CURIE TEMPERATURES OF THE Fe-Ti OXIDES OF BASALTS: IS IT POSSIBLE TO USE CURIE TEMPERATURES TO ASSESS THE SOURCE OR THE DEPTH OF ORIGIN OF THE Fe-Ti OXIDES AND RELATED BASALT MAGMAS?

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Abstract: The Curie temperatures (T_C) of magnetic Fe-Ti oxides of basalts from 31 localities of Central and Southern Slovakia were measured. Titanomagnetites (TMs) are magnetic minerals in basalts with an ulvospinel content in the range from 30 to 70 %. The results of the laboratory tests proved a specific property of the TMs. They are able to change very easily their previous composition depending on either oxidative or reductive conditions. The original magnetic phases (of low $T_C \leq 300$ °C) have been preserved in most of basalts. We suppose that the original — quasi homogeneous TMs were formed within a "dry magma". The basalts from 19 localities contain two magnetic phases. One of them has the $T_C \leq 300$ °C (it is supposed to be the quasi-primary one), and the second — more oxidized phase ($T_C \leq 490$-610 °C). There are basalts of eight localities containing only one, more oxidized phase ($T_C \leq 538$-600 °C). Fe_3O_4, Fe_2O_3 and other Fe-Ti oxidized products are present in these basalts. These basalts are located near Kysihýbeľ-Kalvária, Šavoľ, Šíd, Konrádovce, Blhovce, Blhovce Buda, Pohanský vrch (most of them are located in the NE part of the Cerová vrchovina Upland). The basalts with only one, more oxidized magnetic phase ($T_C \leq 538$-600 °C) were formed probably from a "wet" (saturated by magmatic water) magma. I tried to assess the depths of the origin of basalt magmas, based on the T_C of the TMs of basalts, applying an idea of Petchersky et al. (1981). (The T_C of the quasi-primary phase — $T_C \leq 300$ °C of the TMs oxides were used). The assessed depths are in the range 35-59 km in Central and Southern Slovakia. Huraiová & Konečný (1993) estimated that xenoliths were uplifted from depths of 35-85 km in Southern Slovakia. Fediuk (in Bucha & Blížkovský et al. 1994) deduced from the evaluated results of thermodynamic calculations that balancing of lherzolite nodules took place at depths of about 50-80 km (i.e. under conditions of the uppermost mantle) — in the north of Bohemia, north of Moravia and south of Slovakia. The upper mantle/lower crust boundary lies ca. 27-29 km (Bezák et al. 1995) and melted asthenospheric material lies in the depth ca. 80-60 km, according to Šefara et al. (in press).

The assessed depths of origin of basalt magmas based on the Curie temperatures of the TMs are compared with the data obtained by other authors. Geological phenomena and physico-chemical conditions have been considered in this contribution, to support or deny an idea for deriving the depth of origin of basalt magmas based on the Curie temperatures of the TMs of the basalts.

Key words: basalts, titanomagnetites, Curie temperatures, depths of origin of basalt magmas.

Introduction

Alkali basalt volcanism in Central and Southern Slovakia was active from the Late Miocene to Quaternary time (Konečný et al. 1995). Effusive forms prevail over the explosive or intrusive products.

Basaltic volcanics come from the area of Central Slovakia (Kalvária Basalt Complex; 8.0-6.6 Ma). The products of Podrečany Basalt Formation, extending on the western part of the Lučenec Basin, are slightly younger, being dated to 7.2-6.4 Ma. The alkali basalts of Cerová Basalt Formation are younger (Pliocene to Quaternary age, dated to 5.43-1.16 Ma, Konečný et al. 1995). Majority of basalts of the Cerová Basalt Formation were activated in the course of the reverse polarity of the geomagnetic field — in the intervals: 2.09-2.48 Ma (minor portion); 0.97-1.65 Ma (dominant portion of basalts, Orlický et al. in press). Cinder cone Putikov vŕšok and related lava flows in Central Slovakia are the youngest products of basaltic activity in Slovakia (0.53 ± 0.16 Ma — K/Ar data; 0.13-0.22 Ma, according to the geological position of the basalts; Konečný et al. 1995).

Recently, the composition, and the Curie temperatures of the magnetic minerals of basalts were sudied by Nairn (1966), Kropáček et al. (1981), Orlický et al. (1982, 1992, in press). The main magnetic minerals of basalts from Central and Southern Slovakia are the titanomagnetites (TMs) — $Fe_{3-x}Ti_xO_4$, with the compositional parameter x ≈ 0.3-0.7, according to Orlický et al. 1992. While there is quite comprehensive knowledge about the evolution of the Neogene-Quaternary alkali basalt volcanism of Central and Southern Slovakia, information about the source of the basalt magma, as well as its depth level are very poor.

Pechersky et al. (1981) derived an empirical formula to estimate the depth of a basalt magma chamber, using the mean Curie temperature (T_C) of the Fe-Ti oxides of basalt lava flows. They found linear dependence between the value of the mean T_C of the TMs of basalts and the mean depths of basalt magma chambers.
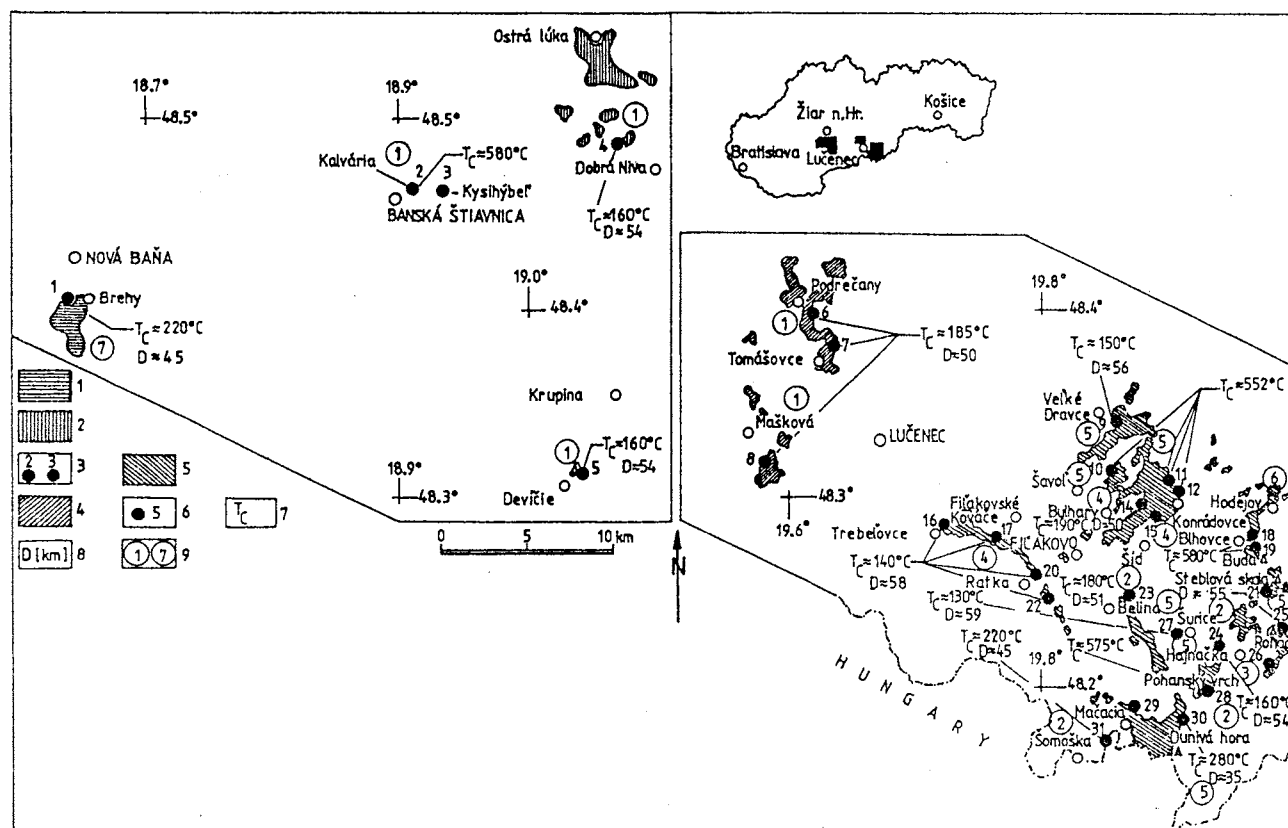
Fig. 1. Sketch map: Basalts of the Central and Southern Slovakia. 1 — Putikov Vršok Complex, 2 — Basalts of the Ostrá lúka, Dobrá Niva and Devičie, 3 — Kalvária Basalt Complex, 4 — Podrečany Basalt Formation, 5 — Cerová Basalt Formation, 6 — number of locality, 7 — mean Curie temperature of the Fe-Ti oxides of basalts, 8 — derived depth of the origin of basalt magma, 9 — volcanic phases 1-7.

The Curie temperatures of the TMs of basalts, as well as the data of Pechersky et al. (1975, 1981) were used to contribute to the solution of the problem concerning the deriving of the depth of the basalt magma sources in the areas of Central and Southern Slovakia. We also present some results for basalts from the Bohemian Massif, Syria and Nigeria.

Methods and basic results

The studied basalts were collected from 31 localities (location of basaltic bodies see Fig. 1). The detection of the Curie temperatures (T_C) of the Fe-Ti oxides of basalts was performed using the apparatus and the procedure described by Orlický (1990). Most samples of the magnetic fraction were measured in the air (in the interval -196 to 700 °C, or 20-700 °C; Fig. 2). Several specimens were measured in vacuum (10^{-4}-10^{-5} Torr., Fig. 3) to detect the alteration of the TM without the presence of oxygen. Some samples (placed into the quartz ampoule, vacuum 10^{-4}-10^{-5} Torr) were heated up to 850 °C, kept there about 2 hours in the furnace at the constant temperature 850 °C, and cooled to room temperature. Thermomagnetic curves show that natural Fe-Ti oxides of basalts mostly contain two magnetic phases of different T_C. One of them is the dominant phase, the other is only a minor portion. Samples from several localities contain only one magnetic phase with high T_C (Tab. 1). The TMs contain magnetic phases with different T_C (120 °C to ca. 610 °C, Tab. 1).

Short description of the titanomagnetites and their alterations

The TMs have a variable composition between magnetite (Fe_3O_4) and ulvospinel (Fe_2TiO_4). Both of these minerals have the cubic crystal structure which allows a complete solid solution, the titanomagnetite series ($Fe_{3-x}Ti_xO_4$) to exist between them. The change in composition from magnetite towards ulvospinel is marked by an increase in size and distortion of the cell, also by a change of magnetic and other characteristics, including their Curie temperatures (T_C).

The composition of TMs is also influenced by alteration processes. Two main alteration processes can determine the state of the Fe-Ti oxides in basalts. These processes have been termed — deuteric oxidation, which is active between 800 °C and 500 °C during initial cooling, and regional hydrothermal alteration, acting between 0 °C and 300 °C, during post-eruptive burial of younger material (Ade-Hall et al. 1971).

Readman & O'Reilly (1970) studied the alterations of the TMs in detail. The authors revealed that an original TM was inverted into the two-phase intergrowth (spinel and rhombohedral phase) after heating to 700 °C and successive cooling. The spinel phase comprises a mineral close to magnetite (in composition) containing a small quantity of Ti and vacancies, and a mineral richer in iron than the original TM. The rhombohedral phase comprises a mineral near to ilmenite (less Ti rich in composition than ilmenite), a mineral near to hematite in composition, pseudobrookite — Fe_2TiO_5, and anatas — TiO_2. We see that complex Fe-Ti oxide also originated due to
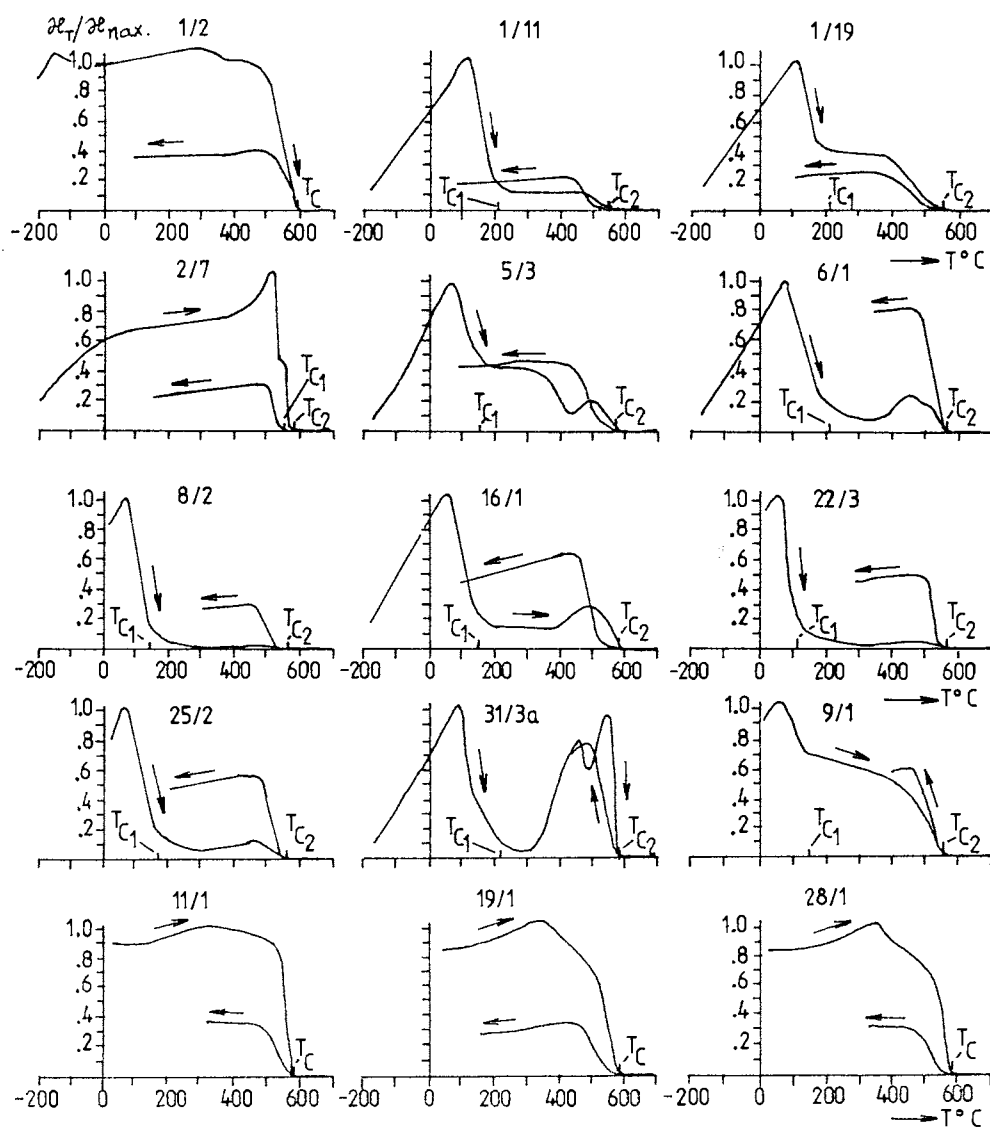
Fig. 2. Thermomagnetic curves of magnetic Fe-Ti oxides of basalts: 1/2 — number of sample, κ_T, κ_{Max} — magnetic susceptibility of the sample at the temperature T and maximal value of magnetic susceptibility from the set of data (κ_{Max}); →, ←, heating, cooling of the sample respectively.

heating and cooling of the previous — quasi homogeneous TM in the oxidative conditions.

The results of the fully automated measurements of a change of the magnetic susceptibility (κ) of samples of the TMs induced by temperature in both, oxidative and reductive conditions are given in Fig. 3.

The TM No. 101/7: this TM was separated from basaltic rock from Central Slovakia. The Mössbauer spectrum of the sample has shown very broad, non-Lorentzian lines (Fig. 4). The following portions of both Fe and Ti were detected using the electron microprobe analysis: FeO = 73.06 % and TiO$_2$ = 25.24 %. The compositional parameter (x) of the TM No. 101/7 sample was evaluated on the basis of the Fe/Ti ratio, according to Reidar et al. (1982), and Furuta (1993). Its value is x = 0.71. The composition of this TM is Fe$_{2.29}$Ti$_{0.71}$O$_4$. The content of the ulvospinel in this sample is 71 %. The Curie temperature of the sample in its basic state is T$_C$= 100 °C. The composition of this TM is very close to that of a homogeneous TM.

The results presented in Fig. 3 (samples 101/7, 101/7,a-101/7,g; samples of compact pieces of basalts — less than 5 mm — 21/2, 21/4, 21/4,k; samples 101/7,k and 21/4,k were measured at an alternative preselected constant temperature) have shown that new — more oxidized magnetic phases originated during heating and successive cooling of the sample in the oxidative conditions. For example while sample 101/7 has T$_C$= 100 °C, sample 101/7,g has T$_C$= 520 °C, after its heating to 700 °C and successive cooling to room temperature. The sample composition is 24.38 % hematite, 18.41 % maghemite, 19.12 % an oxide close to Fe$_3$O$_4$, and 38 % of paramagnetic components in the sample, according to evaluated data of the spectrum (in Fig. 4). The sample corresponds to titanomaghemite in composition. The T$_C$ of the converted Fe-Ti oxide does not correspond to that of the magnetite, or hematite.

The samples 101/7,v; 1/11,v; 1/20,v were measured in vacuum 10^{-4}-10^{-5} Torr (heating to 600 °C; cooling from 600 °C down to room temperature). The T$_C$ of the main magnetic
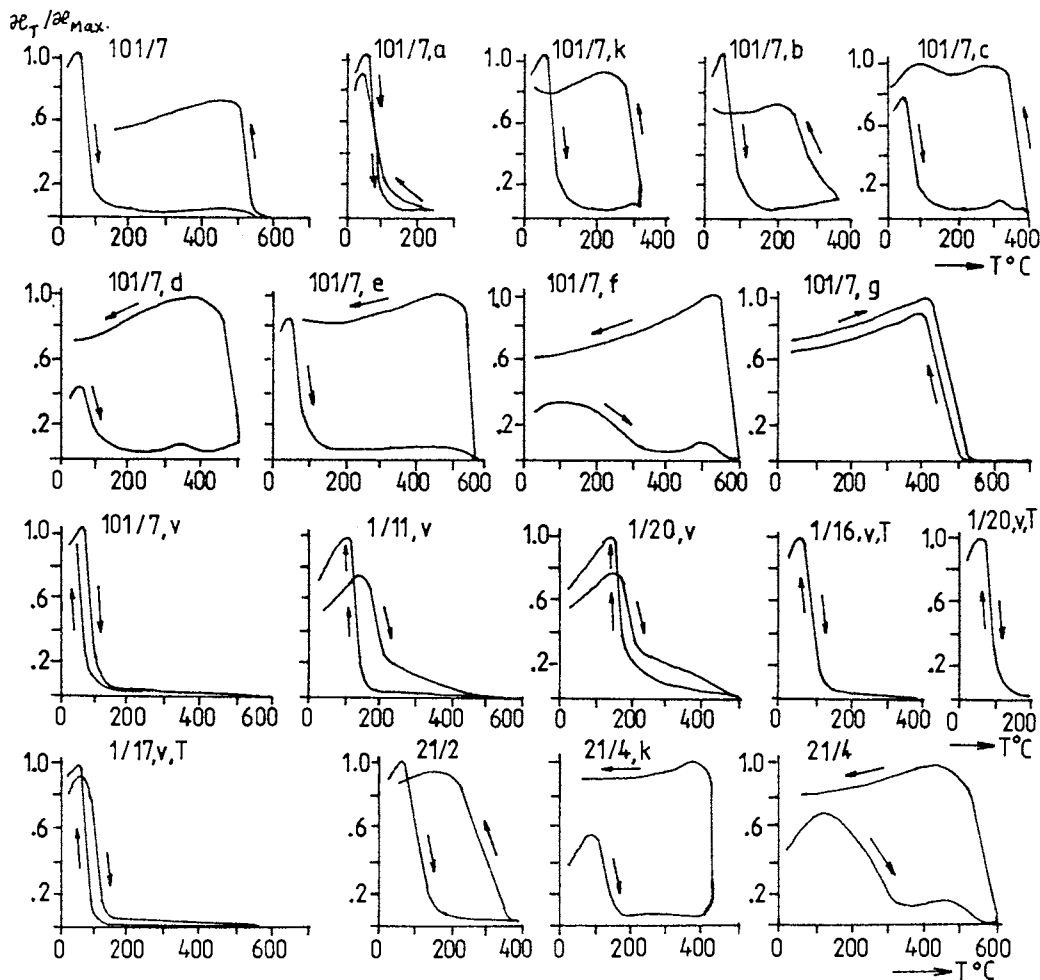
Fig. 3. Thermomagnetic curves of magnetic Fe-Ti oxides of basalts: κ_T, κ_{Max} and →, ← see as in Fig. 2. 101/7 — number of TM of composition $Fe_{2.29}Ti_{0.71}O_4$ of basaltic rock; 101/7-101/7a-g, 21/2, 21/4 — measurements of samples in air from room temperature to different maximal temperatures; 101/7,f,g, 21/4 — repeated measurements whith samples which were firstly measured to 350 °C (101/7,f; 21/4) and to 700 °C (101/7,g); 101/7,k, 21/4,k — measurements in air at constant temperature 312 °C (101/7,k) and 430 °C (21/4) during 90 minutes; 101/7,v, 1/11,v, 1/20,v — measurements in vacuum $(10^{-4}\text{-}10^{-5}$ Torr) from room temperature to different maximal temperatures; 1/16,v,T, 1/17,v,T, 1/20,v, T — measurements in vacuum $(10^{-4}\text{-}10^{-5}$ Torr) after homogenization of samples of TMs in vacuum $(10^{-4}\text{-}10^{-5}$ Torr) at constant temperature over 850 °C during 2 hours.

phase is very close to that detected during heating of the same samples in air. The second magnetic phase usually has a lower value of T_C compared with that obtained by measurements of the same sample in air. The second, more oxidized phase (if any) of the sample has been removed and new quasi homogeneous TM of lower T_C originated during heating and successive cooling down to room temperature (Fig. 3, 101/7,v — $T_C \approx$ 75 °C, instead of $T_C \approx$ 100 °C; 1/11,v — $T_C \approx$ 150 °C, instead of $T_C \approx$ 220 °C; 1/20,v — $T_C \approx$ 170 °C, instead of $T_C \approx$ 220 °C).

Samples 1/16,v,T; 1/20,v,T; 1/17,v,T; (20-400 °C; 20-200 °C; 20-700 °C, respectively). The samples were placed into a quartz ampoule — (vacuum $10^{-4}\text{-}10^{-5}$ Torr). The samples were heated to 850 °C, kept there for 2 hours at constant temperature in the furnace, and cooled to room temperature. The shape of the thermomagnetic curve is the same during heating and cooling (1/16,v,T; 1/20,v,T;). The T_C of the samples was lowered with respect to those obtained by measurements of the same samples in the air (in air: 1/16 — $T_C \approx$ 220 °C, 1/20 — $T_C \approx$ 220 °C; in vacuum: 1/16 — $T_C \approx$ 100 °C, 1/20 — $T_C \approx$ 98 °C). The measurements of sample

1/17,v,T were taken up to 700 °C (Fig. 3). Evidently a lower T_C of the sample has been obtained during heating, compared with that detected by measurements of the same sample in air (in air: $T_C \approx$ 220 °C; in a vacuum: $T_C \approx$ 120 °C — during heating, $T_C \approx$ 96 °C — during cooling of the sample).

The presented results have verified that the composition of the TMs and the Curie temperatures of the TMs depend on the presence/absence of oxygen, during their heating or cooling. We can postulate that the TMs have a very specific property — they are able to change their previous composition very easily depending on oxygen fugacity.

Basic results

The basic results are presented in Tab. 1, in Fig. 2 and figured in Fig. 1. We see from Tab. 1 and Fig. 2 that the original magnetic phases (of low $T_C \le$ 300 °C) have been preserved in most of basalts (single phase, or together with a more oxidized one). The basalts from 19 localities contain two magnetic phases. One of them with the $T_C \le$ 300 °C (it is supposed to be

Table 1: Mean Curie temperatures of the Fe-Ti oxides of basalts and derived depths of basalt magma chambers.

Volcanic phase	Age (m.y.)	Number of locality	Name of locality	Number of samples	Geographic coordinates		$T^*_{C_1}$ [°C]	T_{C_2} [°C]	Dominant phase T_C [°C]	Depth of magma chamber [km]
					φ_L	λ_L				
1	7.6 - 6.3	2	Kalvária	2	48.460	18.917		580	580	–
		4	NW of Dobrá Niva	2	48.486	19.067	160	570	570	54
		5	Devíčie	5	48.317	19.030	160	570	570	54
		6	Podrečany	5	48.399	19.608	220	560	220	45
		7	Podrečany - Tomášovce	4	48.390	19.625	190	570	190	50
		8	Mašková	2	48.320	19.576	140	560	140	58
2	5.7 - 4.5	21	Steblová skala	4	48.250	19.986	140	570	140	58
		23	Belina	2	48.237	19.863	180	560	560	51
		28	Pohanský vrch	2	48.200	19.922		600	575	–
		31	Šomoška	7	48.170	19.842	220	580	220	45
3	3-2.5	24	Hajnáčka - Castle	3	48.219	19.957	160	490	490	54
4	2.5 - 1.7	14	Bulhary	3	48.288	19.862	190	560	190	50
		15	NV of Šíd	2	48.287	19.873		-	570	–
		16	Trebeľovce	4	48.287	19.716	150	580	150	56
		17	Fiľakovské Kováče	3	48.284	19.747	170	570	170	53
		18	Blhovce	2	48.278	19.957		590	570	–
		19	Blhovce - Buda	2	48.266	19.957		590	590	–
		20	WWS of Fiľakovo, Ratka	3	48.264	19.790	120	560	120	61
		22	SW of Fiľakovo, Ratka	2	48.250	19.786	120	560	120	61
5	1.7 - 1.0	9	SE of Veľké Dravce	3	48.348	19.842	150	550	550	56
		10	NE of Šavoľ	2	48.310	19.855		580	570	–
		11	Konrádovce	3	48.296	19.879		580	540	–
		12	Konrádovce	4	48.294	19.883		576	538	–
		25	Hajnáčka - Ragáč	2	48.224	19.990	170	550	170	53
		27	Soví hrad	3	48.228	19.908	130	610	610	59
		30	Dunivá hora	3	48.176	19.871	280	570	280	35
7	0.5 (0.2)	1	Brehy	14	48.410	18.650	220	560	220	45

$T^*_{C_1}$ - values used for the deriving of the depths of the magma chambers.

the primary one), and the second oxidized phase with the T_C ≈ 490-610 °C. There are basalts from eight localities containing only one, more oxidized phase (T_C ≈ 538-600 °C) with a higher content of Fe_3O_4, Fe_2O_3 and other Fe-Ti oxidized products. These basalts are located mostly near Kysihýbeľ, Kalvária, Šavoľ, Šíd, Konrádovce, Blhovce, Blhovce Buda, Pohanský vrch. The basalts with only one magnetic phase (with higher T_C) probably arose from a "wet" (saturated by magmatic water) magma.

Only the T_C of the non-oxidized magnetic phase (probably the primary one) of the TMs of basalts can be used to derive the depth of the basalt magma source. Petchersky et al. (1975, 1981) have presented an idea that primary composition of the TMs of basalts can be reached by the rehomogenization of natural TMs within neutral media at about 1000 °C. I have of course used the T_C of the TMs in their natural state. The depth (D) of the magma sources were calculated according to the empirical formula of Pechersky et al. (1975, 1981):

$D_{(km)}$ ≈ 80-0.16 × T_C (in °C).

The derived depths of the basalt magmas are presented in Tab. 1 and Fig. 1. The mean T_C and calculated depths of basalt magma sources are as follows:

— Putikov vŕšok Complex (loc. 1 — Brehy) — T_C ≈ 220 °C; D ≈ 45 km

— Basalts of the Dobrá Niva and Devíčie localities (loc. 4, 5) — T_C ≈ 160 °C; D ≈ 54 km

— Podrečany Basalt Formation (loc. 6, 7, 8) — T_C ≈ 185 °C; D ≈ 50 km

— Cerová Basalt Formation (loc. 16, 17, 20, 22) — T_C ≈ 140 °C; D ≈ 58 km

— Cerová Basalt Formation (loc. 21, 25) — T_C ≈ 155 °C; D ≈ 55 km

— Cerová Basalt Formation (loc. 27) — T_C ≈ 130 °C; D ≈ 59 km

— Cerová Basalt Formation (loc. 30) — T_C ≈ 280 °C; D ≈ 35 km

— Cerová Basalt Formation (loc. 31) — T_C ≈ 220 °C; D ≈ 45 km

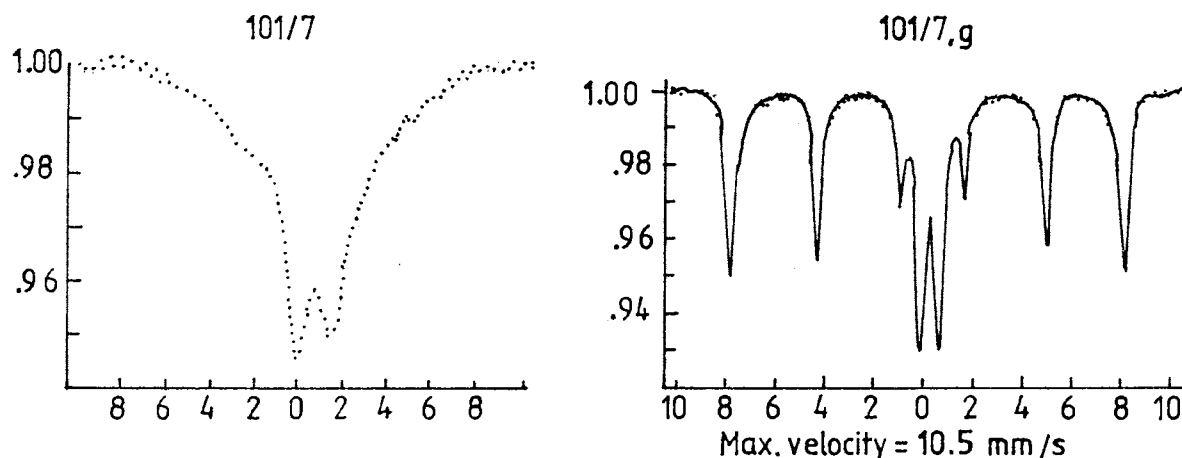**Fig. 4.** Mössbauer spectra of samples 101/7 and 101/7,g; sample 101/7 has a composition $Fe_{2.29}Ti_{0.71}O_4$; sample 101/7,g originated from sample 101/7 during its double heating from room temperature to 700 °C and successive cooling.

The following depths of basalt magma sources for the individual volcanic formations and complexes are estimated:
— Putikov vŕšok Complex (loc. 1, Central Slovakia) —
D ≈ 45 km
— Basalts of the Dobrá Niva and Devičie localities —
D ≈ 54 km
— Podrečany Basalt Formation (Southern Slovakia) —
D ≈ 50 km
— Cerová Basalt Formation (Southern Slovakia) —
D 35-59 km.

Some examples of the study of the Fe-Ti oxides of basalts from another countries

I also studied Fe-Ti oxides of basalts which were collected from other countries (Orlický et al. 1992). Quite low values of the T_C of the TMs were detected in several basalts. Several values of the T_C of the TMs and related depths of the basalt magma sources are presented to make some comparison.

Bohemian Massif: olivine basalts and picrite basalts (age — Tertiary to Quaternary). Obrnice locality — T_C ≈ 60 °C; D ≈ 70 km.

Syria: albitized basalts and hyalobasalts (age 99.15-119.85 Ma — Cretaceous). Latakya area, locality 8/1 — T_C ≈ 70 °C; D ≈ 69 km.

Nigeria: nepheline basanites (age 121.0-163.0 Ma — Cretaceous-Triassic). Runka locality RK-1 — T_C ≈ 120 °C; D ≈ 61 km.

We see from these results that primary TMs have been preserved in comparatively very old basalts and basanites.

Discussion

The composition of the TM is extremely dependent on the T-fO_2 conditions of the last stable magma state (last chamber where the magma has been for a sufficiently long time), considering the creation of the basalt magma in general. Equilibrium redox (fO_2) conditions in the place of accumulation or long standing of magma (primary or intermediate magma chamber) are thought to be preserved in magma up to its outflow on the Earth's surface (Pechersky et al. 1981). Differ-

ences in the depth conditions of rock formation and their influence on the magnetic properties, including T_C are known in basalts of two types of tectonic structures: rift zones and island volcanic arcs. The first ones are tension regions and are characterized by a high penetration of litosphere (last magma rising from the primary source; absence of interaction with surroundings). According to statistics the primary TMs of basalts in rift zones have T_C ≈ 100-200 °C as a rule. The volcanic arcs (pressure regions) are defined by slow rise and magma accumulation at relatively small depths (intermediate chambers). Here the T_C of primary TMs varies from 100 to 500 °C in space, and especially in time (Pechersky et al. 1981). The composition of the TM is influenced by water content and by other volatile oxidants which can be present within the magma. Pechersky et al. (1981) found, that during "dry" melting of basalts in air crystalized TM with the T_C ≤ 360 °C, while after water addition from 1 % to 10 % into the melt (P ≈ 3 kbar) TMs with the T_C ≈ 500-540 °C were formed. Pechersky et al. (1975, 1981) found that the composition of the primary titanomagnetites of basalts are correlated to the depths of their magmatic sources, as proved by seismic data in Kamchatka and Hawaii.

The question of the origin of basalt magma and related magnetic Fe-Ti oxides is very important.

The basalts and the nepheline-rich rocks contain xenoliths which indicate that these rocks have their source within the mantle (Ehlers & Blatt 1980). The depth of origin is placed at 40-100 km in depth (Ehlers & Blatt 1980). Researchers have found that seismic waves travel through the upper mantle at a rate of more than eight kilometers per second, far faster than they would pass through basalts (Bonatti 1994). The only material that could possibly allow such a high velocity is a peridotite. The specialists showed that gradual decompression of very hot peridotite (1200-1300 °C, at pressures more than 10,000 atmospheres, which exist in the suboceanic upper mantle roughly 100 km below the seafloor) melts up to 25 % of the rock. The melt has a basaltic composition. It rises rapidly toward the surface. Peridotites consist mostly of the three silicon-based minerals: olivine, silicate containing magnesium and iron; ortopyroxene and clinopyroxene. Peridotites also have small quantities of spinel, an oxide of chromium, magnesium and iron (Bonatti 1994). Fediuk (in Bucha & Bližkovský et al. 1994) have presented the results of the investigation of

peridotite xenoliths of volcanics from the Czech and Slovak Republics. The analyzed peridotite lherzoliths contain olivine, orthopyroxene, clinopyroxene and spinel. While olivine contains only Fe (except for other Si-, Al-, Mg-, Ca-cations) clinopyroxene and spinel contain both the Fe- and Ti-cations (besides Si-, Al-, Mg-, Ca-cations, in both minerals, and Cr-, Na-, K-cations in spinel). The results have shown that both the Fe- and Ti-cations were present, as the basic components for the formation of the TMs within the peridotites. We can presume that the TMs of basalts arose from minerals, which were originally present in the peridotites.

Hoernle at al. (in Downes & Wilson 1995) showed that the ultimate source of alkaline magmas of central and western Europe is an upwelling which stretches from the Canary Islands to Poland. The isotopic signature of this upwelling mantle can be detected in all Neogene alkaline magmatic activity in Europe, including the Western Carpathians and the Pannonian Basin. The location of magmatism is affected by local tectonics (e.g. rifting and back arc extension). Downes & Wilson (1995) have shown that the alkali basaltic volcanism is the product of an asthenospheric mantle source mixed with components from the lithosphere.

Huraiová & Konečný (1993) studied the xenoliths of the spinel lherzolits of alkali basalts of the locality Fiľakovské Kováče of the Cerová vrchovina Upland (Southern Slovakia). The xenoliths came from depths of about 35-85 km. Slightly reduced conditions, compared to the alkaline province are confirmed by the oxygen fugacity as well as by the presence of N_2, CO in CO_2 rich inclusions, according to the authors.

Fediuk (in Bucha & Blížkovský et al. 1994) presented the temperature balance and pressure values of lherzolite xenoliths of volcanics from the north of Bohemia, the north of Moravia and south of Slovakia. He deduced from the evaluated results of thermodynamic calculations that balancing of lherzolite nodules took place at depths of about 50-80 km, i.e. under conditions of the uppermost mantle. The ultramafic nodules of the three quite distant regions (Northern Bohemia, Northern Moravia, Southern Slovakia) are "basicly identical with partial diversities". It has been deduced that a particular layer of the uppermost mantle is, in the Czech and Slovak part of Central Europe, homogeneous, in the first approximation. In detail, however, it is characterized by inhomogenities which are mainly quantitatively mineralogical, but derived from that, also of a chemical nature.

Bezák et al. (1995) and Šefara et al. (in press) modelled a very low thickness of the Earth's crust (attaining ca. 24-26 km) in the southern part of the Western Carpathians and in the Pannonian region. The upper mantle/lower crust boundary lies about 27-29 km beneath the Earth's surface in the Cerová vrchovina Upland area, according to their interpretation. Similarly, Hegedüsh et al. (1993) modelled a very low thickness of the Earth's crust in the Pannonian Basin (22 km). The melted astenospheric materials have risen to very low depths beneath the surface (ca. 80-60 km), according to Bezák et al. (1995).

The derived values of the depths of the basalt magma sources based on the Curie temperatures of the TMs of basalts of Central and Southern Slovakia are in the range 35-59 km. Ehlers & Blatt (1981) have supposed that the xenoliths have their source within the mantle, at depths of 40-100 km. Huraiová & Konečný (1993) have derived that the xenoliths of spinel lherzolits of alkali basalts of Southern Slovakia rose from depth of about 35-85 km. Fediuk (in Bucha & Blížkovský et al. 1994) has deduced that balancing of lherzolite nodules

took place at depths of about 50-80 km (under conditions of the uppermost mantle) in the north of Bohemia, north of Moravia and south of Slovakia. We see that the derived depths of basalt magma sources based on the Curie temperatures of the TMs correspond quite closely with those presented by other authors. But Konečný P. (written communication) has deduced that basalt magma is supposed to be in liquid state at such a depth under Southern Slovakia, hence the crystallization of the Fe-Ti oxides could hardly be expected in su.h conditions. In this respect we can also consider the other possibility for the origin of the TMs with the low Curie temperatures (homogeneous TMs). Laboratory tests have verified that the TMs are able to change their previous state (the composition), depending on either oxidative or reductive conditions. We can assume that if there are reductive conditions during an upwelling of basalt magma (even during its standing on the Earth's surface), TMs of low Curie temperatures should be formed at any depth level. In such a case the derived depths of basalt magma sources based on the Curie temperatures of the TMs will be ambiguous.

I expect that the method of deriving the depth of the basalt magma source based on the Curie temperature of the TMs will be perfected in the future.

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