO_2 content of > 99 vol. % in free gases can only be detected in the four gas escape centres and at the southern boundary of the CO_2-free zone south of the Cheb Basin. As the gas flux decreases, the CO_2 content also decreases with a corresponding increase in the N_2 content. In the margin areas of the gas escape centres, the N_2 content is between 10 and 40 vol. % (Fig. 3).

This trend is most distinct in the north of the Cheb Basin in southern Vogtland, where an almost continuous change from almost pure CO_2 gases in the Cheb Basin, to gases with 3-42 vol. % N_2 in the area around Bad Elster and to almost pure nitrogen gases in the Schönbrunn fluorite mine (Weinlich 1989) can be observed. To the south of the Eger Rift, in the surrounding area of Mariánské Lázně, this trend is also recognizable. A very high CO_2 content (> 99 vol. %) is connected here - beside the narrow zone lying directly south of the Cheb Basin - to the gases of the mineral springs of Mariánské Lázně and to the area east of the Mariánské Lázně deep fault.

To the west of the fault zone, the N_2 content in the investigated spring gases (Skelné Hutě, Panský vrch, # 36, 35) increases very rapidly to up to 12 vol. %. At a greater distance from Mariánské Lázně, the N_2 content in the gases of the western Bohemian uranium mines mostly

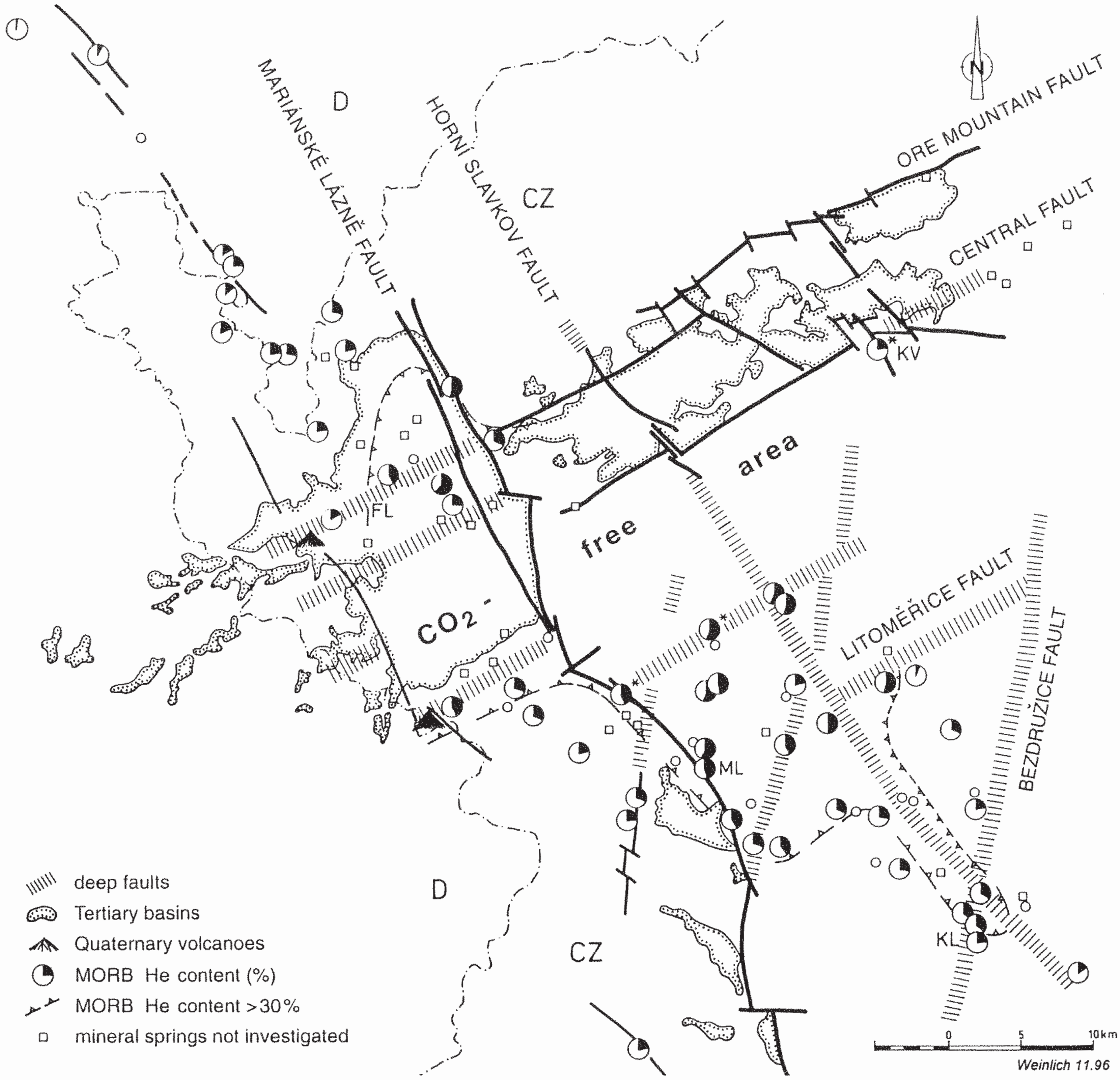

Fig. 4. Distribution pattern of mantle derived He proportions in gases in mineral springs and mofettes in the region of the western Eger Rift
Gas escape centres: Františkovy Lázně (FL)/Cheb Basin, Mariánské Lázně (ML), Konstantinovy Lázně (KL) and Karlovy Vary (KV)
He data is given as proportion MORB-He: R/R_a MORB = 8 and crust R/R_a= 0.02
* data from O'Nions et al. (1989)

reaches values of > 90 vol. %, with a methane content of 3-12 vol. % (Markovič 1979). In the uranium mine Vítkov II, the N_2-rich gases found in various underground wells are connected to warm Ca-Na-Cl-(SO_4) brines with a temperature of up to 28 °C. The liberated gas quantities range between 27 l/hr and - initially only - 360 l/hr. This gas and water composition is similar to the fluids in the KTB bore hole in the Oberpfalz, Germany (67 vol. % N_2 and 32 vol.% CH_4 and a Ca-Na-Cl type water; Heinschild 1990, Lodemann 1992). Near Tachov, isolated from the mineral springs in the Mariánské Lázně area, approximately 5 km SE of the uranium mine Vítkov II, in the mineral spring Alej mineralka (# 37), spring gases occur with 99.8 vol. % CO_2 (60 l/hr). As there is no evidence of mixtures of CO_2 and N_2 in uranium mine gases, the existence of non-communicating fracture systems must be assumed.

To the east of Mariánské Lázně, the same distribution pattern emerges visibly. With increasing distance from the gas escape centres, the N_2 content increases here to the east to 24 vol. % (Úterý, Křivce; # 66, 67). Once again, gases with 99.6-99.9 vol. % CO_2, connected with higher gas flux, occur in a smaller area around Konstantinovy Lázně. The Konstantinovy Lázně gas escape centre is separated from the Mariánské Lázně centre by mineral springs with higher N_2 contents of 1.5-3 vol. % in the spring gases (Křepkovice, Zahrádka and Zhořec; # 61, 63, 65). SE of Konstantinovy Lázně the CO_2 contents decrease again while N_2 increases to 3-4 vol. % (Kozí vrch, Břetislav; # 69, 71) even within the 3 km distance. The most southern mineral spring (Horské Domky at Trpisty; # 74) contains 33 vol. % N_2.

Along the NE flank of the Mariánské Lázně gas escape centre, gases without increased N_2 contents occur, in contrast to the southern and eastern limits. The gas flux ends abruptly without changes in composition.

We did not investigate the mineral springs of Karlovy Vary and the thermal water inflow in the Solokov Basin. Krajča (in Kolářová and Myslil 1979) reported CO_2 contents higher than 99 vol. % (air-free) for these gases. An increase of the N_2 contents to the East is indicated by 6 vol. % N_2 (air-free) in the gas of the Ottův spring in Kyselka.

4.3. *$^3He/^4He$ in free gases*

The distribution pattern of the R/R_a values (Table 3) is congruent with the gas composition (Fig. 4).

In the mofettes and gas-rich springs in the Cheb Basin, the R/R_a values ranging from 2.16 to 5.0 demonstrate high proportions of mantle derived components. Towards the north, the mantle derived helium proportions decrease to R/R_a 1.93-2.34 in Bad Brambach and R/R_a 1.67-2.08 in Bad Elster. The lowest R/R_a values were measured in Schönbrunn and Neumühle (# 2 and # 1) with 0.71 and 0.18 respectively.

To the south of the Eger Rift, the occurrence of high R/R_a values is restricted to the Mariánské Lázně gas escape centre. The highest values were measured in Mariánské Lázně (# 42-46), Grünská Kyselka (# 41) and in Otročin (# 56) with R/R_a 4.36-4.73. Similarly high values were reported in Prameny (4.87), the mofettes of Smrad'och (4.69) and Kynžvart (3.8) by O'Nions et al. (1989). Outside the Mariánské Lázně gas escape centre, high R/R_a equal to 3.45 were measured in the gas of Kyselecký Hamr (# 29) near Železná Hůrka. Increased R/R_a values of 2.8-2.9 also occur in the comparatively small Konstantinovy Lázně gas escape centre, in contrast to the surrounding area.

The R/R_a values decrease in the spring gases in proportion to the distance from the gas escape centres (Fig. 4) in a similar pattern as the described gas flux and gas composition pattern. Nevertheless the range between R/R_a 1.8 and 2.3 in the margin areas is still above the values for crustal helium (R/R_a 0.02). The lowest R/R_a values from the southern part of the investigated area were detected in Poseč (# 57) with 0.66 and Horské Domky (# 74) with 1.31.

5. Discussion

5.1. *Geochemistry of the gases*

High R/R_a values and isotopically heavy CO_2 with $\delta^{13}C$ values between -1.8 and -3.2 ‰ (Pačes 1974, 1987, Weinlich et al., 1998) demonstrate the magmatic origin of the gases in the western part of the Eger Rift. The highest mantle derived He proportions are bound to the main gas escape centres with a large gas flux of almost pure CO_2.

With increasing distance from the gas ascent centres, the CO_2 contents in the free gas phase decrease in connection with the gas flux (Fig. 5). In the CO_2-rich gases of the mofettes in the Cheb Basin and Mariánské Lázně, with a high gas flux, approximately 6 to 30 l/hr N_2 is liberated (assuming in Mariánské Lázně the same gas composition in the Mariiny mofette and Ferdinadův spring). However, in the mineral springs of the marginal areas with the higher N_2 contents in the gas phase, only approximately 0.1 to 2 l/hr N_2 (air-free) escapes. The absolute N_2 flux (air-free) is higher in the gas escape centres than in the margin areas, therefore the increase of the N_2 contents in the gas phase cannot be explained as an admixture of metamorphic N_2. The relative enrichment of N_2 (+ inerts) is rather a result of a fractionation of the gas composition with an increase in migration paths (Weinlich et al. 1997).

The distribution of a gas *i* in the gas phase and aqueous phase is governed by Henry's law and can be described by a solubility equilibration model (Zartmann et al. 1961, Bosch and Mazor 1988, Ballentine et al. 1991). The number of moles of *i* in the gas phase $[i]_g$, is related to the volumes of water and gas V_w and V_g by:

$$[i]_g = [i]_{total}/[(V_w/V_g K_i) + 1]$$

where $[i]_{total}$ is the total number of moles *i* in the system. The ratio of a gas *i* relative to CO_2 in the gas phase is related to the ratio in water, the gas water ratio and the solu-

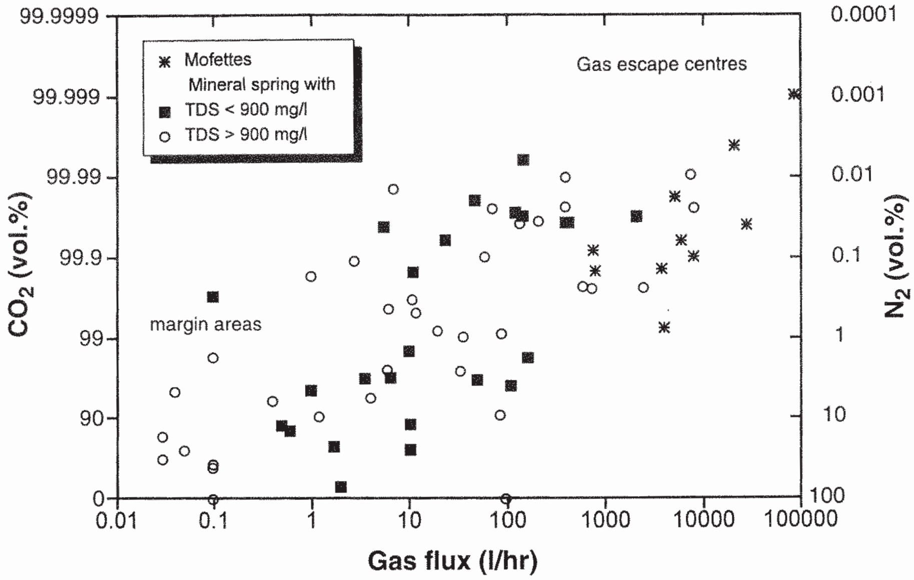

Fig. 5. Decreasing of the CO_2 contents of the gases with the gas flux in mineral springs and mofettes in the western part of the Eger Rift with increasing distance from the gas escape centres

CO_2 shown as 100-CO_2, balance to 100 vol.% N_2 (air-free) and traces of He and hydrocarbons; TDS according to Kolářová and Myslil, 1979 and own data; correlation coefficient < 900 mg/l TDS - 0.81; > 900 mg/l TDS - 0.69 (without gases of N_2 content = 0)

The scattering is caused by the existence of springs with low gas flux and almost pure CO_2 in the gas escape centres. With the splitting of the CO_2 saturated waters near to the surface, larger and smaller gas escapes can occur next to each other, with unchanged ± identical gases. By a deep splitting of the gas-water flow transported on the faults, the migration paths and durations to the surface are correspondingly longer. The CO_2 removal by solution and the fractionation are therefore more distinct. In the margin areas with low gas flux, the mineralization of the waters can play an additional role, because the salinity gradually reduces the gas solubilities. The analytical errors in the case of CO_2 contents > 99.99 vol. % play additional role

bilities defined by the Henry's law coefficient K_i by:

$(i/CO_2)_g = (i/CO_2)_w [V_g/V_w + (K_{CO2})^{-1}]/[V_g/V_w + (K_i)^{-1}]$.

In the cases of the limit as $V_g/V_w \rightarrow \infty$, then $(i/CO_2)_g \rightarrow (i/CO_2)_w$ and as $V_g/V_w \rightarrow 0$, then $(i/CO_2)_g \rightarrow (i/CO_2)_w \cdot (K_i/K_{CO2})$. Thus the ratio of gas (mainly CO_2) and water controls the gas composition.

As shown by the plots of gas flux vs. CO_2 content in the gas phase in Fig. 5, correlations exist between gas flux and gas composition. With the decreasing gas flux the CO_2 contents decrease and the N_2 (+ inert) contents increase in the gas phase. This is consistent with the distribution pattern of the gases.

No fractionation of the gas composition is detectable in the mofettes of the gas escape centres with almost pure CO_2. Due to the generally high gas flux in the gas escape centres, the mineral waters are completely saturated with CO_2 (2300-3000 mg/l). Corresponding to the high CO_2 partial pressure and gas water ratios mostly of > 0.5 to 6 l/l in the mineral springs, the exsolved gas phase is also CO_2-rich. Therefore, in the areas with complete CO_2 saturation, gases in mineral springs with low gas flux are also CO_2-rich.

The case is different in the margin areas of gas escape centres. With lower gas flux the gas water ratios of 0.01-0.1 l free gas/l water are significantly lower and the waters contain less dissolved CO_2 (1200-1700 mg/l). In many cases the increase in N_2 contents, caused by the CO_2 loss by increased HCO_3^- fixing, leads to an exceeding of the saturation pressure and therefore to gas liberation. The result is the fractionation of the exsolved gas phase. The effect

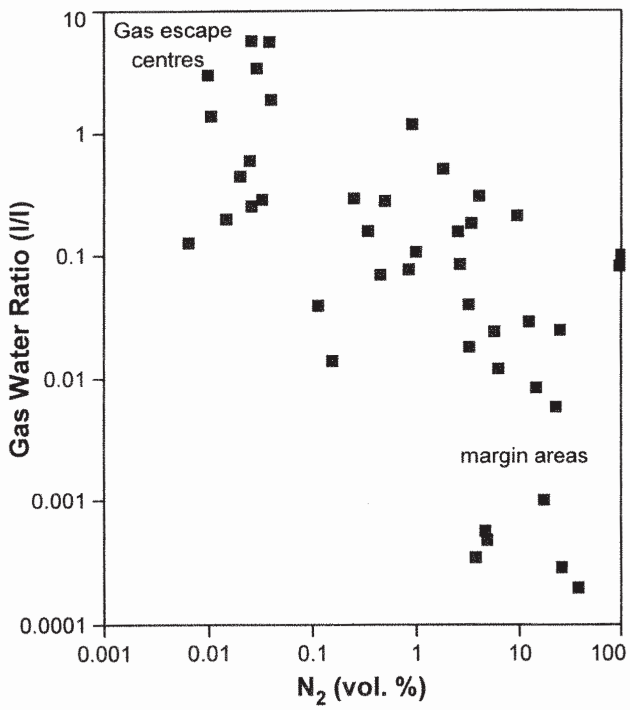

Fig. 6. Increasing of the N_2 (air-free) contents in the gases with decreasing of the free gas-water ratio by increased fractionation of the gases. A scattering is inevitable, because the varying air proportions in the spring gases by different partial pressures influence the saturation pressure of the gas-water systems

of fractionation is thus larger, the lower the volume of the free gas phase is in relation to the aqueous phase (Zartmann et al. 1961, Bosch and Mazor 1988, Ballentine et al. 1991). Corresponding to the solubilities of the individual gas components in the aqueous phase by the exsolution of smaller gas volumes, the gas components with the lowest solubilities in the aqueous phase are enriched in the gas phase. This process is well known in the behaviour of hydrocarbon systems as the differential liberation of free gases (Dodson et al. 1953, Amyx et al. 1960, Jacobson 1967). The plot of N_2 vs. gas-water ratios shows (Fig. 6) the dependence of the N_2 (air-free) content in the free gas phase on the gas-water ratios.

The relative increase of N_2 content in the gases of the margin areas is a result of the fractionation and a consequence of the CO_2 removal by CO_2 solution and HCO_3^- formation with longer migration paths. This gives no evidence of increased crustal proportions in the gases or of N_2 addition. The low contents of hydrocarbons in the gases are also no evidence for crustal proportions, because small contents of hydrocarbons are also contained in volcanic gases of Iceland (Arnorsson and Barnes 1983, Armannsson et al. 1989).

With these tools, the gas flux distribution and the gas fractionation at longer migrations path from the gas escape centres, an analysis of the tectonic structure is possible.

5.2. *Gas migration and tectonic structure*

In distribution patterns of gases in crystalline basement complexes, the model of an anisotropic fracture reservoir must be assumed, which is different from the isotropic pore reservoirs of sediment basins. This complicates the presentation of the distribution pattern of gas components. The gas (and water) migration in crystalline basement is bound on the higher fracture permeabilities of the fault. This allows the interpretation of the tectonic structure using gas flux measurements, combined with the changes of the gas composition. The regional distribution pattern of gas flux thus indicates many features of the tectonic structure of the western Eger Rift.

In the Cheb Basin, the mineral springs normally escape along the NNW-SSE striking secondary faults with a slight fault throw, which run parallel to the Mariánské Lázně fault zone. This distribution pattern was described by Kolářová and Myslil (1979) and Egerter et al. (1984).

The occurrences of the CO_2-rich mofettes and the most gas-rich mineral springs in the Cheb Basin in Horní Častkov, Bublák near Vackovec, Hartoušov, Soos and Františkovy Lázně are arranged differently to the mineral spring lines in a WSW-ENE striking narrow zone (Kolářová 1965, Pačes 1974). The northern limit of this zone corresponds to the extension to the Ore Mountain fault (Fig. 3). In this zone, within the Cheb Basin, there are also bound accumulations of gas in the Tertiary sediments, resulting in large gas eruptions in brown coal exploration wells in 1957 near Františkovy Lázně (well H-11) (Kolářová 1965). From this zone outwards, the gases such as in Františkovy Lázně or in Bublák and Hartoušov are obviously only distributed by NNW-SSE striking faults in the area near to the surface. The gas flux distribution in the Cheb Basin thus obviously documents the continuation of the Ore Mountain fault in a western direction beneath the Cheb Basin and its good permeability for fluids west of the Mariánské Lázně fault zone.

In the zone with the greatest gas flux in the Cheb Basin, there are the highest Na_2SO_4 contents of the waters bound to the Cheb Basin (Kolářová 1965), i.e. the highest deep water proportions (Pačes 1987). As shown in Fig. 7, there is a connection between gas flux and water chemistry. A greater Na_2SO_4 content in the mineral waters is connected in general to a greater gas flux in the western part

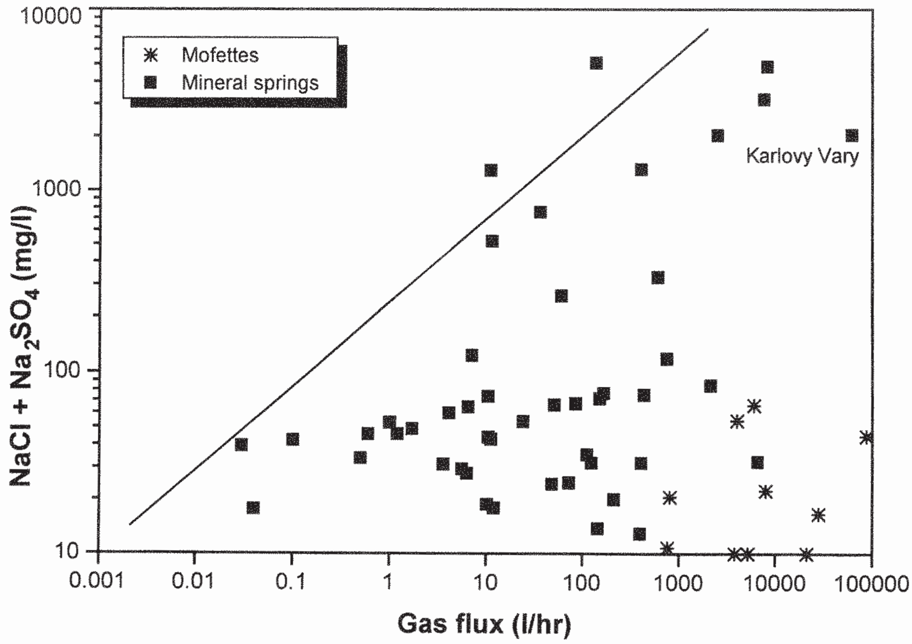

Fig. 7. Relationship between the gas flux and the NaCl and Na_2SO_4-contents; proportions of the deep saline water of the Bohemian Massif (Pačes 1987) in the mineral waters in the surrounding area of the western Eger Rift: the gas flux is independent from the mineralisation of the waters; but as a result of gas lift larger NaCl + Na_2SO_4-contents are connected with high gas flux

of the Eger Rift. This means that the magmatic gas - (CO_2) - flux in the form of a gas lift supports the ascent of more highly mineralised deep waters. This assumption is supported by the fact that in the Cheb Basin and Mariánské Lázně the waters of the mineral springs with a higher gas flux tend to be warmer than those with a lower gas flux.

No mineral springs exist east of the Mariánské Lázně deep fault, apart from some springs situated in close proximity to the deep fault. According to Hurník and Havlena (1984), the Ore mountain fault on the northern edge of the North Bohemian brown coal basin has the character of a flexure with only secondary fracturing, so it obviously prevents the migration of mineral water and gases to this structure line.

In the southern part of the Cheb Basin, south of the WSW-ENE striking line Tršnice-Nebanice-Pochlovice (*a-c*, Fig. 1), a significant zone without CO_2 and therefore without mineral springs was found. Any references to mineral springs which have dried up or have become overflooded by the Cheb dam lake do not exist there either (Laube 1884, Jahnel 1937, Dietl 1942). The absence of CO_2 cannot be attributed to covering clay layers, because no inflows of CO_2-bearing water could be detected in wells existing in this area (Kolářová 1965).

The southern boundary of this CO_2-free zone is formed by the reoccurrence of the following mineral springs: Kyselecký Hamr (# 29), Palič, Salajna, Ždírnice (*e-g*) and Podlesi (# 33). They are aligned along a WSW-ENE striking line at the southern edge of the Cheb Basin. These mineral springs also have increased gas flux - partly up to 400 l/hr - of almost pure CO_2. In the same way, increased proportions of Na_2SO_4 of approximately 810-880 mg/l (2500-4000 mg/l TDS) occur in the mineral springs of Kyselecký Hamr and Podlesi, indicating higher deep water proportions.

In the gas escape centre around Mariánské Lázně, the largest gas fluxes released in mineral springs and mofettes (Mariánské Lázně, Farská kyselka, Smraďoch, Sirňák, Čihaná) with the highest CO_2 content are restricted to the area east of the NNW-SSE striking Mariánské Lázně deep fault.

To the west of the Mariánské Lázně fault zone, no larger gas fluxes can be detected. The N_2 content also partly increases to over 10 vol. %. It is therefore obvious, that the Mariánské Lázně deep fault does actually distribute the mineral waters and gases; but presents, however, a barrier towards the west for the gas fluxes from greater depths, and so tectonically controls the gas migration.

The WSW-ENE striking CO_2-free zone established in the Cheb Basin is clearly shifted to the SE and widens east of the Mariánské Lázně deep fault (Fig. 3). In the north, the spread of CO_2 in the Sokolov Basin is more extensive towards the SE than in the Cheb Basin. The Šabina mineral spring (*d* in Fig. 1) which lies on the Central fault, and further east the springs at Karlovy Vary and Kyselka (*j*) are clearly shifted to the SE compared to the most southern mineral springs in the Cheb Basin.

In the same manner, on the southern limits of the CO_2-free zone to the east of the Mariánské Lázně deep fault, the CO_2 escapes and therefore the mineral springs do not occur until the Kynžvart (*h*), Prameny (# 38, 39), Nová Ves (# 40) line, being shifted towards the SE. At the Horní Slavkov deep fault (Fig. 3), as is indicated by the location of the springs at Brť (*i*), Otročín (# 55) and Poseč (# 56), this southern boundary of the gas-free zone is limited and again shifted to the SE.

The gases of the mineral springs at the northern edge of the gas escape centre in the east of Mariánské Lázně are as CO_2-rich as those in the south of the Cheb Basin. They have large gas fluxes of up to 8 m^3/hr. With increased mantle helium proportions, these gases are no different to the unmodified magmatic gases in the Cheb Basin and in Mariánské Lázně. In contrast to the continuous changes in the south and east, there are no recognisable gas fractionations. The gas flux terminates abruptly at the northern edge of the gas escape centre of Mariánské Lázně, which indicates a tectonic restriction of the CO_2 migration.

The absence of CO_2 in the gas-free zone is also demonstrated by the fact that no CO_2 escapes, not even by the pressure release of the waters, in the tin mines in Horní Slavkov, only 10 km SSW of Karlovy Vary. In contrast, mines in Prameny (see Fig. 3) had to be shut down due to CO_2 blow-outs (Laube 1884).

The existence of the CO_2-free zone can be explained by the deep tectonic structure of the Eger Rift (Kopecký 1979, Šťovíčková 1980, Conrad et al. 1983). The opposite dip of the Litoměřice deep fault to the north and the Central fault (of the České středohoři Mts.) and the Ore Mountain Master Fault to the south leads to the tectonic shielding of this area by the outwardly directed permeability paths of the faults with the formation of the Y-shaped structure of the Eger Rift (Fig. 8). This leads to an absence of the CO_2 flux. Accordingly, the gas-rich mineral springs at the boundaries of the CO_2-free zone reflect the course of the main deep faults of the Eger Rift.

In the north of the CO_2-free zone, CO_2-rich gases in the Sokolov Basin and the Karlovy Vary region only occur in the area between the Central fault and the Ore Mountain fault. The course of the Central fault and the Ore Mountain fault without Tertiary cover is mapped. In the Cheb Basin, as described, the course of the Ore Mountain fault beneath sediments of the Cheb Basin can be followed further to the SW with the northern edge of the zone characterized by the highest gas fluxes. The southern boundary of the CO_2 occurrences in the Cheb Basin can be explained by the continuation of the Central fault.

The line of gas-rich mineral springs at the southern boundary of the CO_2-free zone obviously indicates the course of the Litoměřice deep fault. The course of the Litoměřice deep fault to the north of Mariánské Lázně is only indicated by a shift of the N-S directed river bed of the Teplá river near Bečov in the geological surface picture.

The detected course of the Litoměřice deep fault, using the gas distribution south of the CO_2-free zone, shows in

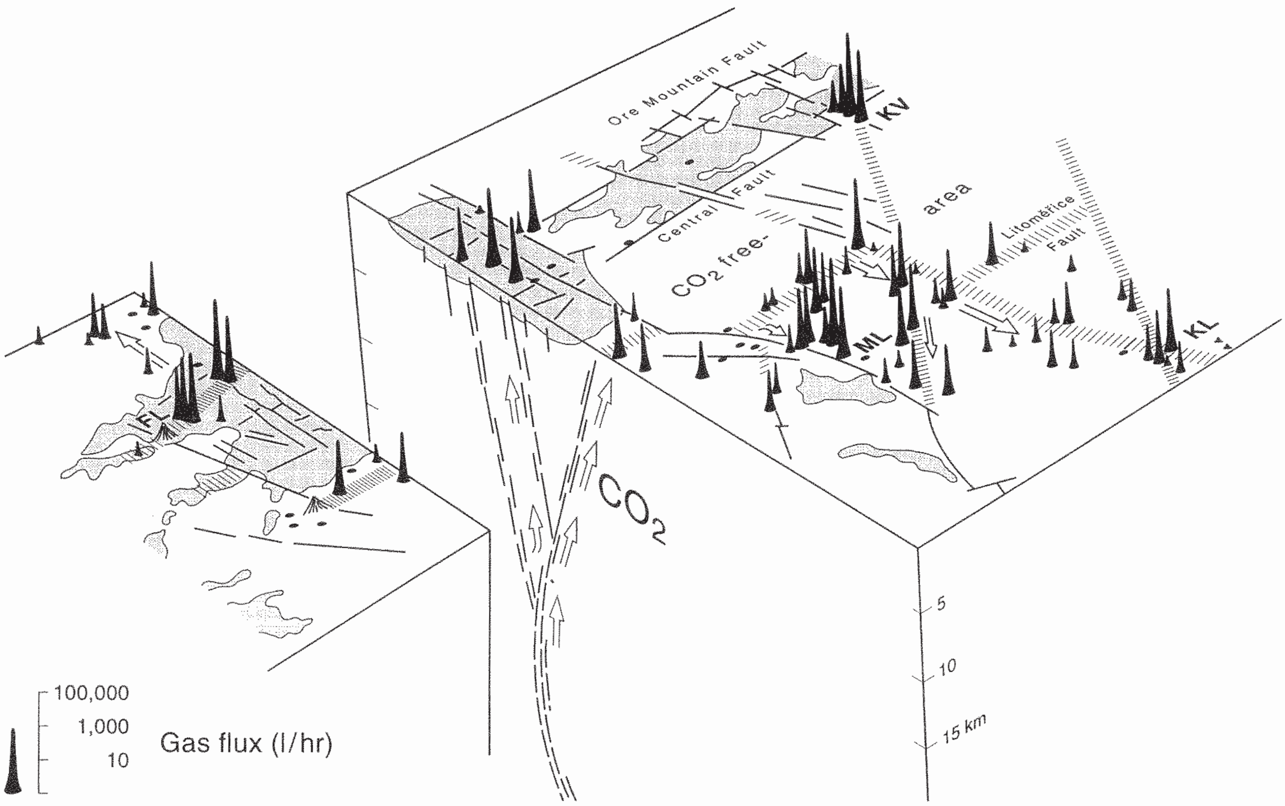

Fig. 8. Gas flux and tectonic structure of the western Eger Rift
Splitting of the magmatic gas flux by the Y-shaped structure by the main faults of the Eger Rift and forming of the central CO_2-free zone

the western part of the Eger Rift (Fig. 3) - with the clear shifts of this deep fault by the NNW-SSE striking faults of Mariánské Lázně and Horní Slavkov - the narrowing of the Eger Rift towards the west. The shifting to the north of the western blocks is shown in the geological surface pattern as taking place only at a small amount of shifts of the Central fault towards the Horní Slavkov deep fault south of the Sokolov Basin. The positions of the quaternary basalt occurrences of Komorní Hůrka (Kammerbühl) in the area of the main gas escape zone of the Cheb Basin and of Železná Hůrka (Eisenbühl) on the gas escape and mineral spring line south of the Cheb Basin (Fig. 3) prove the deep reach of these elements and thus support their interpretation as main deep faults of the Eger Rift.

With this tectonic distribution pattern, the gas migration from the depths is mainly connected to WSW-ENE striking tectonic elements and to the younger elements striking parallel to the Mariánské Lázně fault zone, which only have a distributive character in the upper levels. The small area with increased gas flux and release of pure CO_2 around Konstantinovy Lázně is thus probably the result of gas migration in a southerly direction along the Horní Slavkov deep fault and of good ascent paths in the area of intersection with the Bezdružice deep fault.

6. Conclusion

The gases in the mineral springs and mofettes (dry CO_2 gas vents) in north-western Bohemia and in the South Vogtland were investigated for gas flux, gas composition and $^3He/^4He$ isotopic ratios. With the almost exhaustive investigation of the gas exhalations in mineral springs and mofettes, four main gas escape centres are detected in the western part of the Eger Rift which are tectonically separated from one another: Františkovy Lázně/Cheb Basin, the area east of Mariánské Lázně, Konstantinovy Lázně and Karlovy Vary. From these centres outwards, the gas flux decreases from partially more than 30 m^3/hr to continuously less than 1 l/hr.

The entire gas flux (natural flux) in the western part of the Eger Rift can be estimated in a first attempt as a minimum of 5.31 million m^3/a free gas; including dissolved CO_2 and HCO_3^- of 8.13 million m^3/a.

The almost pure CO_2 gases of the gas escape centres are isotopically heavy and contain, with R/R_a values of 4-5, high proportions of mantle derived helium. The gas flux decreasing from the gas escape centres towards the margin areas, corresponds with a decrease in CO_2 contents. This change in the gas composition is caused by a gas fractionation by enrichment of N_2 (and inerts) by the preferred CO_2 solution and HCO_3^- formation. The N_2 content in the gas phase increases in the margin areas with only lower gas fluxes and lower gas-water ratios.

Tectonically shielded by the opposite dip of the main Eger Rift faults a gas flux free zone without mineral springs was detected between the gas escape centres of the Cheb Basin and Mariánské Lázně. The WSW-ENE striking Y-shaped structure of the main Eger Rift faults splits the gas flux at a depth of about 15 km and forms this central gas-free zone. Differences in gas composition or in the isotopic composition of He in the gases of the gas escape centres to the north and south of this structure cannot be detected. At the borders of the gas-free zone, unmodified CO_2-rich gases escape with high proportions of mantle derived He. In contrast to the margin areas this demonstrates a tectonic termination of the gas flux. Therefore, the southern border of this gas-free zone can be interpreted as the course of the Litoměřice deep fault. At the younger NNW-SSE striking Horní Slavkov deep fault and the Mariánské Lázně deep fault, the Litoměřice deep fault always shifts to the north-west.

The westward narrowing of the Eger Rift can be identified by the NW shift of the respective western blocks by these NNW-SSE striking younger deep faults. The location of the mineral springs in the Oberpfalz and Oberfranken (Quentin 1970) in Bavaria indicates for Neualbenreuth, Kondrau and Wiesau the prolongation of the Litoměřice deep fault and for Hohenberg and Bad Alexandersbad that of the Ore Mountain fault.

According to this distribution pattern, the gas migration is principally bound to the WSW-ENE striking Eger Rift main faults; the younger NNW-SSE faults striking parallel to the Mariánské Lázně deep fault have only a distributive character in the upper tectonic level, because no gas transport occurs on them in the gas-free zone. The smallest gas escape centre of Konstantinovy Lázně is thus probably the result of gas (and water) migration in a southerly direction along the Horní Slavkov deep fault and of good ascent paths in the area of intersection with the Bezdružice deep fault.

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Distribuce výronů plynů v minerálních pramenech a tektonická struktura západní části ohareckého riftu

Práce předkládá výsledky měření a analýz výronů plynů, jejich složení a poměru $^3He/^4He$ studovaných ve více než 70 minerálních pramenech a mofetách (studených exhalacích suchých plynů) v z. části ohareckého riftu. Regionální distribuce výronů plynů a jejich složení jsou závislé na tektonické struktuře.

Jsou detekována čtyři hlavní centra výronů plynů z části s vydatností větší než 150 m^3/hod. volného plynu: Františkovy Lázně/chebská pánev, Mariánské Lázně, Konstantinovy Lázně a Karlovy Vary. Plyny uvedených center se vyznačují velmi podobným složením, přičemž > 99 obj.% plynu tvoří CO_2. Podíl izotopicky těžkého CO_2 a vysoký podíl helia odvozeného z plášťového zdroje indikují magmatický původ těchto plynů. V důsledku frakcionace plynů rozpouštěním v CO_2 a tvorbou HCO_3^- vzrůstají relativní obsahy N_2 ve směsném plynu směrem k nižším příkonům plynů a k okrajům území. Podle stávajícího odhadu dosahuje příkon přírodních plynů v z. části ohareckého riftu min. 5,31 milionu m^3/rok volného plynu, včetně rozpuštěného CO_2 a HCO_3^- 8,13 milionů m^3/rok.

Protiklonná pozice hlavních zlomů ohareckého riftu tvoří strukturu tvaru písmena Y a rozštěpuje plyny přiváděné z hlubinného zdroje v hloubce přibližně 15 km pod povrchem do dvou pásem s mezilehlou zónou bez významnějšího přívodu CO_2. Hranice této zóny odpovídají hlavnímu ohareckému zlomu a na jihu litoměřickému hlubinnému zlomu. Oharecký rift je posunován na mladších zlomech směru SSZ-JJV a zužuje se směrem k Z.

Migrace plynů magmatického původu je vázána zejména na hlavní zlom ohareckého riftu o směru ZJZ-VSV, kdežto mladší zlomy směru SSZ-JJV mají pouze distributivní funkci. Migrace plynů směrem k J podél hlubinného zlomu Horního Slavkova vytvořila výronové centrum Konstantinovy Lázně, v místě odpovídajícím průsečíku s bezdružickým hlubinným zlomem.