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PALEOMAGNETISM OF VOLCANICS OF THE SLÁNSKE VRCHY, VEĽKÝ MILIČ MTS. AND ZEMPLÍNSKE PAHORKY HILLS AND ITS GEOLOGICAL INTERPRETATION

(Fig. 1—5)

Abstract: Volcanic activity of the Slánske vrchy, Veľký Milič Mts. and Zemplínske pahorky in eastern Slovakia took place from the Eggenburgian to the Pliocene. The products of volcanic activity from Badenian to Pliocene were investigated paleomagnetically. On the basis of stratigraphic criterii the volcanics were divided into VII groups, which are characterized in the paper more in detail. Paleomagnetic measurements show that volcanic activity of the Slánske vrchy, Veľký Milič Mts. and Zemplínske pahorky Hills, when compared with that of the Vihorlat Mts. was asynchronnous in the Pannonian-Pliocene period although lithostratigraphical data indicate a synchronnous character of volcanism.

Резюме: Вулканическая деятельность Сланских гор, Велкего Милича и Земплинских холмов в восточной Словакии проходила от эггенбурга до плиоцена. Продукты баденской и плиоценовой деятельности были исследованы палеомагнетически На основании стратиграфических критерий вулканиты были разделены на семь групп, которые в этой работе охарактеризованы детально. Палеомагнетические измерения указывают на то, что вулканическая деятельность Сланских гор, Велкего Милича, Земплинских холмов напротив Вигорлата была в панон-плиоцене ассинхронная, хотя и литостратиграфические данные указывают на синхронность вулканизма.

Introduction

Systematic paleomagnetic investigation of neovolcanics in eastern Slovakia continued in the years 1971—1972 in the area of the Slánske vrchy Mts., Veľký Milič massif and Zemplínske pahorky Hills, including their wider environments as far as Kráľovský Chlmec.

The purpose of these measurements was to complete classical geological mapping and to obtain new data for better characterization of time-succession of volcanic events as well as for a more profound analysis of the mountains structure.

The presented analysis of geological and paleomagnetic development is a continuation of the geological works (J. Slávik — J. Tözsér 1973) and paleomagnetic investigation, which was started in the Vihorlat Mts. (O. Orlický — P. Pagáč — J. Slávik 1970).

Geological structure of the area

The Slánske vrchy Mts. and Veľký Milič massif are situated at a significant geotectonic knot, formed by the boundary of important tectonic units. At the tectonic line with a permanent pulsative mobility frome the Lower Miocene to the Pliocene a volcanic activity proceeded, which gave rise to the mountain range in its present shape.

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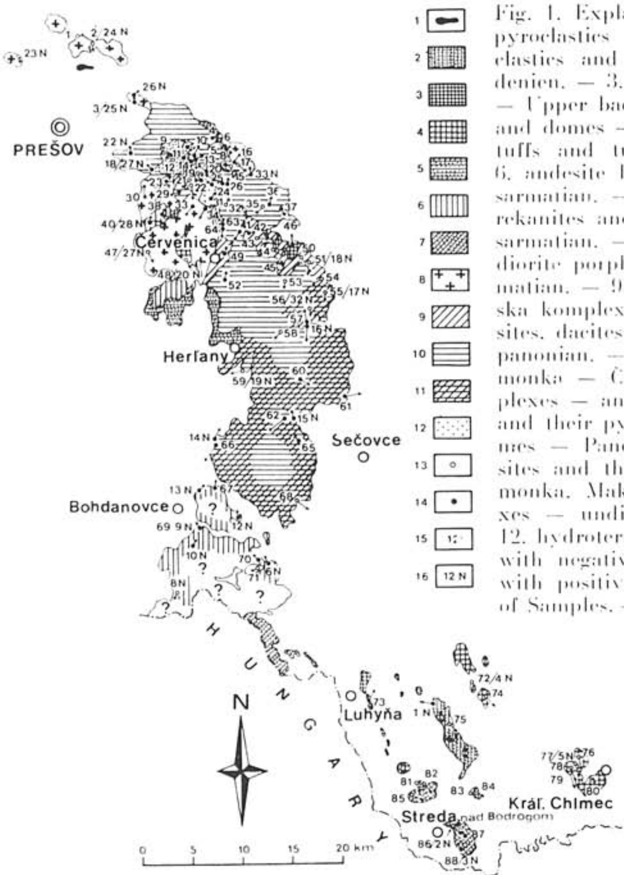


Fig. 1. Explanations: 1. Rhyolites and their pyroclastics — karpat. — 2. rhyolite pyroclastics and domatic bodies — Lower badenien. — 3. rhyolite domes and pyroclastics — Upper badenien. — 4. andesite lava flows and domes — Upper badenien. — 5. rhyolite tuffs and tuffites — Lower sarmatian. — 6. andesite lava flows and domes — Lower sarmatian. — 7. rhyolite tuffs, perlites, marekanites and obsidians — Middle to Upper sarmatian. — 8. andesites, their pyroclastics, diorite porphyrities — Middle to Upper sarmatian. — 9. Lower volcanic stage — Ošvarska komplex of Slánske vrchy Mts — andesites, dacites and their pyroclastics — Lower panonian. — 10. Upper volcanic stage — Šimonka — Čierna Hora and Makovica komplexes — andesites, dacites, basalto andesites and their pyroclastics, lava flows, dykes, domes — Panonian to Pliocene. — 11. Andesites and their pyroclastics of Ošvarska, Šimonka, Makovica and Čierna hora komplexes — undivided Panonian to Pliocene. — 12. hydrotermaly altered zones. — 13. Samples with negative RM polarity. — 14. Samples with positive RM polarity. — 15. Numbers of Samples. — 16. Numbers of A. E. M. Nairn's Samples.

Synthetic works on the area of the Slánske vrchy Mts. were published by M. Kuthan (1948), J. Slávik — J. Čverčko — R. Rudinec (1968), J. Slávik (1968), the last and most detailed synthetic work from the Slánske vrchy Mts. was presented by J. Slávik — J. Tözsér (1973).

Beside the quoted works by J. Slávik (1968) and J. Slávik — J. Čverčko — R. Rudinec (1968), J. Forgáč (1965) was dealing more in detail with the Veľký Milič area.

The area of the Zemplínske pahorky Hills and their surroundings, where volcanic rocks, cropping out, form the apical parts of the extensive buried Zemplín volcanic mountain range, is characterized in the work by B. V. Merlič et al. (1968) and J. Slávik (1972).

Paleomagnetic investigation of volcanics in eastern Slovakia, besides the work by O. Orlický et al. (1970), was studied by A. E. Nairn (1967).

In the sense of the mentioned works taking into consideration also newly established information, development of volcanism in this area may be characterized as follows (fig. 1): post-Oligocene uplift of the Paleogene geosyncline was accompanied by forming of inner downwarping Transcarpathian Inner Deep. In its basal parts we are finding products of volcanic activity in the form of fine — to medium-grained rhyolite tuffs and tuffites, at present mostly bentonitized and seladonitized (J. Březina, 1960; J. Slávik, 1968). Thickness of volcanic deposits attains up to 5 m as maximum (Čelovce, Fintice, Terňa).

Further volcanic activity occurred as late as the basal Karpatian below the salt-bearing formation in the area under consideration. Its product are rhyolite pyroclastic rocks occurring SE of the community of Fintice in the area of elev. point 318.2.

In the Lower Badenian an extensive volcanic activity took place, producing several layers of rhyolite tuffs which are pelitomorphic in the northern part of the area (Šarišská Poruba, Zlatá Baňa, Zlatá Studňa), and in the southern part of the area, in the Zemplínske pahorky Hills there are coarse-grained pyroclastic rocks, often with allothigenic fragments of limestone and dolomite (Žipov area).

A part of rhyolites in the environments of the Zemplínske pahorky Hills, mainly between Hrčel and Cejkov, represents domes which belong to this volcanic activity. With it we put into connection also formation of rhyolite tuffs and foamed lavas occuring near Luhyňa. Rhyolite volcanic activity along the southern margin of the East Slovakian Neogene basin persisted until the Badenian (J. Slávik 1972). On the basis of setting relations we suppose that to this horizon, dated by fauna from the area of Stretava, rhyolite tuffs from the environs of Michaľany and Veľký Kazimír belong. Rhyolite volcanism is also manifested in the northern area of the Slánske vrchy Mts. Its products are deposited in a freshened environment near the communities of Lesíček, Mirkovce, Tuhrina and Varhaňovce. The products of rhyolite to rhyodacite composition, deposited on a wide surface in the northern part of the Slánske vrchy Mts., are derived from a rhyolite volcano, which was situated south of the community of Zamutov in the area of elev. p. Valenčica.

In the marine Upper Badenian in the area of the Zemplínske pahorky Hills also andesite volcanism occurs, proved in the area of Žipov and Zatín, and later by absolute dating of surficial volcanic rocks near Kráľovský Chlmec, Sírnik, Hraňa and Brehov.

In the northern part of the Slánske vrchy Mts. Upper Badenian andesites are known only from a freshened devolopment (Kolčov formation) in the area of Opiná, and on the basis of setting relations we range here also andesite from the northern margin of the community of Vyšná Kamenica. Andesite volcanism reaches beyond the boundary of the Upper Badenian. Its last explosions took place as late as the basal Sarmatian and their product are the Olšava beds (J. Švagrovský 1964), which is equivalent to the zone with *Elphidium reginum* and J. Švagrovský ranges them to the Lower Sarmatian.

Probably synchronnously with termination of andesite volcanism in the southern part of the area, i. e. in the area of the buried Zemplínske pohorie Mts. and the Veľký Milič massif in the northern part of the area explosive rhyolite volcanism started, the products of which are found in the Sarmatian complex, paleontologically characterized best by J. Švagrovský (1954) — Myšľa beds and J. Jiříček (1965). The finds of fauna enable to date evidently the age of this volcanism as Lower Sarmatian, zone B. We range here the upper part of the complex of Bankovce rhyolite tuffs and tuffites.

The products of Lower Sarmatian andesite volcanism are lying below the sediments of the East Slovakian Lowland in the shape of the buried Malčice volcano and the double volcano Beša—Vojany (J. Slávik 1972). It is proved that this volcanism started at the time internal between the zones with *Cibicides badenensis* and of large elphidia. Its products are exposed mainly in the Veľký Milič massif (Ruskov, Kalša, Rákoš).

Andesites of that age occur in the northern part of the Slánske vrchy Mts. between Žehňa and Lesíček and were encountered in boreholes between Tuhriná and Červenica, where they are resting on the Rankovce rhyolite tuffs. Conventionally, we range to this volcanism also clastolavas in the Šťavica Valley and at the Libanka in the wider environs of Zlatá Baňa (J. Slávik — J. Tözsér 1973).

Acid effusive-explosive volcanism continues also in the higher part of the Sarmatian in the *Elphidium hauerinum* Zone in the area of Veľký Milič and the Zemplínske pahorky Hills. Its products were found near Lastovce and Kuzmice and in a formation dated by fauna near Kráľovský Chlmec.

On the surface are found these rocks in the area of Streda nad Bodrogom, Byšta, Brezina, Viničky represented by obsidians, perlites, marekanites, rhyolites and rhyolite tuffs with the content of hydrated volcanic glass (Streda nad Bodrogom). This volcanic activity is restricted to the southern part of the area only.

In the north volcanism was manifested later in the time at the boundary of the *Hauerinum* and *Porosononion* zones. It is represented by pyroxene-amphibole andesites, sometimes with quartz and garnet and diorite porphyrites. Regionally they are found between Abramovce, Opiná and Červenica, where above all supercrustal varieties, pyroclastic rocks and lava streams, domes and cumulodomes occur (Brestov—Abramovce formation). Along the northern margin of the East Slovakian Neogene basin predominantly semiintrusive bodies of diorite porphyrites occur (Oblazy, Oblík, Hrb, Veľká Stráž etc).

Post-Sarmatian volcanism is represented in this area by effusive-explosive, subordinately shallow-intrusive members, predominantly of intermediate, only rarely of more acid, scarcely of basic composition.

At the base of this volcanic complex a horizon of garnetiferous rhyolite tuffs occurs, found in boreholes near Kráľovský Chlmec (J. Slávik 1968).

In the northern part of the Slánske vrchy Mts, where the mentioned tuffaceous horizon has not been found so far, J. Slávik — J. Tözsér (1973) distinguish two volcanic stages among the products of post-Sarmatian volcanism, separated by pelitic and coal-bearing sediments with limnoquartzites in the areas of Zamutov, Červenica, Banské and Herľany.

The lower volcanic stage of the Slánske vrchy Mts. — the Ošvarská complex — is made up of pyroxene andesites and their pyroclastic rocks occurring in the area near the elev. p. Ošvarská near Zamutov and forming an extensive area of the lower parts of volcanogenic complexes between elev. p. Šimonka a and the community of Banské. Beside that they occur in the valley of the Červenický potok brook and at the southern slopes of the Dubník dacite body.

On the body of the position of the lower volcanic stage of the Slánske vrchy Mts. below the Červenice volcanic-sedimentary formation — tuffs, tuffites, tuffitic conglomerates, rhyolite tuffs, pelites, limnoquartzites, coal seams (J. Tözsér 1972), they are considered as Pannonian in age by J. Slávik and J. Tözsér (1973). Proceeding from the regional correlation of R. Jiříček (1972) and from the presence of a large amount of andesite tuffites established within the extent of the whole basin, we range this volcanic activity stratigraphically to the Pannonian C.

The upper volcanic stage of the Slánske vrchy Mts., probably Pliocene in age, is built up from lava streams and pyroclastic rocks of pyroxene andesites, amphibole-pyroxene andesites, less of andesito dacites, dacites, subordinately also basaltic andesites, which we range to the complexes Šimonka—Čierna Hora and Makovica synchronnous in age. The mentioned complexes build up the main ridge of the Slánske vrchy Mts. between elev. p. Čierna Hora, Šimonka, Makovica, farther they occur near elev. p. Bodoň in the area south of Zlatá Baňa.

The volcanotectonic depression of Zlatá Baňa (J. Slávik — J. Tözsér 1973) is intruded by small domes, dykes and necks of andesite and dacite-andesite composition. The above quoted authors consider rhyodacites of elev. p. Ordanka as the youngest member of the Makovica complex.

The commencement of volcanism of the upper volcanic stage in the Slánske vrchy Mts. may be placed to the uppermost Pannonian provided that volcanism could have persisted as late as the Pliocene.

Volcanic complexes equivalent in age build up extensive top parts of the massifs Lazy and Bogota in the central and southern part of the Slánske vrchy Mts. Isolated manifestations of Pliocene volcanism are known from the area of the Zemplínske pahorky Hills near Streda nad Bodrogom, stratigraphically dated in boreholes from the area of Kráľovský Chlmec. At present-day state of our information, however, it has neither been possible so far to range the products of Pliocene volcanism in the central and southern part of the Slánske vrchy Mts. nor in the area of the Zemplínske pahorky Hills more precisely as to their age.

Methods of paleomagnetic investigation

The choice of localities for sampling of rocks was done on the basis of geological knowledge of this area so that paleomagnetic measurement could be used for a more precise investigation of the geological structure of the neovolcanic complex in the mountain range under study. In the majority of cases sampling from quarries is concerned.

From each followed locality 2—5 samples were taken. Sampling in common position was carried out by aid of a geological compass. Under laboratory conditions samples were adjusted to the shape of cube with and edge of 2 cm from common position to an oriented system against north and the horizontal plane. The number of adjusted samples at the individual localities varies from 1 to 15. In the case of little coherent samples from several localities only one sample could be adjusted.

Measurement of natural remanent magnetization (NRM — J_n and volume magnetic susceptibility ($\varkappa$) was realized with astatic magnetometer LAM-1, with sensibility about $2 \cdot 10^{-7}$. Oe/mm. From the samples of individual localities one was chosen, in several cases even three samples, on which alternating demagnetization was carried out in the interval 25—500 Oe, for the purpose of establishing paleomagnetic stability of rocks. On the basis of the results of demagnetization of chosen samples, for demagnetization of the remanning samples a field value of 200 Oe was selected out in compensated magnetic field with rotating sample.

The residual field in the centre of the compensation field was measured with a highly sensible millioerstedmeter with permalloy probe. The measurements of remanent magnetization (RM) were carried out with rotating magnetometer JR-2.

From the fundamental measured data the values J_n, $\varkappa$ and Q were calculated. From the measurements performed on rotating magnetometer declination (D) and inclination (I) RM for individual samples, the mean values of the mentioned parameters for the respective locality, then the coefficient of dispersion (k), half-angle of the cone of probability ($\alpha_{0.95}$) geographical coordinates of the paleomagnetic pole (φ_p, λ_p) and the

Table 1

I. Domatic bodies

Design of local.	Coordinates of loc. φ_L	Coordinates of loc. λ_L	Number of samples	$J_n \cdot 10^6$	$\varkappa \cdot 10^6$	Q	D_L	I_L	k	α	φ_P	λ_P	δ_f	δ_m
12	48.965	21.392	3	878	2013	0.9	295	−67	52 779	1	24	62	2	1
19	48.956	21.425	10	235	548	0.9	167	−60	188	18	78	253	15	23
21	48.949	21.417	10	967	1246	4.5	226	−51	189	9	51	119	8	12
22	48.950	21.428	8	198	871	0.6	270	−60	3	45	55	315	33	55
24	48.944	21.446	3	1700	7593	0.5	303	71	16	68	24	53	104	118
28	48.944	21.418	7	584	863	1.4	172	−31	77	14	58	195	9	16
31	48.932	21.445	2	309	116	5.3	40	68	198	18	65	92	30	25

II. Pannonian-Pliocene

Design of local.	Coordinates of loc. φ_L	Coordinates of loc. λ_L	Number of samples	$J_n \cdot 10^6$	$\varkappa \cdot 10^6$	Q	D_L	I_L	k	α	φ_P	λ_P	δ_f	δ_m
18	48.957	21.366	2	1335	8116	0.3	308	72	66	31	57	329	48	55
55	48.851	21.601	12	2325	41	113.4	185	−61	265	3	83	172	4	5
56	48.835	21.582	8	308	—	—	181	−69	43	10	86	35	15	18
57	48.825	21.557	11	47	53	1.7	185	2	2	53	39	195	26	53
60	48.773	21.568	12	2046	1336	3.1	119	46	5	21	3	81	17	27
61	48.761	21.659	12	534	418	2.5	83	12	2	50	12	105	26	50
62	48.735	21.549	6	165	843	0.4	233	11	1	109	18	145	56	111
65	48.722	21.566	10	184	1689	0.2	310	78	41	8	58	326	14	14
66	48.713	21.453	1	40	793	0.1	213	5	—	—	30	162	—	—
68	48.660	21.565	6	1078	872	2.6	130	29	40	11	12	251	7	12
14N	48.721	21.453	5	—	—	—	32	42	—	9	55	145	—	—
15N	48.738	21.551	4	—	—	—	350	58	—	11	78	240	—	—
16N	48.828	21.581	5	—	—	—	353	20	—	9	30	208	—	—
17N	48.851	21.599	6	—	—	—	185	−52	—	4	73	185	—	—
21N	48.958	21.368	5	—	—	—	289	59	—	19	41	314	—	—
22N	48.972	21.336	6	—	—	—	355	66	—	7	86	270	—	—
32N	48.847	21.583	6	—	—	—	188	−59	—	10	78	165	—	—

III. Upper volcanic stage

7	48.978	21.413	7	—	—	—	64	68	7	25	49	83	34	41
10	48.971	21.420	6	10053	12	168.0	25	46	165	10	60	144	8	12
13	48.967	21.426	9	3089	846	7.3	177	51	616	4	9	203	3	5
14	48.966	21.415	6	1936	366	10.6	63	33	6	29	31	121	38	50
20	48.971	21.438	3	1610	5949	0.6	314	52	—	—	54	104	—	—
23	48.949	21.385	2	—	—	—	87	59	548	10	30	83	12	16
25	48.944	21.462	4	280798	8586	65.4	299	6	681	5	21	270	2	5
26	48.946	21.466	3	2320	2429	2.0	12	69	57 113	1	81	76	2	2
27	48.942	21.412	6	541	598	1.8	134	—45	4	70	48	278	56	88
29	48.937	21.402	5	1212	996	2.5	258	66	191	18	29	332	25	30
32	48.929	21.463	3	15844	1472	21.5	27	68	1774	2	74	93	3	4
35	48.924	21.516	4	5879	3980	3.0	228	—57	276	5	55	112	5	7
36	48.924	21.523	2	580	368	3.1	23	62	167	19	72	122	—	—
37	48.924	21.542	3	2569	5466	1.0	158	70	4529	2	15	36	3	3
41	48.920	21.487	4	1945	3534	1.1	212	51	1020	4	4	172	4	5
52	48.859	21.463	4	761	747	2.0	15	61	237	24	78	135	34	41
53	48.862	21.547	3	1558	2483	1.3	191	—65	88	7	81	131	11	14
58	48.813	21.536	9	1040	124	16.0	224	—59	63	7	57	110	7	—
33N	48.956	21.499	7	—	—	—	357	60	—	6	82	220	—	—

IV. Lower volcanic stage

42	48.902	21.495	2	8101	5236	3.1	76	69	7670	3	44	79	—	—
43	48.897	21.507	8	173	786	0.4	95	—51	27	11	26	311	10	15
49	48.883	21.466	3	415	—	—	20	66	408	6	86	112	8	10
50	48.882	21.568	4	432	3417	0.3	152	—25	5	49	48	238	28	52
51	48.876	21.578	3	4255	381	22.7	183	—33	546	5	59	196	3	6
54	48.864	21.596	2	27	—	—	238	—47	189	18	63	248	15	24
18N	48.878	21.579	5	—	—	—	202	—63	—	8	76	120	—	—

V. Upper and Middle Sarmatian

Design of local.	Coordinates of loc.		Number of samples	$J_n \cdot 10^6$	$\varkappa \cdot 10^6$	Q	D_L	I_L	k	α	φ_P	λ_P	δ_f	δ_m
	φ_L	λ_L												
1	49.075	21.263	3	1233	1147	2.2	21	−71	10 614	1	15	9	1	2
2	49.068	21.278	4	2771	2184	2.6	247	−12	575	5	20	124	—	—
3	49.016	21.382	2	1047	1114	1.9	277	73	1119	8	43	336	12	13
4	48.987	21.448	7	1790	4639	0.8	61	84	63	16	54	39	—	—
5	48.984	21.453	9	1005	2586	0.8	240	48	24	13	5	332	—	—
6	48.979	21.464	4	1562	963	3.2	148	43	522	5	12	231	4	6
8	48.978	21.465	4	—	—	—	78	77	80	14	40	349	24	26
15	48.963	21.472	1	323	1949	0.3	166	−43	—	—	63	229	—	—
16	48.964	21.477	4	711	2860	0.5	37	55	246	16	61	127	16	23
17	48.964	21.482	3	349	2727	0.2	129	−55	58	34	51	288	34	48
30	48.932	21.357	3	2191	1395	3.1	356	38	3260	2	61	219	2	2
33	48.927	21.422	3	717	1064	1.3	212	47	337	4	9	352	3	5
44	48.887	21.531	2	553	2102	0.5	16	49	—	—	68	164	—	—
45	48.889	21.558	4	2106	6232	0.7	213	−65	261	8	68	102	5	9
47	48.881	21.484	3	182	783	0.5	152	−47	34	22	59	258	18	28
48	48.873	21.411	3	332	309	2.1	148	−57	87	13	64	279	14	19
85	48.405	21.718	6	677	152	8.9	113	−42	82	14	33	291	10	17
86	48.380	21.775	9	89	364	0.5	137	−37	20	14	46	268	10	17
87	48.373	21.740	6	775	590	2.7	322	76	100	8	64	341	13	14
88	48.357	21.785	9	866	279	6.2	331	65	110	5	71	295	7	9
2N	48.381	21.776	5	—	—	—	141	−54	—	16	57	282	—	—
3N	48.357	21.786	6	—	—	—	334	60	—	4	69	283	—	—
20N	48.867	21.414	6	—	—	—	189	−59	—	2	79	166	—	—
23N	49.057	21.182	6	—	—	—	175	−73	—	7	80	18	—	—
24N	49.068	21.282	6	—	—	—	172	−69	—	5	84	330	—	—
25N	49.017	21.342	6	—	—	—	351	68	—	8	83	315	—	—
26N	49.025	21.340	6	—	—	—	42	70	—	5	65	86	—	—
27N	48.883	21.361	5	—	—	—	103	−70	—	9	44	148	—	—

VI. Lower Sarmatian

9	48.972	21.382	2	757	1312	1.2	352	−68	184	18	9	26	—	—
11	48.968	21.406	3	282	1763	0.3	39	43	23	27	52	135	20	33
34	48.923	21.437	8	764	966	1.6	214	40	27	11	13	169	—	—
38	48.918	21.377	3	4901	5868	1.7	23	68	383	6	76	92	9	11
40	48.907	21.489	3	187	1336	0.3	2	67	291	7	89	70	10	12
46	48.889	21.558	4	2106	6232	0.7	351	32	261	8	57	216	5	9
63	48.906	21.461	3	3903	1559	5.0	13	62	149	10	79	60	12	16
64	48.906	21.461	7	977	384	5.9	98	63	1966	2	26	72	2	3
67	48.675	21.453	7	103	512	0.5	6	52	126	5	74	184	5	7
69	48.639	21.441	9	75	164	1.0	319	71	37	9	64	321	13	15
70	48.610	21.517	5	1076	355	6.1	330	67	331	4	72	304	6	7
6N	48.610	21.528	5	—	—	—	334	59	—	—	68	272	—	—
8N	48.631	21.404	6	—	—	—	201	−75	—	—	71	55	—	—
9N	48.639	21.433	6	—	—	—	345	65	—	4	80	285	—	—
10N	48.623	21.425	3	—	—	—	28	67	—	10	73	95	—	—
12N	48.649	21.486	3	—	—	—	353	63	—	—	83	71	—	—
13N	48.675	21.435	5	—	—	—	40	70	—	7	66	82	—	—
28N	48.911	21.364	6	—	—	—	3	68	—	14	87	65	—	—

VII. Upper Badenian

59	48.781	21.489	3	47	281	0.4	256	−38	125	11	25	106	8	13
71	48.603	21.517	1	88	523	0.3	248	−67	—	—	49	83	—	—
72	48.507	21.800	6	52	143	0.8	147	−78	215	5	66	350	8	9
74	48.492	21.820	2	926	587	3.1	139	−36	68	31	46	264	21	36
75	48.467	21.767	7	100	102	2.0	145	−46	26	12	55	264	9	15
76	48.440	21.942	3	309	717	0.9	168	−40	2253	3	62	228	2	3
77	48.433	21.938	6	438	833	1.1	162	−28	108	6	53	232	4	7
78	48.430	21.923	15	274	628	0.9	160	−29	126	4	54	233	2	4

Design of local.	Coordinates of loc. φ_L	Coordinates of loc. λ_L	Number of samples	$J_n \cdot 10^6$	$\varkappa \cdot 10^6$	Q	D_L	I_L	k	α	φ_P	λ_P	δ_f	δ_m
79	48.425	21.933	6	430	998	0.9	162	−19	171	6	47	230	3	6
81	48.415	21.725	8	1338	67	39.9	163	−45	31	4	71	257	25	40
82	48.413	21.740	8	160	700	0.4	142	−40	113	6	49	266	5	8
83	48.407	21.800	7	252	785	0.7	141	−69	23	13	64	314	18	22
84	48.407	21.808	6	108	480	0.5	137	−52	69	8	53	280	8	11
4N	48.507	21.800	2	—	—	—	237	−57	—	8	47	106	—	—
5N	48.435	21.940	6	—	—	—	168	−24	—	10	52	222	—	—
19N	48.781	21.492	2	—	—	—	214	−54	—	22	2	173	—	—

VIII. Lower Badenian

73	48.487	21.665	5	—	—	—	27	31	5	37	20	173	23	41
1N	48.486	21.746	6	—	—	—	279	31	—	10	19	295	—	—

Table 2

Designation of group	Number of local.	Number of samples	Mean value of group coordinates φ_s	Mean value of group coordinates λ_s	J_{ns}	$\varkappa s \cdot 10^6$	Q_s	D_s	I_s	Coordinates of group paleopoles φ_p	Coordinates of group paleopoles λ_p
I Domatic bodies	7	43	48.946	21.431	695	1893	0,7	24,8	63,2	72,6	116,2
II Pannonian Pliocene	17	117	48.822	21.550	806	1573	1,0	58,0	77,0	56,0	61,0
III Upper volcanic stage	19	90	48.914	21.478	3395	2372	2,9	16,9	74,7	74,4	52,6
IV Lower volcanic stage	7	27	48.887	21.523	2234	2455	1,8	341,4	61,6	75,7	273,0
V Upper and Middle Sarmat.	28	135	48.840	21.480	1015	1760	1,2	331,1	71,4	72,2	325,6
VI Lower Sarmatian	18	88	48.791	21.424	1376	1859	1,5	358,5	73,2	79,8	17,0
VII Upper Badenian	16	88	48.496	21.778	348	526	1,3	340,2	44,7	63,0	243,7

dimensions of the oval of reliability of the position of poles (δ_f, δ_m) were calculated. All the calculated parameters are mentioned for the individual localities in tab. 1. The table is ordered according to distinguished groups.

The calculated data of medium directions of individual localities were the base for compiling of the map of directions of the remanent magnetization of localities, completed with a geological sketch-map (fig. 1). The results achieved by us were completed with paleomagnetic results obtained in the mountain range under consideration by A. E. M. Nairn (1967). These results are designated with an ordinal number with index N in all tables and graphs. All the measurements performed by the quoted author were obtained with equal methodical approach. On the basis of geological and paleomagnetic results given in the map (fig. 1) more precision was given to ranging of localities into the individual groups.

When analysing the demagnetization curves we find the rocks observed to display paleomagnetic stability. We conclude that after cleaning by alternating field magnetization is of thermoremanent magnetization (TRM) type. This assumption may be confirmed by several results, achieved on neovolcanic rocks.

For completeness, however, it is necessary prove these assumptions by the results of thermomagnetic analysis which may also confirm direct magnetization, so far supposed on the basis of mineralogical composition of rocks, comparison with similar types of rocks and the shape of the larger majority of demagnetization curves. Rocks from localities with a positive TRM polarity display approximately equal J_n and $\varkappa$ values as rocks of localities with a negative TRM polarity. This fact also testifies to a paleomagnetic stability of these rocks.

The analysis of the curves of alternating demagnetization permits us to distinguish about 8 typs among them (fig. 2).

The curves, typical representatives of which are 30 b with a positive inclination RM and 85 b_2 — with a negative inclination RM are displayed in rocks, in which the measured magnetization correspond only to one component — to the primary magnetization with a high stability of directions and relatively high coercitive force. Volcanic rocks of the studied area and with analogous types of alternating demagnetization curves are mostly not characterized by high values of magnetic characteristics. An exception are rocks from locality no. 32, which are characterized a high J_n. The Königsberger's coefficient of rocks from localities with these types of curves reaches the values 0.9—21.5. Further on, a relatively high „k" value and low values α 0.95 may be observed in them.

Rocks from localities with curves of alternating demagnetization displaying a similar course as 26 c (fig. 2) are characterized by predominating positive polarity RM, however, also cases with a negative RM polarity are observed. Also rocks from localities with a similar character of demagnetization curves as in this cas $81b_1$ show mostly a positiver, however, there are cases of negative polarity RM too. In rocks from localities with a character of demagnetization curves similar to 25a (fig. 2) we observe cases of positive as well as negative polarity RM. Some rocks showing a type similar to 25a are characterized by a larger dispersion of RM declination values after demagnetization by alternating field within the interval of values 25—500e. This larger dispersion of D and I we observe in rocks with $\varkappa$ essentially exceeding NRM, also in cases of a high secondary RM. In rock samples dispalying a course of demagnetization curves identical with types 25a and $81b_1$ we can point to the presence of a relatively soft secondary magnetization which may be removed by alternating field up to 200 k. The primary component, stable in direction, probably corresponding to TRM,

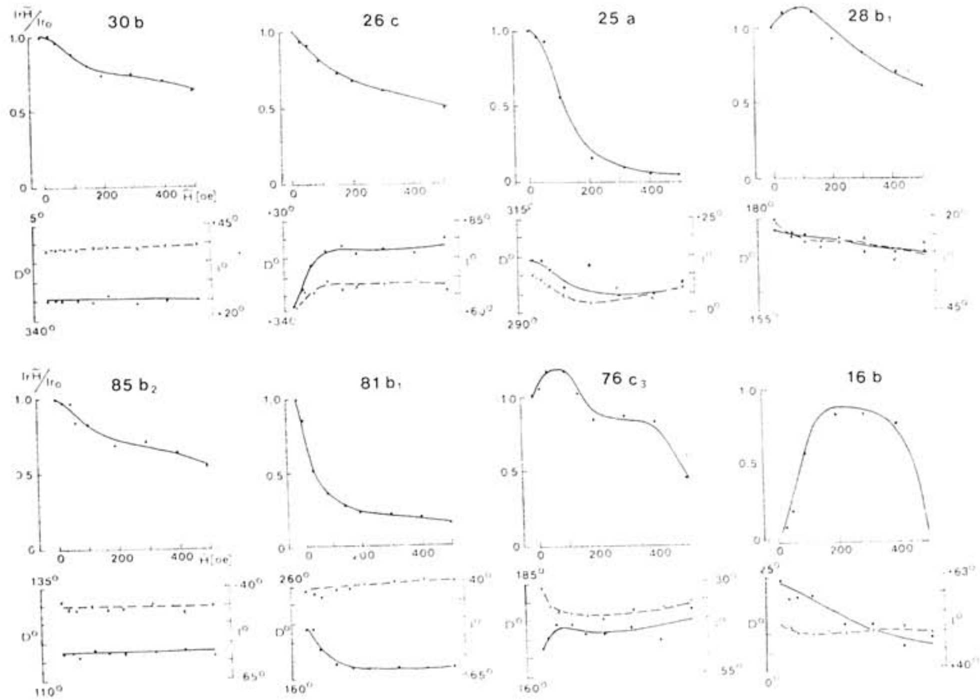


Fig. 2. Selected characteristic types of demagnetization curves: J° — magnitude of remanent magnetization before demagnetization of rock; J_H — Magnitude of remanent magnetization after demagnetization with a certain value of the field; Do — Declination of remanent magnetization; I° — Inclination of remanent magnetization.

Rock from localities with a course of curves identical with $28b_1$ and 76 c_3 (fig. 2) show a negative polarity RM only. The resulting NRM consists of a soft positive viscous magnetization and of directions of stable primary, probably TRM.

From the total number of the localities observed by us only the samples from iocality 17 display a character of curves identical with 16b (fig. 2). It may be seen from fig. 2 that sample 16b identical with as well as further samples corresponding to this locality display a positive polarity RM. Samples from locality 17 with a similar character of demagnetization curve, however, show a negative polarity RM.

At the presented stage of investigation similarity of demagnetization curve types has not been applied for giving more precision to distinguishing of rocks. Especially in individual samples the ferrimagnetic fraction has not been observed, we do not know the precise mineralogical composition, the size and shape of grains, even admixtures of impurities, having an essential influence on the character of demagnetization curve.

When evaluating the magnetic characteristics (J_n and $\varkappa$) of the individual groups we may observe that the highest values are in rocks of the upper volcanic stage — the complexes Šimonka, Čierna hora, Makovica (tab. 2). In the given arrangement of groups remanent magnetization increases in direction from the domatic bodies to rocks of the upper volcanic stage. The lowest J_n values display Upper Badenian rocks.

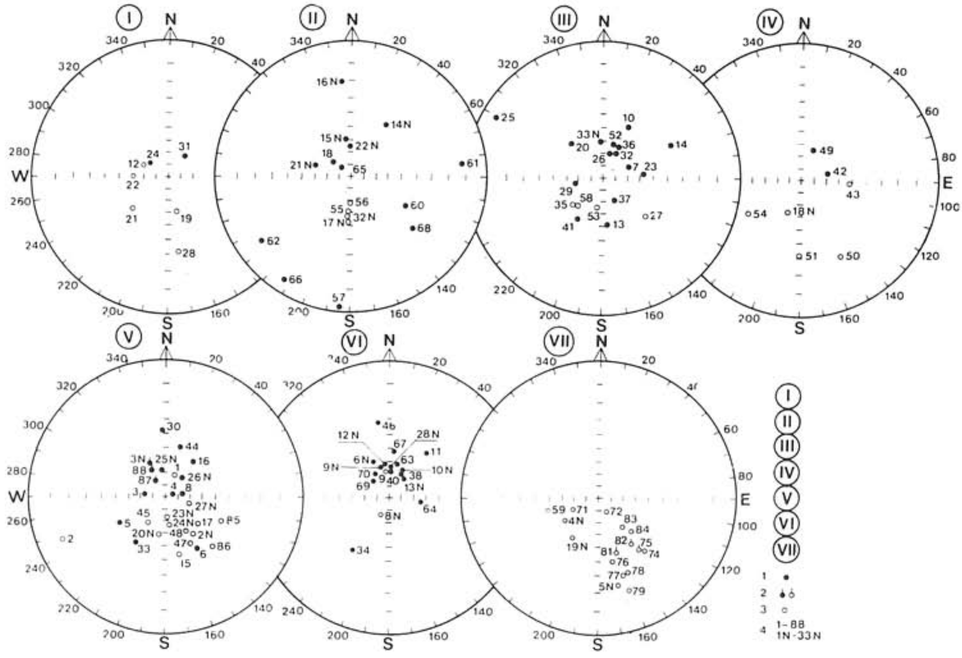


Fig. 3. Medium directions of remanent magnetization of localities of volcanic rocks: I. Domatic bodies, II. Pannonian + Pliocene — post-Sarmatian volcanics, III. Upper volcanic stage — Čierna Hora — Šimonka — Makovica complexes, IV. Lower volcanic stage — Ošvárska complex, V. Middle and Upper Sarmatian Komplex Brestov—Abramovce, VI. Lower Sarmatian, VII. Upper Badenian, o — Localities with negative RM polarity, ● Localities with positive RM polarity, — Rhyolites ● O — Andesites.

Magnetic susceptibility is highest in rocks of the lower and upper volcanic stage. In rocks of domatic bodies, of the undivided Pliocene, of the Lower Middle and Upper Sarmatian susceptibility attains comparable values. The lowest ϰ values are reached in Upper Badenian rocks.

Polarity TRM which we use in correlation of the observed rocks as the fundamental paleomagnetic criterium appears to be the most objective date among others.

The medium RM directions of individual localities are variously dispersed (fig. 1).

In the first group corresponding to domatic bodies, beside five localities with a negative RM polarity, also two localities with a positive RM polarity occur (fig. 3). Although relatively a few localities are concerned, the results require to consider a time differentiation of forming of these rocks.

In rocks from localities of the IInd group, corresponding to the undivided Pannonian and Pliocene, localities with a positive RM polarity are prevalent (fig. 3). In the case of 8 localities with a positive RM polarity a large dispersion in derictions is to be observed. Four localities of this group display a negative RM polarity. Also in this case the results point to a long-dated interval of time of formation of rocks of this complex.

From the total number of 18 localities ranged to group III corresponding to the complexes Šimonka, Čierna hora—Makovica four localities display a negative and further 14 ones a positive RM polarity. The results indicate the need of distinguishing these rocks in a time succession.

Rocks of group IV. in the complex Ošvárska, show in the case of two localities a positive RM polarity in the case of 5 localities a negative RM polarity. Regarding to the paleomagnetic stability of rocks we cannot suppose a contemporaneity of localities with positive and negative RM polarity of this group.

Also RM polarity of the individual localities of Upper and Middle Sarmatian rocks (group V. fig. 3) points to a time differentiation of forming of rocks from localities with a time differentiation of a positive and negative RM polarity. Among the total number of 26 localities 12 display a positive and 14 a negative RM polarity.

The localities of the Lower Sarmatian (group VI. fig. 3) represent a set relatively complete as to directions. Among 18 localities of this group only two display a negative RM polarity, the remaining ones show a positive RM polarity. Preliminarily we suppose that the investigated Lower Sarmatian rocks have a positive RM polarity only. We consider as suitable to take into account occasional incontemporaneity of forming of Lower Sarmatian rocks only after the up to present results are completed with further ones from localities of the Lower Sarmatian not observed paleomagnetically so far.

Most complete is the group VII — Upper Badenian. The observed localities are characterized by a negative RM polarity only.

To establish more precisely the time succession of volcanic activity in the mountain range under consideration on the basis of exclusively paleomagnetic characteristics is problematic. We cannot use the coordinates of the virtual pole in this stage of investigation for giving more precision to the time succession of volcanic activity as the influences of secular variations as well as further influences not analysed precisely so far, have not been eliminated from the results of measurements.

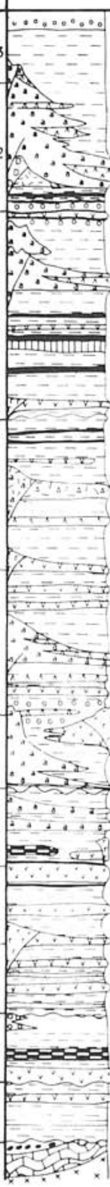
For the time being we apply for correlation of stratigraphic groups the so called geomagnetic scale of time, compiled by J. R. Heirtzler et al. (1968).

Geological interpretation

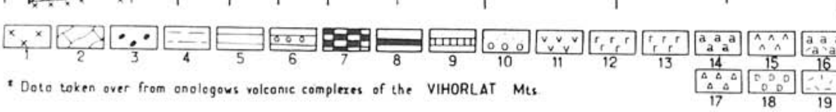
The oldest measured group of volcanic rocks (VII) are Badenian volcanics, mainly from the southern margin of the East Slovakian Neogene and from the area of the Slánske pohorie Mts. (see the lithostratigraphical profile and map — fig. 1 and 4). A characteristic property of this set of paleomagnetic measurements is an exclusively negative RM polarity. Basal rhyolite complexes may belong to the period of negative polarity, of the earth's magnetic field ranging 16.41—17.33 mill. y. Formation of Badenian andesite complexes of the Zemplínske pahorky Hills and the Slánske pohorie Mts. we may place to the interval of negative polarity of the earth's magnetic field dated back 15.45—15.71 mill. y. (fig. 5). However, we do not exclude the possibility that andesite complexes of southern Zemplín and/or their lower parts could have formed already in the period of negative polarity 16.41 mill. y. ago.

→

Fig. 4. Cumulative lithostratigraphic table of the Slánske vrchy Mts. and Zemplínske pahorky Hiles. Explanations: 1. Pre-Mesozoic substratum of the area. 2. Envelope Mesozoic — limestones, dolomites (Triassic). 3. Central Carpathian Paleogene Neogene. 4. Clays and marly clays; 5. sandstones; 6. conglomerates; 7. salt; 8. coal seams; 9. diatomite; 10. graved, gravelous sand; 11. rhyolite tuff; 12. rhyolite; 13. perlitic rhyolite; 14. pyroxene andesite; 15. pyroclastic rocks of pyroxene andesite; 16. amphibole — pyroxene andesite, diorite — porphyrite; 17. pyroclastic rocks of amphibole-pyroxene andesite; 18. dacite; 19. dacite pyroclastic rocks.



STAGE		Max. thickness in m sedim.	volc.	Abs. age in mill. y.	PETROGRAPHIC TABLE OF COMPLEX sediments	volcanics	SIGNIFICANT LOCALITES OF VOLCANICS	STRATIGRAPHIC LOCATION of individual measured objects for RM		STRATIGRAPHIC GROUPS - -COMPLEX	
Romanian	Pl_3	~200	~600	8±0,3*	gravels, sands	— domes, dykes lava fields, stratovolcanoes of pyrox. andesites andesite- -dacites dacites	Zlatá Baňa Šimonka Hermanovský hrebeň Ridge Bodoň Makovica Bogota Lazy, Dubník Boreholes Kráľ. Chlmec Streda n. Bodr.	23, 10, 58, 52, 7, 29, 27, 13, 14, 20, 26, 25, 53, 37, 36, 35, 32, 41, 33 N	28, 21 22, 19 31, 24, 12, — 55, 56, 57, 66, 62, 60, 65, 66, 61, 18,	I III COMPLEX ŠIMONKA - ČIERNA HORA AND MAKOVICA	II
Dacian	Pl_2				Coal-bearing strata with tuffites and limno- quarcites. gravels with andesite						
Pannonian	c	300	~300	11±1*		Fine-grained rhyolite tuff predominantly stratovolcanic pyroxenic andesites	Červenica, Zamutov Banské Červenica Zamutov Banské Herľany	54, 43, 51, 50, 42, 49,	14N, 16N, 17N, 22N, 31N, 21N, 15N, 32N	IV COMPLEX OŠVÁRSKA	
	b				Coal-bearing clays, marly clays, diatomites						
	a		~90			Rhyolite pyroclastic rocks	boreholes near Kráľovský Chlmec	—	—		
Sarmatian	Middle and Upper	400	~250 ~300	11,75±0,25* 12,0±0,5	Coal-bearing clays, marly clays, pred. spotted	Amf-pyroxen andesites and their pyroclastic rocks, diorite-porphyrites, clastolavas Rhyolites, tuffs, perlites, obsidians	Stráž, Oblík, Brestov, Vorhanovce, Maglovec, Kuria Hora, Oblazy, Abranovce Streda n. Bodrogom, Viničky, Lastovce, Byšta, Kuzmice	47, 48, 33, 6, 5, 4, 8, 17, 15, 16, 45, 30, 44, 3, 2, 1, 86, 3N, 20N, 23N, 24N, 25N, 26N, 27N, 85, 2N, 87, 88,		V	FORMATION BRESTOV - ABRAMOVCE
	Lower	1500	20 1000 30 20	13,0±1 14,0±1 13,6±2,1	Marly clays Clays, marly clays	Stratovolcanoes of pyrox andesites, clastolavas of pyrox andesite, rhyolite tuffs	Lesíček, Žehyňa, Tuhrina, Kolša, Libanka, Malčice, Beša, Vojany Slanec Ruskov, Rákoš N.Myšla, Rankovce Olšava	67, 69, 40, 64, 63, 9, 11, 34, 38, 7N, 8N, 9N, 10N, 6N, 12N, 13N, 28N, 70, 46		VI	
Badenian	d	1700	350	14,7±1,4 15,0±2,0	Conglomerates, clays	Mainly Rhiolite lava streams of pyrox andesite, te volcanism mainly pyroclastic rocks	Brehov, Opina, Zamutov, Simik, V. Kamenica, Stráň, Tuhrina, borehole Žipov, Kráľ. Ch, Mirkovce, Varhaňovce, Zatín	59, 76, 83, 72, 71, 79, 84, 77, 78, 74, 4N, 5N, 19N		VII	
	c		800	16,7±0,1 16,0±0,8 16,2±2,0 16,5±0,5	Clays, marly clays Marly clay salt	Rhyolite tuffs	M. Bara? Michaľany Veľky Kazimír		75, 82, 81, 18N		
	b	700	100	16,5±0,5 16,0		Rhyolite pyroclastic rocks	Šarišská Poruba Zlatá Studňa				
	a		60 ~10 ~10	15,7±2,8 16,0±2,0	Clay shales, marly and shaly clays, sandstones	Rhyolite pyroclastic rocks and domes	Hrčel, Luhyňa, Cejkov, Žipov borehole, Kašov	73, 1N			
Karpatian		1200	50	–	Conglomerates, marly-shaly clays grei-violet sandstones, salt	Rhyolite pyroclastic rocks	Fintice				
Eggenb.	low. upp.	300	5	–	Sandstones, shales	Bentonitized and celadonitizet tuffs	Fintice, Terňa, borehole Čelovce				



* Data taken over from analogows volcanic complexes of the VIHORLAT Mts

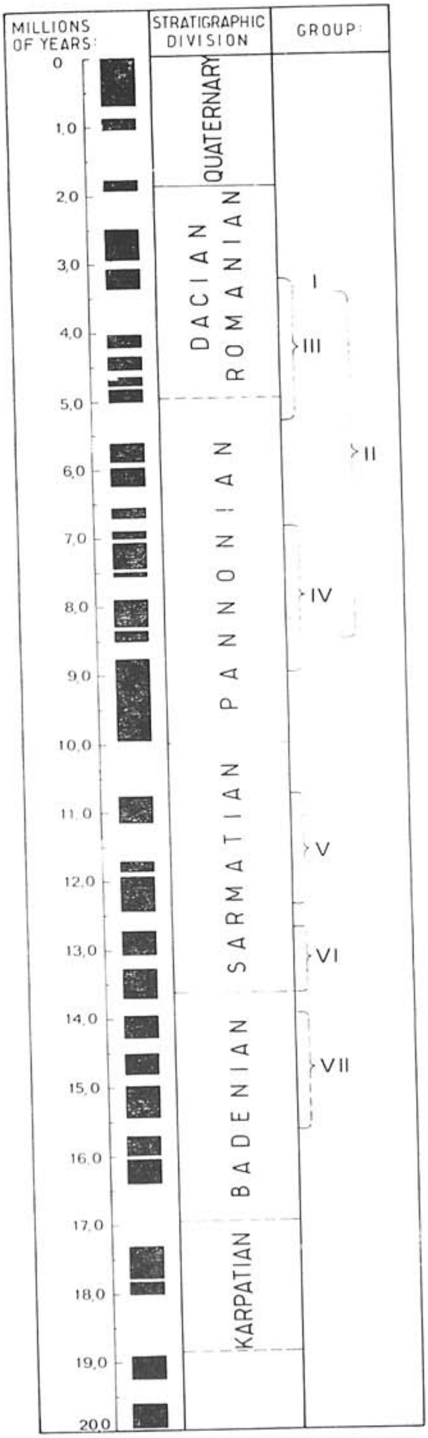


Fig. 5. Correlation of stratigraphic groups with the geomagnetic time scale of J. R. Heirtzler et al. (1968). Numbering 0—80 on vertical scale given in millions of years. The empty fields represent intervals of negative polarity of the earth's magnetic field. With numbers I—VII are designated individual distinguished groups.

The group of Lower Sarmatian rocks (VI) displays a very small dispersion in RM directions and almost the whole group has a positive RM polarity, with the exceptions of samples no. 9 and 8N. Sample no. 9 was taken from lavaclastic rocks, where already in the time of their formation rotation could have taken place, which fact explains the different polarity of this sample when compared with the remaining set. Sample no. 8N may belong to Badenian andesite volcanism as it was taken from andesites layin at the base of the Veľký Milič massif, where such a stratigraphic ranging is probable.

On the basis of preferred directions with a negative RM polarity in Upper Badenian andesite complexes and with a positive RM polarity in Lower Sarmatian andesit complexes, we may apply RM polarity in pre-Middle Sarmatian andesite complexes of eastern Slovakia as one of the most suitable criterri for their stratigraphic division, especially important in the case of the Veľký Milič massif and the buried Zemplínske pohorie Mts.

Group V includes mainly amphibole-pyroxene andesites and diorite porphyrites of the northern part of the Slánske vrchy Mts. Grouping of positive and negative RM polarities is relatively homogeneous with not a large dispersion, however, the difference in polarities in bodies near geologically and in situation testifies to that volcanic activity having given rise to the Middle—Upper Sarmatian Brestov—Abramovce formation and to the group of semi-intrusive and domatic bodies extending from the Šariš castle to Oblazy proceeded in a certain time succession and it was not a sudden event. A more precise determination of age of these volcanic complexes will be possible after their reliable absolute dating only.

To this group we assign, conventionally, also rhyolites from the area of Streda nad Bodrogom because of their geological proximity to obsidian-bearing rhyolite tuffs, the Middle Sarmatian age of which can be supposed.

Paleomagnetic evaluation of the Ošvárska complex (J. Slávik — J. Tözsér 1973 — group IV) displays a negative RM polarity in samples convincibly ranged stratigraphically (samples no. 43, 50, 51, 18 N). A positive RM polarity display samples only probably ranged to the lower volcanic stage. Due to this fact we suppose that the major part of Pannonian volcanics will display a negative RM polarity, where in the case of a suitable area it will be necessary to verify the presence of positive RM polarities, which may testify to a longer-dated formation of the Ošvárska complex.

Characteristic of the culminating volcanic stage of the Slánske vrchy Hills (group III) i. e. of the complexes Šimonka—Čierna Hora and Makovica (J. Slávik — J. Tözsér 1973) is the predominating positive RM orientation (13 positive and 5 negative orientations) and it has obviously formed in a longer period of time. Various polarities confirm these facts and show that several volcanic events, differing in age, can be distinguished in the upper volcanic stage.

The group of volcanics of the undivided Pannonian—Pliocene (II) is characterized by a very wide dispersion of directions, also of RM polarity. This reflects the fact that post-Sarmatian volcanics are assigned to it, which cannot be ranged more precisely in stratigraphy so far.

Particular attention should be paid to samples no. 57, 61, 62, 66, lying at the periphery of the diagram, what may point to the afact that volcanics passed through Curie's point in the period close to the inversion of magnetic field. To such a period also sample no. 26 from the volcanic complex Šimonka—Čierna Hora may be ranged.

To the Ist group bodies of unaltered or slightly altered rocks in the hydroternally highly altered area of the Zlatá Baňa volcanotectonic depression are assigned. The variety of petrographic composition of these volcanics indicates many stages of their formation. It is not excluded that some of these bodies can be undecomposed relicts of original volcanogenic structures.

Conclusions

Paleomagnetic-geological investigation of the Slánske vrchy Mts., Veľký Milič and Zemplínske pahorky Hills makes not only detailed distinguishing of the individual volcanic complexes and RM characterization but also correlation between them and the Vihorlat Mts. possible (O. Orlický — P. Pagáč — J. Slávik 1970).

Paleomagnetic investigation calls attention to the time accordance of forming of the Vinné—Závadka formation in the Vihorlat area and of the Brestov—Abramovce formation of the Slánske vrchy Mts. This coincidence in time is also defined by two RM polarities in the Vihorlat Mts. However, whilst in the Vihorlat Mts. volcanic bodies with various RM polarity are also separated spatially, in the Slánske vrchy Mts., it has not been possible to find the regularities in spatial distribution of volcanic bodies of various polarity of this volcanic formation. This we may consider as an evidence of a longer period of its formation.

Different is the picture of post-Sarmatian volcanism in both areas. Whilst in the Vihorlat the lower volcanic stage (Kyjov—Orechová formation) displays unambiguously a positive RM polarity, in the Slánske vrchy Mts. the Ošvárska complex shows predominantly a negative RM polarity. The contrary is in the upper volcanic stage, which i clearly negative in the Vihorlat Mts. (Valaškovce formation), whilst in the Slánske vrchy Mts. area most measurements display a positive RM polarity.

On the basis of geological and/or geomorphological reasons, according to which the Vihorlat is a younger mountain range than the Slánske vrchy Mts., we suppose that the upper volcanic stage of the Slánske vrchy Mts. (Šimonka—Čierna Hora and Makovica complexes) is older than in the Vihorlat Mts. (Valaškovce formation). It is similar also in the case of the lower volcanic stages of both mountain ranges.

The performed paleomagnetic investigation of the Slánske vrchy Mts., Zemplínske pahorky Hills and Veľký Milič massif maked not only a more precise knowledge of the structure of the mountain range but also getting a more precise succession of individual volcanic events possible. At the same time it provides a key for a detailed study of the mountain range structure and this way also for solving of some metallogenetic problems.

Translated by J. PEVNÝ.

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