HYDROTHERMAL ALTERATIONS OF ROCKS IN THE TRIASSIC DOLOMITE AREAS ADJACENT TO THE DANUBIAN ANDESITE MOUNTAINS

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The study on the hydrothermal and metasomatic phenomena observed in the Triassic limestone areas bordering on the Danubian andesite mountains (Visegrádi Mountains, Börzsöny Mountains) GY. VITÁLIS—J. HEGYI-PAKÓ 1974) has been extended to the adjacent dolomite areas as well. In accordance with their composition and the circumstances, the hydrotherms have produced various alterations in the dolomite sequence too, which are connected with the hydrothermal processes of the aftermath of the Tertiary andesite volcanism of the Danubian andesite mountains.

The distribution of the Triassic dolomite and Tertiary andesite sequences at the surface of the area under study as well as the major boreholes that hit or cut the dolomites and the points of sampling are shown in *Fig. 1.* The Triassic limestone sequence can be found in the footwall of the adjacent Triassic limestone deposits or, in the areas of the Mesozoic basement, immediately below the basin sediments, at comparatively greater depth throughout the territory (*Fig. 2*).

In the above areas the hydrothermal solutions, which ascended along open fractures from rocks of diversified composition and/or which traversed these with considerable shifts in time and which acquired thus different chemical compositions, resulted in various rock alterations, i.e. mineral and rock varieties, in the individual rocks affected (dolomites, limestones, andesites).

These changes in rock composition belong, practically, to the *group* of *slight hydrothermal* (hydrothermal cementation, hydrothermal decomposition, pulverization of dolomite) and *heavy hydrothermal* or *metasomatic* (epigene calcitization, silicification, magnezitization) effects. The slight hydrothermal effects do not change the chemical composition of the rock either in the dolomites or in the limestone sequences studied earlier, whereas the heavy hydrothermal (metasomatic) effects have produced, in dependence on their intensity, a chemical composition, different from the original one, in both the rock types concerned.

Traces of slight hydrothermal effects can be found along places of one-time hot spring emergences throughout the areas studied, thus being common. Epigene calcitization and silicification, assigned to the category of heavy hydrothermal effects, were observed to occur more widely in the vicinity of major fractures, while magnezitization could be observed only in the form of faint traces of local occurrence.

The processes of rock alterations provoked by slight and heavy (metasomatic) hydrothermal effects in the major rock sequences of the investigated territory (dolomite, limestone, andesite) have been summarized in *Table 1,* on the basis of the petrometallogenetic tables of V. SZÉKY-FUX (1970), according to the principles to be expounded in the present paper.

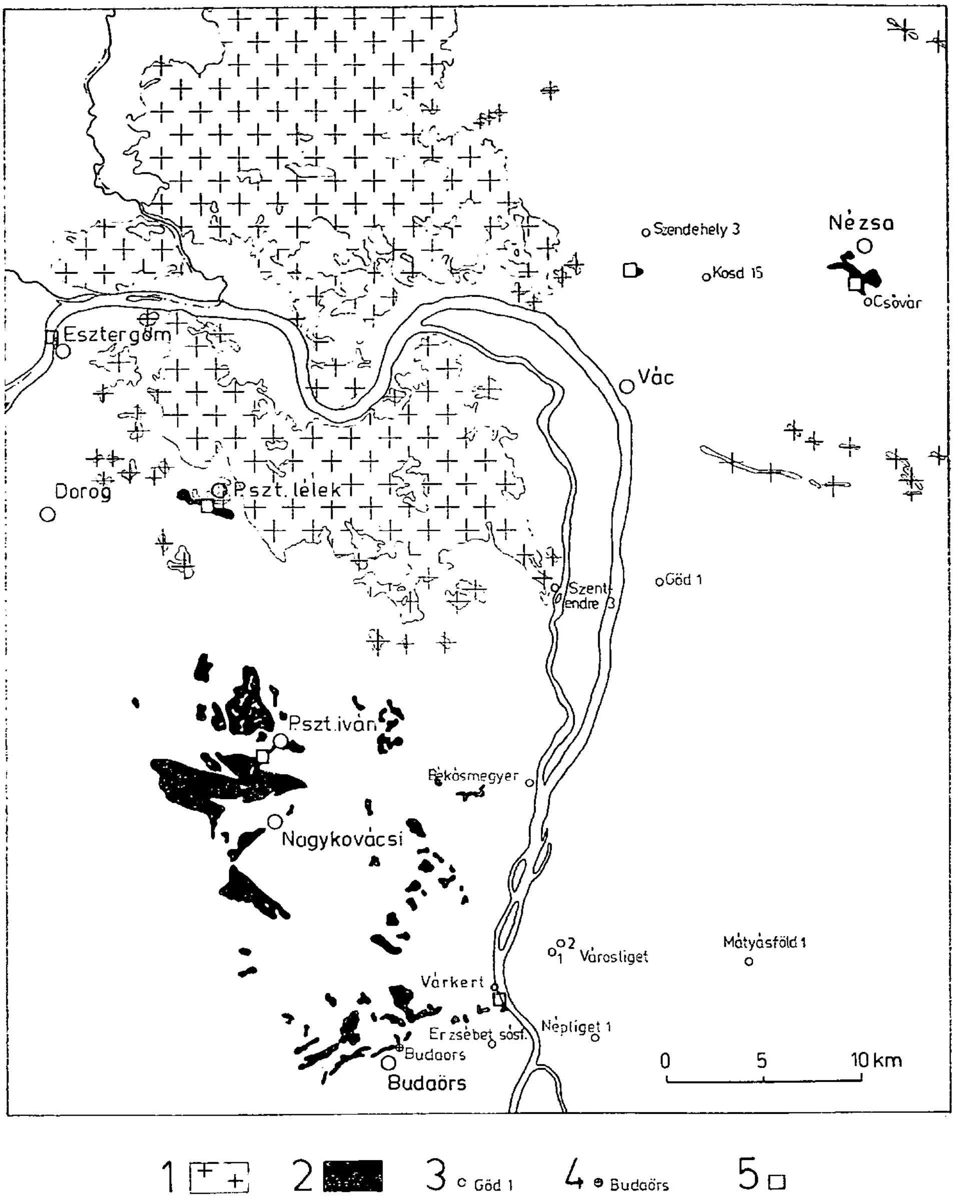


Fig. 1. Geological map-scheme of the Danubian andesite mountains and the dolomite areas adjacent to them (simplified after map information from the Hungarian Geological Institute) 1. Andesites and their tuffs *(Tertiary)*; Diplopora dolomite *(Ladinian)*, dolomite *(Carnian)* and Hauptdolomit *(Norian)* at the surface; 3. Major borehole reaching or intersecting dolomites; 4. Major borehole intersecting andesites in the dolomite sequence; 5. Sampling points

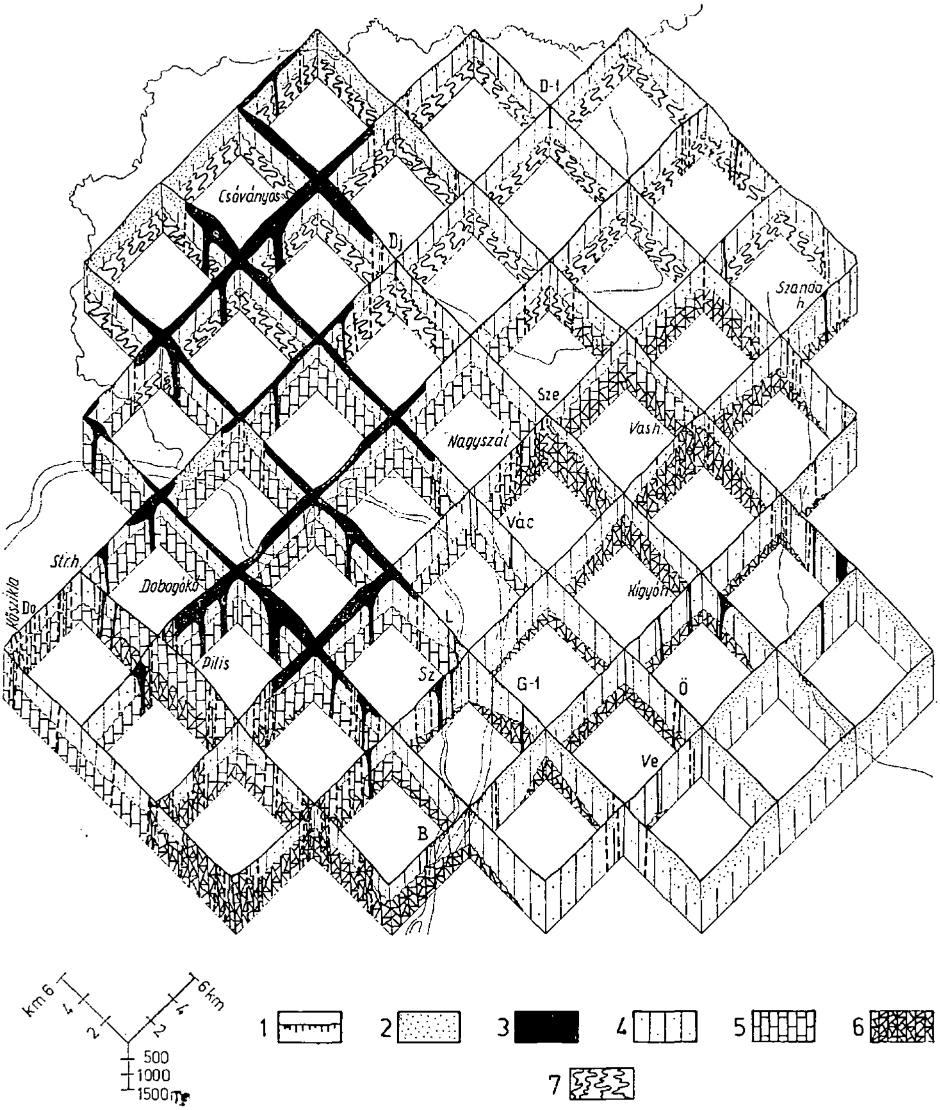


Fig. 2. Schematical geological block-diagram of the Danubian andesite mountains and the dolomite areas adjacent to them (simplified after map information from the Hungarian Geological Institute) (Base level of reference: —1400 m below sea level) 1. Fluviatile alluvium *(Quaternary)*; 2. Gravel, sand, sandstone, clay, argillaceous marl, limestone *(Neogene)*; 3. Andesites and their tuffs (*Tertiary*); 4. Sand, sandstone, argillaceous marl, limestone *(Paleogene)*; 5. Limestone, 6. Dolomite sequence *(Mesozoic)*; 7. Shale, phyllite, micaschist, gneiss *(Paleozoic)*

TABLE 1.

Hydrothermal effects and alterations of rocks

Hydrothermal effect	Hydrothermal rock alteration process		
	In dolomite (Triassic)	In limestone (Triassic)	In andesite (Tertiary)
	sequence		
Slight hydrothermal effect	hydrothermal cementing, hydrothermal decomposition, pulverization of dolomite	hydrothermal decomposition, pulverization of limestone	hydrothermal decomposition, pulverization of andesite
Heavy hydrothermal (metasomatic) effect			
Hydrothermal (H_2O)	—	—	argilization, sericitization
Hydrothermal (Si)	silicification	silicification	silicification
Hydrothermal (Fe, S)	ankeritization-sideritization, dispersion of pyrite	sideritization, dispersion of pyrite	pyritization
Hydrothermal (Ca, CO_2)	calcitization	calcitization	carbonatization
Hydrothermal (Mg, CO_2)	magnesitization	dolomitization	carbonatization
Hydrothermal (K)	—	—	K-metasomatism

TABLE 2.

Summarization of the chemical and mineralogical analyses

Serial number	Name and locality of rock	Chemical composition									Mineralogical composition	
		Loss on ignition	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O*	K_2O*	SO_3	Based on thermal	Based on X-ray
		per cent by weight									analyses	
1.	Hydrothermally cemented dolomite, cliff facing the dolomite quarry near the viaduct at Pilisszentlélek	46,92	0,27	0,10	0,40	33,28	19,40	0,10	0,10	0,02	dolomite	dolomite, calcite (feldspar)**
2.	Hydrothermally cemented dolomite along a fault at Pilisszentiván Ördögtorony	46,80	0,55	0,20	0,13	31,32	20,84	0,10	0,10	0,06	dolomite	dolomite, (calcite)
3.	Hydrothermally cemented dolomite, cliff behind the dolomite quarry near the viaduct at Pilisszentlélek	47,23	0,27	0,58	0,08	30,11	21,62	0,10	0,14	0,05	dolomite	dolomite
4.	Hydrothermally cemented dolomite, dolomite quarry near the viaduct at Pilisszentlélek	47,20	0,33	0,10	0,04	31,08	21,67	0,10	0,10	0,02	dolomite	dolomite (feldspar, calcite)
5.	Hydrothermally decomposed dolomite, western side of the hill Várhegy at Esztergom, at the foot of thecastle wall	44,99	1,80	1,99	0,24	29,84	19,78	0,10	0,21	0,58	dolomite, pyrite	dolomite, (quartz, feldspar)
6.	Hydrothermally decomposed dolomite, at the western foot of the hill Várhegy, opposite to the property of 18, Berényi Street	46,90	0,31	0,25	0,16	32,38	19,79	0,10	0,10	0,06	dolomite	dolomite
7.	Hydrothermally decomposed dolomite, south of the triangulation point 534 on the Nagyszál at Vác	46,96	0,37	0,39	0,50	30,66	20,66	0,10	0,10	0,10	dolomite, calcite	dolomite, (calcite, feldspar)
8.	Pulverulent dolomite, Kecskés valley at Csővár	46,34	2,52	1,19	0,19	23,40	20,05	0,10	0,10	0,34	dolomite	dolomite, kaolinite, quartz, feldspar
9.	Pulverulent dolomite, Pilisszentlélek, 21,8 km of the Esztergom — Dobogókő road	47,02	0,53	0,16	0,14	30,62	21,00	0,10	0,10	0,11	dolomite	dolomite, calcite, (feldspar)
10.	Calcareous dolomite, dolomite quarry near the viaduct at Pilisszentlélek	45,22	0,19	0,39	0,18	42,75	11,26	0,10	0,10	0,06	dolomite, calcite	dolomite, calcite
11.	Rheniform-nodular, calcareous dolomite, at the parking place near the viaduct at Pilisszentlélek	45,01	1,23	0,22	0,20	39,86	12,90	0,10	0,10	0,02	dolomite, calcite	dolomite, calcite (feldspar)
12.	Limonitic, dolomitic limestone, dolomite quarry near the viaduct at Pilisszentlélek	42,22	1,26	1,27	3,01	46,71	5,13	0,22	0,10	0,06	calcite, dolomite, limonite, (clay minerals)	dolomite calcite
13.	Siliceous dolomite, opposite to the property of 78, Somlói Street, Gellérthegy, Budapest	22,62	51,48	0,33	0,16	15,12	9,75	0,10	0,10	0,20	dolomite, quartz	quartz, dolomite, calcite
14.	Spongy, siliceous matrix, opposite to the property of 78, Somlói Street, Gellérthegy, Budapest	3,55	89,76	0,50	3,05	2,12	0,84	0,10	0,10	0,44	quartz, limonite, dolomite	quartz, dolomite
15.	Dolomite of very low magnesite content, borehole Nagyszál XV—1, 50,0 m, at Vác	47,36	0,10	0,10	0,03	30,17	22,03	0,10	0,10	0,01	dolomite, (magnesite)	dolomite, calctie
16.	Dolomite of very low magnesite content, along a fault, dolomite quarry near the viaduct at Pilisszentlélek	47,40	0,18	0,10	0,12	30,17	22,10	0,10	0,10	0,01	dolomite, (magnesite)	dolomite

* The 0,10 per cent value of Na_2O and K_2O is lower than 0,10%

** The minerals in brackets are present in very low quantities.

TABLE 3.

Average trace element content of the examined samples, combined by rock types, in ppm

Rock name (serial number)	Trace element Cu	Ag	Be	Zn	B	Ga	In	Ge	Zr	Sn	Pb	V	As	Sb	Cr	Co	Ni	Mo	Y	Sc	Sr	Ba
Hydrothermally cemented dolomite (1—4.)	8	1	2	D	10	10	1	1	D	10	10	7	33	5	4	10	11	4	3	1	53	6
Hydrothermally altered dolomite (5—7.)	10	1	2	100*	14	10	1	1	48	5	13	6	24	5	4	10	10	3	3	1	70	90
Pulverulent dolomite (8—9.)	5	1	2	D	10	10	1	1	66	5	10	5	22	5	8	10	10	3	4	1	65	55
Calcareous dolomite (10—11.)	7	1	2	D	10	10	1	1	D	5	10	7	19	5	4	10	10	3	5	1	60	15
Dolomitic limestone (12.)	13	2	2	D	10	10	1	1	D	5	10	14	50	5	15	10	10	9	5	1	80	60
Siliceous dolomite (13.)	50	30	2	50	17	10	1	1	42	140	130	4	72	180	36	16	10	3	3	1	54	200
Spongy siliceous matrix (14.)	50	1	9	240	50	10	2	2	31	5	25	15	300	24	10	17	100	5	3	1	34	200
Dolomite of very low magnesite content (15—16.)	5	2	2	100	10	10	1	1	D	5	12	8	24	5	4	10	10	6	6	1	45	14

Remark: The numbers of the samples are identical with the serial numbers of *Table 2!*
D = Not evaluable because of the dark beckground.
* = Results obtained by classic (wet) analytical methods.

Of the mineralogical, petrographical and chemical analyses of rock samples representative of the various hydrothermal effects, those obtained for some type specimens have been presented in *Tables 2* and *3*. The samples have been listed for each particular rock type in the order of increasing MgO content.

The chemical and instrumental analyses were performed at the Department of Silicate Chemistry of the Central Research and Design Institute for Silicate Industry, the analyses for trace elements were carried out by M. HORVÁTH of the Chemistry Department of the Mining Research Institute, thin section photographs, under crossed nicols, and their interpretation were made by I. CSORDÁS of the Department of Mineralogy and Petrography of the Technical University of Heavy Industry

Slight hydrothermal effects are represented by the hydrothermally cemented dolomite (samples 1 to 4), hydrothermally altered dolomite (samples 5 to 7), and pulverulent dolomite (samples 8 and 9) shown in *Table 2*.

The epigene calcitization due to hot springs that penetrated the dolomites, which, in the form of veins, produced partly calcareous dolomites (samples 10 and 11), partly dolomitic limestones (sample 12 and J. HEGYI-PAKÓ 1973), can be considered to represent *heavy hydrothermal (metasomatic) rock alterations*. One of the characteristic manifestations of this process is the rheniform-nodular dolomite, consisting of an aggregate of dislocated crystals without the onionshaped spherical jointing of pisolites, in a form resembling that of cauliflower (sample 11). The more or less intensive silicification of dolomite is also due to heavy hydrothermal (metasomatic) effects (samples 13). The cellular-spongy matrix of siliceous dolomite is illustrated by the analytical results obtained for sample 14.

Averaged by rock types, the trace element contents of the samples of *Table 2* have been summarized in *Table 3*. Figuring in highest quantities, the Sr, Ba, As, Pb, Sn. Cu, V. and Cr contents are relatively "mean" in the dolomites affected by slight hydrothermal effects, whereas in the rock affected by heavy hydrothermal (metasomatic) effects, the trace elements are partly poor (e.g. dolomites of very low magnezite content [sample 15—16], calcareous dolomite [samples 10—11]), partly rather abundant (e.g. dolomitic limestone [sample 12], siliceous dolomite [sample 13], spongy, siliceous matrix [sample 14].

On the field, the changes in rock composition are readily reflected by the morphology. The hydrothermal effects will partly loosen the rock, partly cement it. For instance, the cliffs soaring in the vicinity of Pilisszentlélek or the Ördögtorony at Pilisszentiván represent rock portions more resistive to erosion, being, at the same time, indicative of places, where hot springs used to well up. Because of hydrothermal effects, the rock here has been cemented by a partly siliceous, ferrous, partly calcitic matrix (sample 1 to 4, and sample *3 and 4*).

The hydrotherms responsible for silicification are — in accordance with those described in the Buda Mountains (Z. SCHRÉTER 1912, F. SCHAFARZIK 1928, E. SCHERF 1928) — in connection with the earlier hot spring activity, those responsible for epigene calcitization and dolomite pulverization being due to the later (Quaternary) activity. It should be noted in this connection that, wherever siliceous hydrotherms penetrated the rock, no pulverization of dolomite took place (conf. L. JAKUCS 1950a, 1950b and 1971).

Piercing the Triassic dolomite sequence of several hundred metres thickness, the magnesium-ion-rich hydrotherms have also caused some slight metasomatic magnezitization of the dolomites. Very slight manifestations of this are shown by the results obtained for samples 15 and 16.

In a pure dolomite of Ca : Mg = 1 : 1 ratio the MgO content is 21.74%. According to the classification proposed by FROLOVA (1959) (see: G. CHILINGAR—H. BISSEL—R. FAIRBRIDGE 1967, p. 108, Table VII/, the CaO/MgO ratio of the dolomite of very low magnezite content is 1.25 to 1.40. The MgO content of sample 15 is 22.03, its CaO/MgO ratio is 1.37; in case of sample 16 the quantity of MgO is 22.10%, the CaO/MgO ratio being 1.36. In addition, a slight curvation characteristic of magnezite can be seen on the thermograms of both samples, before the double endothermal peaks characteristic of the decomposition of dolomite with a temperature maximum of about 700 °C. Magnezite does not appear in the X-ray results, which is seemingly due to its very low quantity.

The metasomatic dolomitization of the limestone areas adjacent to the Danubian andesite mountains (GY. VITÁLIS—J. HEGYI-PAKÓ 1974) and the hydrotherms which penetrated dolomite areas as well are facts calling attention to the possibility of *magnezitization.* The process of metasomatic dolomitization of limestones is notably followed—according to the processes of ore deposition—by the magnezitization of these, without any pause between the two processes (I. VITÁLIS 1914).

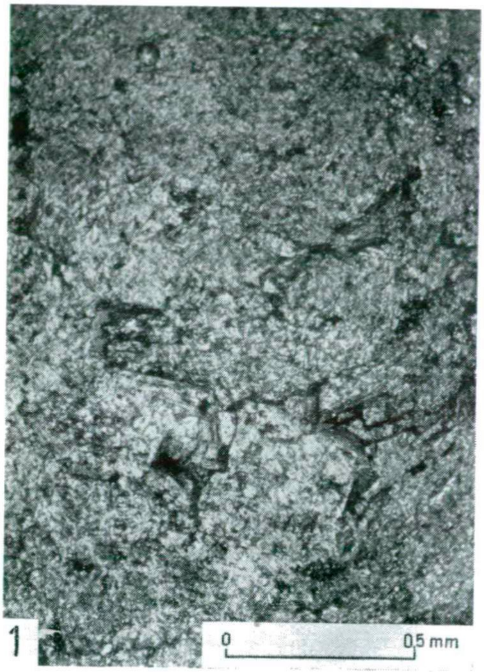
The initial process of magnezitization is evidenced by the dolomite of slightly higher MgO content, compared to the typical dolomite, recovered from the dolomite quarry of Pilisszentlélek (sample 16) and from the 50 m of borehole Nagyszál XV-1 at Vác. *It is also possible that dolomites affected by more intensive magnezitization may also occur at considerable depths* in both areas (GY. VITÁLIS—J. HEGYI-PAKÓ 1973).

Analyzing the origin of the magnesium ions required for metasomatic dolomitization, one may even suppose the presence of *magnezite deposits connected with* deeper Triassic *sedimentary rocks* (H. LEITMEIER 1953) which were traversed by the hot springs.

In order to enable a study of the processes of hydrothermal rock alteration, and a better recognition of the rock-forming minerals and the matrix, petrographic microphotographs were made of polished sections by etching and replica techniques. This method is unambiguously suitable for the distinction between calcite and dolomite.

The microphotographs made for the examination of hydrothermally cemented dolomites representative of *slight hydrothermal effects* (*Photographs 1—2*) show a calcitic fill observable along fissures. In *Photograph 1* the calcite fill can be observed to form ramifications along the fissures, whereas in *Photograph 2* an interstitial, postgenetic calcitization between dolosparite grains can be recognized. In the microphotographs of hydrothermally altered dolomite (*Photographs 3 and 4*) the texture of a tectonically fractured rock, consisting of massive xenotopic crystals cemented by a poor, argillaceous and carbonate matrix, has been shown.

The example of epigene calcitization from among the *heavy hydrothermal* (*metasomatic*) *effects* has been illustrated in *Photographs 5 and 6.* In *Photograph 5* a hypidiotopic dolomite of equal grain size and predominantly carbonate cement can be seen. In an additional detail of the same photograph (*Photograph 6*) a xenomorphic quartz inclusion at the contact of idiogranular dolosparite and calcite-sparite is visible. In the texture of a fault-controlled dolomite of very low magnesite content (*Photographs 7 and 8*) xenomorphic calcite nests sit in the pore spaces of a heavily crushed, grained dolosparite.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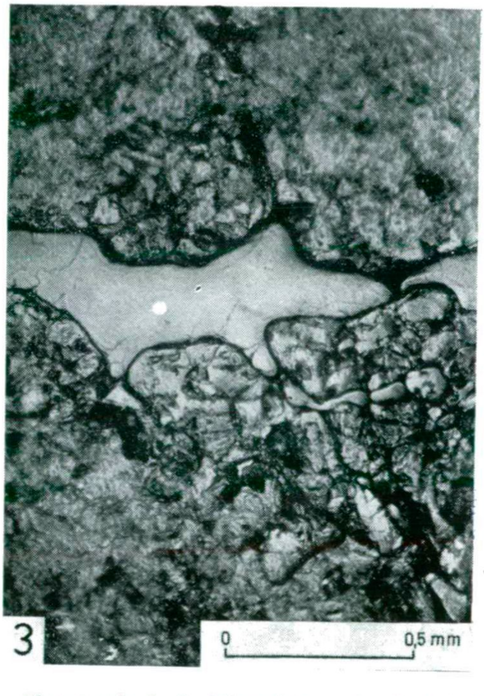
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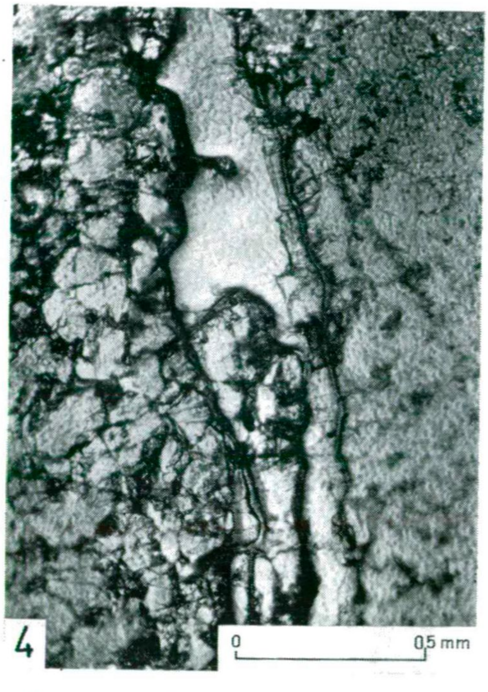
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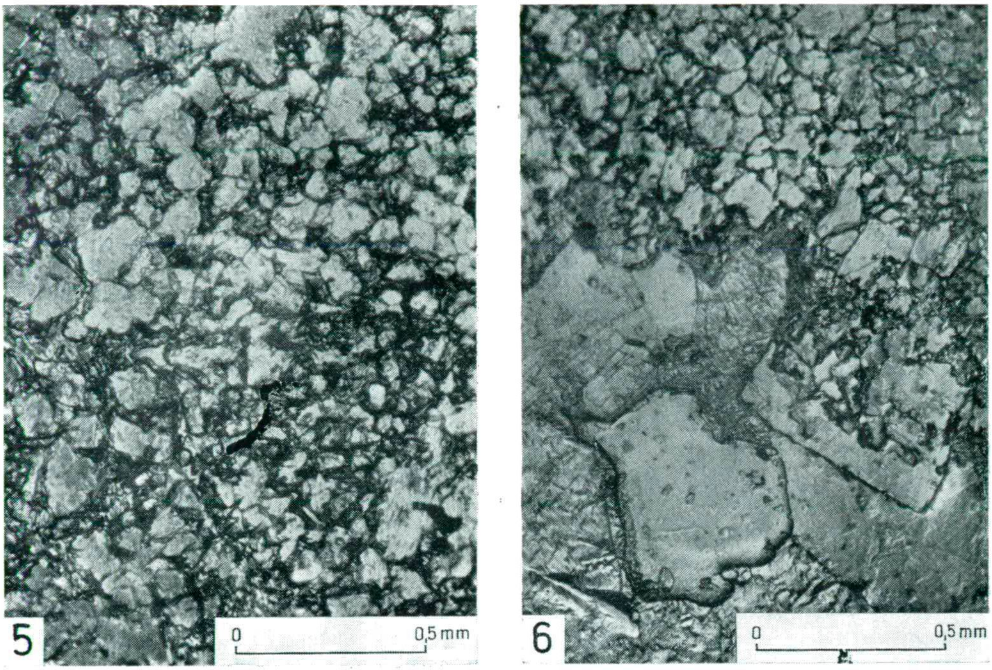
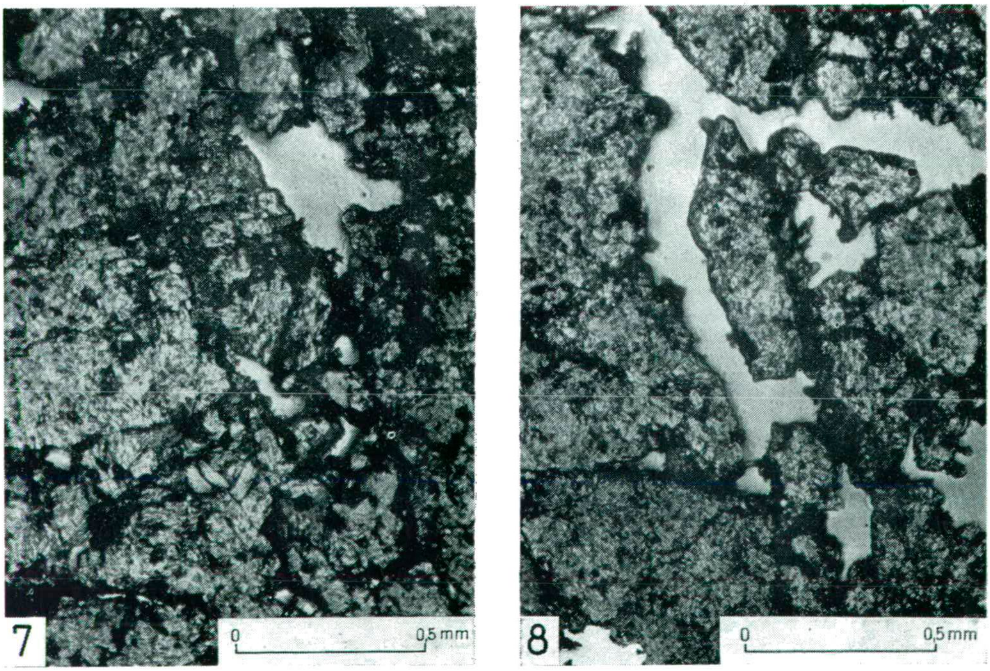
Photographs 1—2. Microphotographs of a hydrothermally cemented dolomite from the vicinity of Pilisszentlélek

Photographs 3—4. Microphotographs of a hydrothermally decomposed dolomite from the Nagyszál at Vác





Photographs 5—6. Microphotographs of a calcitized dolomite from the vicinity of Pilisszentlélek
Photographs 7—8. Microphotographs of a dolomite of very low magnesite content from the vicinity of Pilisszentlélek

The microphotographs readily illustrate both the hydrothermal and structural effects upon the dolomites. Practically, these processes evolve in the dolomite sequence megaloscopically in the same way as observable under the microscope. As far as the relationship between the structure of the dolomites (fractures, fissures, etc.) one one hand and their hydrogeological setting and hydrothermal effects on the other, is concerned, let us note that hydrothermal changes in rock composition are possible not only along major fractures and fissures, but, on account of the presence of a fractured dolomite sequence, practically throughout the entire sequence as well (conf. ZS. BÁRDOSSY-LIESZKOSZKY 1959, p. 276).

Traces of hot springs occurring in the dolomite outcrops of relatively limited extent adjacent to the Danubian andesite mountains (*Fig. 1*) and responsible for hydrothermal rock alterations are very frequent and have produced, especially in the territory of the Pilis Mountains, a peculiar hydrothermal dolomite karst. On this basis, the one-time hot spring activities may be considered to have been very widely distributed and intensive.

The tectonic movements connected with the Tertiary andesite volcanism and those which followed it led to a change in the spatial position of the Triassic dolomite and limestone sequence and thus allowed the enormous mass of water accumulated during millions of years to return to the surface. The emergences of springs were more intensive in the successive orogenic phases and weaker in the epirogenic ones (GY. VITÁLIS 1975). The "paleo"-karstic water contained in the Triassic carbonate rocks of several hundred m thickness udnerlying the Tertiary andesite complex and adjacent to it (see: GY. VITÁLIS—J. HEGYI-PAKÓ 1974, *Fig. 2*) was first mixed with the juvenile water that reached the surface in the course of volcanic activities, then, after the end of the activity, it emerged to the surface in the form of karstic springs yielding initially hot, later subthermal, waters.

The morphologically conspicuous traces of hot spring activities in a homogeneous dolomite sequence may provide valuable information which can well be used in the practice for the detecting of major faults (F. SEMPTEY 1943) and the eluciation of the hydrogeological conditions and the tracing of potential, most probably metasomatic, ore mineralization (magnezitization) of deeper subsurface position, alike.

Those are the relationships which the present writers have sought to outline as a basic information that may be relied on in further research work.

REFERENCES

Bárdossy-Lieszkovszky, Zs. (1959): Ipari dolomitliszt és murva kutatása Pilisvörösvár környékén (Prospecting for industrial dolomite silts and granules in the vicinity of Pilisvörösvár) — *A Magyar Állami Földtani Intézet Évi Jelentése az 1955—56. évről,* 269—279.

Chilingar, G.—Bissel, H.—Fairbridge, R. (1967): Carbonate rocks. Developments in sedimentology 9 A. Elsevier Publishing Company, *Amsterdam—London—New York,* 1—471.

Frolova, E. K. (1959): On classification of carbonate rocks of limestone — dolomite — magnesite series. *Novosti Neft. Tekhn., Geol.,* 3. 34—35.

Hegyi-Pakó J. (1973): Thermal and Material Testing of Raw Materials for the Cement and Lime Industries in Hungary. *SZIKKTI Tudományos Közlemények,* 36. 1—87. + 36 Chart

Jakucs, L. (1950a): A dolomitporlódás kérdése a Budai-hegységben (The question of pulverization of dolomites in the Buda Mountains) — *Földtani Közlöny,* LXXX. 361—380.

Jakucs, L. (1950b): Újabb hozzászólás a Budai-hegység hidrothermáinak eredetéhez (A new contribution to the origin of the hydrotherms in the Buda Mountains) — *Hidrológiai Közlöny,* XXX. 233—235.

Jakucs, L. (1971): Szempontok dolimittérszínek karsztosodásának értelmezéséhez (On the interpretation of the karstification of dolomite surfaces) — *Földrajzi Értesítő,* XX. 89—98.

Leitmeier, H. (1953): Die Entstehung der Spatmagnesite in den Ostalpen. *Tschermaks Mineralogische und Petrographische Mitteilungen,* III. 4. 305—351.

Schafarzik, F. (1928): Visszapillantás a budai hévforrások fejlődéstörténetére. Rückblicke auf die Entwickelungsgeschichte der Budapester Thermen. *Hidrológiai Közlöny,* I. 1921. 9—14. und 57—61.

Scherf, E. (1928): Hydrothermale Gesteinsmetamorphose im Buda—Piliser Gebirge. *Hidrológiai Közlöny,* II. 1922. 107—206.

Schréter, Z. (1912): Die Spuren der Tätigkeit tertiärer und pleistozäner Thermalquellen im Budaer Gebirge. *Mitteilungen aus dem Jahrbuche der kön. ung. Geologischen Reichsanstalt,* XIX. 5. 197—262.

Semptey, F. (1943): A Nagykovácsi és Pilisszentiván közt kiemelkedő Szénás-hegycsoport földtani viszonyai. Bölcsészdoktori értekezés (Geology of the Szénás hill group soaring between Nagykovácsi and Pilisszentiván. Ph. D. thesis) *Supplement to the Földtani Szemle,* 1—54.

Széky-Fux, V. (1970): Telkibánya ércesedése és kárpáti kapcsolatai (The Telkibánya mineralization and its Intra—Carpathian connexions), Akadémiai Kiadó, *Budapest,* 1—266.

Vitális, Gy. (1975): Vízföldtani gondolatok Budapest centenáriumán (Hydrogeological considerations at Budapest's Centenary) — *Hidrológiai Tájékoztató,* 1973. 6—7.

Vitális, Gy.—Hegyi-Pakó, J. (1973): A hidrotermális hatások és az ércesedés kapcsolata a Dunai andezithegységgel határos karbonátos kőzetekben (Relationship between hydrothermal effects and ore mineralization in the carbonate rocks adjacent to the Danubian andesite mountains) — *Bányászati és Kohászati Lapok — Bányászat,* 106. 774—779.

Vitális, Gy.—Hegyi-Pakó, J. (1974): Hydrothermal and metasomatic phenomena in the Triassic limestone areas bordering on the andesite mountain of the Danube. *Acta Univ. Szegediensis Miner. — Petr.,* XXI. 2. *Szeged,* 219—227.

Vitális, I. (1914): A magyarországi magnezitelőfordulások földtan-telepismerettani szempontból (Economic geological considerations on the magnesite deposits of Hungary) — *Bányászati és Kohászati Lapok,* XLVII. I. 409—419.