HYDROTHERMAL AND METASOMATIC PHENOMENA IN THE TRIASSIC LIMESTONE AREAS BORDERING ON THE ANDESITE MOUNTAIN OF THE DANUBE

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INTRODUCTION

In the course of the limestone prospecting carried out in the western part of the Nagyszál of Vác and on the Kőszikla of Dorog, besides hydrothermal traces indicating the one-time thermal spring activity, the epigenetic dolomitization of the limestone of the Norean age was also observed. Dolomitization and other thermal water traces were associated with the hydrothermal processes following the Neogene volcanization of the andesite mountains of the Danube (Börzsöny Mountains, Mountain of Visegrád). The magnesium ions of the several hundred metres thick Carnian dolomite deposited under the limestone group of the Norean age were elutriated by the hydrotherms, then getting them ascendingly into the crevices of the limestone, they caused the dolomitization of the limestone to different extent. Practically, the traces of the thermal spring activity taking place from the Middle-Miocene epoch to the end of the Pleistocene epoch can be investigated both in the limestone and volcanic group, as well as in the covering formation in the entire region.

After the Nagyszál of Vác, the traces of hydrothermal effects observed also on the Kőszikla of Dorog, called our attention to investigate the developments of the limestone areas bordering on the andesite mountains of the Danube as well. By doing so, it was possible to record the rock alterations of hydrothermal origin associated with volcanic activity on the one hand and to get a basis for studying the metasomatic sulfide mineralization probably taking place on the border of the Triassic limestone and the Neogene andesite on the other.

THE GEOLOGICAL SETTING AND EVOLUTION OF THE AREA

The geological setting of the andesite mountains of the Danube and the adjacent limestone areas is summarized by the reconnaissance geological map *(Fig. 1)* and geological section *(Fig. 2)*. The evolution of the area is outlined in the following.

During the *Upper Triassic epoch* in the entire area continuous marine deposits, on the Carnian stage dolomite, in the Norean stage, in the region of Dorog, limestone white dolomite shelves, then limestone of Dachstein; in the region of Vác limestone of the Dachstein type are formed. At the end of the Triassic period, the entire area rises to a minor extent under the effect of Old-Cimmerian movements.

In the region of Dorog, sedimentation (limestone — marl) continues *in the Jurassic period*, the region of Vác is already a continent since the end of the Triassic

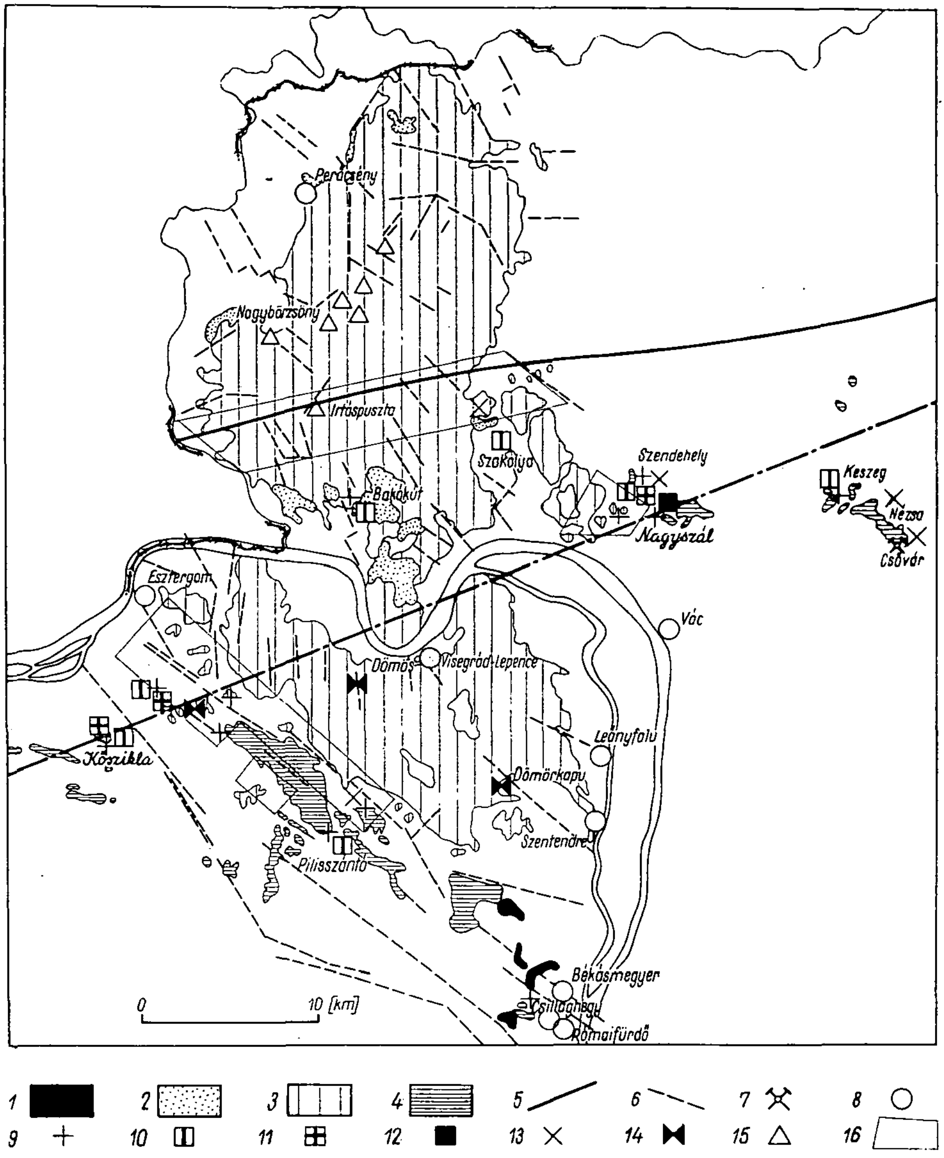


Fig. 1. Reconnaissance geological map of the andesite mountains of the Danube and the adjacent limestone areas (After the 1:200 000 map detail of the hydrogeological map of Hungary, with supplementation) *1.* Fresh-water limestone *(Pleistocene)*, *2.* Lajta limestone *(Neogene)*, *3.* Andesite — andesite tuff *(Neogene)*, *4.* Limestone *(Triassic)* on the surface; *5.* Border of Paleozoic and Mesozoic basement below the surface; *6.* Aquiferous break; *7.* MÁFI perspective prospecting bore; *8.* Thermal well and lukewarm spring; *9.* Trace of thermal spring; *10—12.* Formed by hydrothermal metasomatism: 10. Dolomitic limestone, *11.* Calciferous dolomite, *12.* Dolomite; *13.* Limonite of thermal spring origin; *14.* Pyrite impregnation; *15.* Sulfide mineralization; *16.* Prospective area from the point of view of metasomatic sulfide mineralization; *17.* Section line.

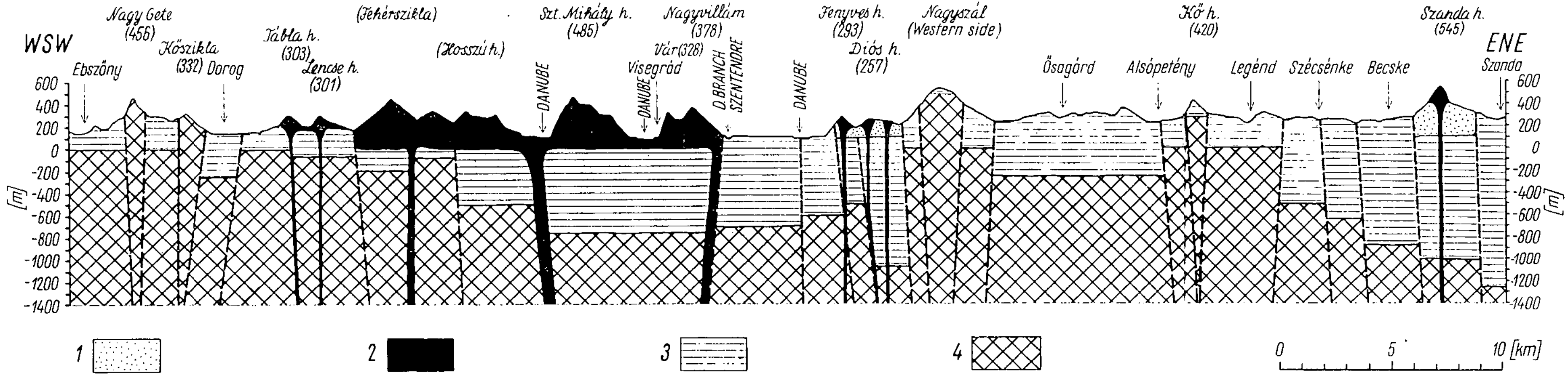


Fig. 2. Draft geological section of the andesite mountains of the Danube and their surrounding (After the 1:300 000 geological map of Hungary and the uncovered, scale 1:500 000 geological map of the Paleozoic and Mesozoic formations of Hungary, with contraction) *1.* Clay, sand, sandstone, clayey marl, limestone *(Neogene)*; *2.* Andesite and andesite tuff *(Neogene)*; *3.* Sand, sandstone, clay, clayey marl, marl, limestone *(Palaeogene)*; *4.* Limestone, dolomite *(Triassic)*.

Summary table of chemical and mineralogical-petrographical analyses **TABLE 1**

Name and place of origin of the rock	Chemical composition									Mineral composition on the basis of			Trace elements		
	Ign. loss	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	Thermal	Radiographic	Thin section	100—1000	50—100	<50
	weight percent									examination			g/t		
Hydrothermally decomposed limestone, Dorog, Strázsa Mountain Quarry	43,86	0,27	0,10	0,17	55,77	0,10	<0,10	<0,10	0,03	calcite	calcite	calcite, dolomite		Sr	
Saccharoidal algaic limestone, Keszeg Limestone Quarry	43,87	0,10	0,10	0,04	55,58	0,10	<0,10	<0,10	0,34	calcite	calcite	calcite			Sr
Hydrothermally decomposed striated limestone, Keszeg Limestone Quarry	43,87	0,20	0,10	0,03	55,49	0,10	<0,10	<0,10	0,32	calcite	calcite	calcite			Sr, Ba
Pyritic limestone, Dorog Strázsa Mountain Quarry	43,28	1,12	0,10	0,11	55,27	0,10	<0,10	<0,10	0,03	calcite, pyrite	calcite, quartz, kaolinite	calcite		Sr, As	
Hydrothermally decomposed limestone, Dorog, entrance of Sátorkőpuszta Cave	44,01	0,12	0,09	0,10	54,72	0,90	<0,10	<0,10	0,04	calcite	calcite, quartz	calcite		Sr	
Hydrothermally decomposed limestone, Keszeg Limestone Quarry	43,09	1,40	0,46	0,19	54,68	0,10	<0,10	<0,10	0,39	calcite	calcite	calcite, quartz			Sr
Hydrothermal vein filling between Keszeg and Csővár	40,14	5,65	1,23	2,66	49,56	0,10	<0,10	<0,10	0,37	calcite, dolomite	calcite				Sr, Rb, Ba
Striated, dolomitic limestone, Pilisszántó, Pilis Mountain Limestone Quarry	44,47	0,33	0,10	0,07	51,90	3,00	<0,10	<0,10	0,11	calcite, dolomite	calcite, dolomite	calcite		Sr	
Dolomitic limestone, Dorog, Small Strázsa Mountain	44,30	0,06	0,10	0,11	52,64	3,10	<0,10	<0,10	0,02	calcite, dolomite	calcite, dolomite	calcite		Sr	
Dolomitic limestone, Keszeg, drilling No. 6, 14,2 m	45,40	0,10	0,31	0,17	45,61	8,41	<0,10	<0,10	0,01	calcite, dolomite	calcite, dolomite, quartz	calcite, dolomite		Sr	
Saccharoidal, dolomitic limestone, Dorog, Strázsa Mountain Quarry	49,43	0,22	0,10	0,46	44,57	9,49	<0,10	<0,10	0,02	calcite, dolomite	calcite, dolomite	calcite, dolomite		Sr	
Calciferous dolomite, Dorog, Small Strázsa Mountain	46,02	0,33	0,10	0,11	40,32	13,20	<0,10	<0,10	0,02	calcite, dolomite	dolomite, calcite	dolomite, calcite		Sr	
Hydrothermally decomposed andesite, Piliszentlélek, Esztergom—Dobogókő highway 23,8 km	2,54	72,12	15,91	1,12	2,65	0,20	2,30	2,57	0,31	clay mineral	feldspar, quartz, montmorillonite, illite, kaolinite	plagioclase, garnet, biotite	Sr	Rb	Ba
Striated, hydrothermally decomposed, garnetoid biotite andesite, Pilisszentlélek, Esztergom—Dobogókő highway 23,8	3,28	71,20	15,10	2,44	2,65	0,10	2,09	2,36	0,54	clay mineral	feldspar, quartz, montmorillonite, illite	plagioclase, garnet, biotite	Sr	Rb	Ba
Biotite-amphibole andesite, Vác, Diós Mountain excavation between 42—43 km	1,22	61,29	17,85	5,61	7,42	1,68	2,46	1,68	0,50	clay mineral	feldspar, amphibole	plagioclase, biotite, amphibole	Sr	Ba	Rb
Hydrothermally decomposed andesite tuff, Vác, Diós Mountain excavation between 42—43 km	1,80	59,99	18,03	6,13	7,70	2,10	2,39	1,54	0,30	clay mineral	feldspar, amphibole, montmorillonite	plagioclase, augite, biotite		Sr	Ba, Rb, Mn

period. At the end of the Jurassic period, in consequence of the New-Cimmerian movements, a dry period, then erosion takes place in the entire area.

In the Lower Cretaceous period, the region of Dorog is covered by sea again, then the entire area is a continent. At the border of the Lower and Upper Cretaceous periods in the Austrian, then during the Subhercyn orogenesis, karst formation, and at the end of the Cretaceous period bauxite formation (Nézsa), then erosion take place.

During the movements of the Laramide, *in the Lower Eocene period* subsidence, in the region of Dorog and Vác (Kosd), and partly between the two areas as well, brown coal formation, then marine transgression (clayey marl — marl — limestone), repeated in the *Middle and Upper Eocene periods* too, follow. Due to the Pyrenean movements (Upper Eocene), the series of Eocene layers which got into a deeper position are more complete because it was more protected against the infra-Oligocene denudation.

During the *Lower Oligocene* period, in the region of Dorog large-scale erosion (infra-Oligocene denudation) takes place, in the region of Vác sandstone of „Hárshegy" and conglomerate; in the *Middle Oligocene period*, of the entire area, Foraminiferous clay — clayey marl ("clay of Kiscell"), in the *Upper Oligocene period* sand, sandstone and clay are formed.

In the region of Dorog (due to the orogeny of Sava) Miocene deposits are not known, in other parts of the area, the formations of *Burdigalian* and *Helvetian* are of mechanical character. The andesite volcanism of the Danube region starts as early as the middle of the Helvetian stage, however, the main mass of the mountain emerges to the surface in the *Lower Tortonian substage*. The volcanism is accompanied in some places by sulfide mineralization containing precious metals (Nagybörzsöny). The covering formation of the volcanic group is Lajta limestone of the *Upper Tortonian substage*, and the *Sarmatian stage* is represented by clayey marl and limestone.

The post-volcanic hydrothermal effects caused sulfide mineral impregnations, mineral veins in the andesite group and dolomitization in the adjacent Triassic limestone area. It is probable that scarnic and polymetallic sulfide mineralization took place at the border of limestone and andesite.

Owing to the hydrothermal effects, siliceous sinter and fresh-water limestone (Szokolya) are formed, and in the Lajta limestone, deposited on the andesite group, only slight dolomitization (Zebegény) can be observed. The siliceous binding material of the limestone of "Hárshegy" can also be associated with the post-volcanic activity.

The *Lower Pannonian* clayey and the *Upper Pannonian* sandy — clayey formations are deposited only at the edge of the Danube andesite mountains rising as an island from the Pannonian internal lake and at the edge of the surrounding Mesozoic limestone — dolomite islands. Thermal water activity continues in the Pliocene period, too. The break through of the Danube at Visegrád starts at the end of the Pliocene period.

During the *Pleistocene* thermal water activity, dolomite pulverization and rock decomposition is caused by the hot, then by the moderately warm karstic springs welling up along the aquiferous cracks; calcite veins, fresh-water limestone and labyrinths with spherical cavities are formed. During the young post-Pannonian movements, the entire area rises to its present height, thermal water activity ceases on the elevated parts, erosion and karst formation continue.

The present *(Holocene)* state is shown by the geological section illustrated in *Fig. 2*.

THE PLACE OF ORIGIN OF THE SAMPLES INVESTIGATED

The rock samples documenting the hydrothermal and metasomatic effects were collected in the area of the Triassic island blocks, in the area of the Szendehely blocks, as well as in the area of the block group of Keszeg — Csővár. The samples originating from the Triassic limestone group of the Pilus Mountain were taken from the quarries on the Mt. Kis Strázsa and Mt. Nagy Strázsa and in the region of Kesztölc, Pilisszentkereszt and Pilisszántó along the Kétágúhegy — Pilis — Hosszúhegy range.

For the investigation of the hydrothermally decomposed Neogene andesite near the Mesozoic limestone group, fresh and more decomposed andesite varieties were also collected from the road cuts of the Esztergom — Dobogókő highway, in the region Pilisszentlélek and from the Mt. Tábla between the Strázsa Mount and Kétágúhegy Mountain in the region of Dorog.

RESULTS OF MATERIAL TESTING

The samples were subjected to complete chemical analysis, thermal, radiographic, semi-quantitative X-ray spectrometric and microscopic testing. The more important mineralogical — petrographical characteristics determined on the basis of the complete chemical analyses and instrumental tests — according to genetic types — are summarized by Table 1.

The chemical and instrumental analyses were made at the Department of Silicate Chemistry of the Central Research and Planning Institute for the Silicate Industry. The photographs of the rock thin-sections with crossed nicols were taken and were evaluated by I. CSORDÁS, at the Mineralogical and Petrographical Department of the Technical University of Heavy Industries, and the semi-quantitative X-ray spectrographic analyses were carried out by DR. L. BOGNÁR, at the Mineralogical Department of the Eötvös Loránd University.

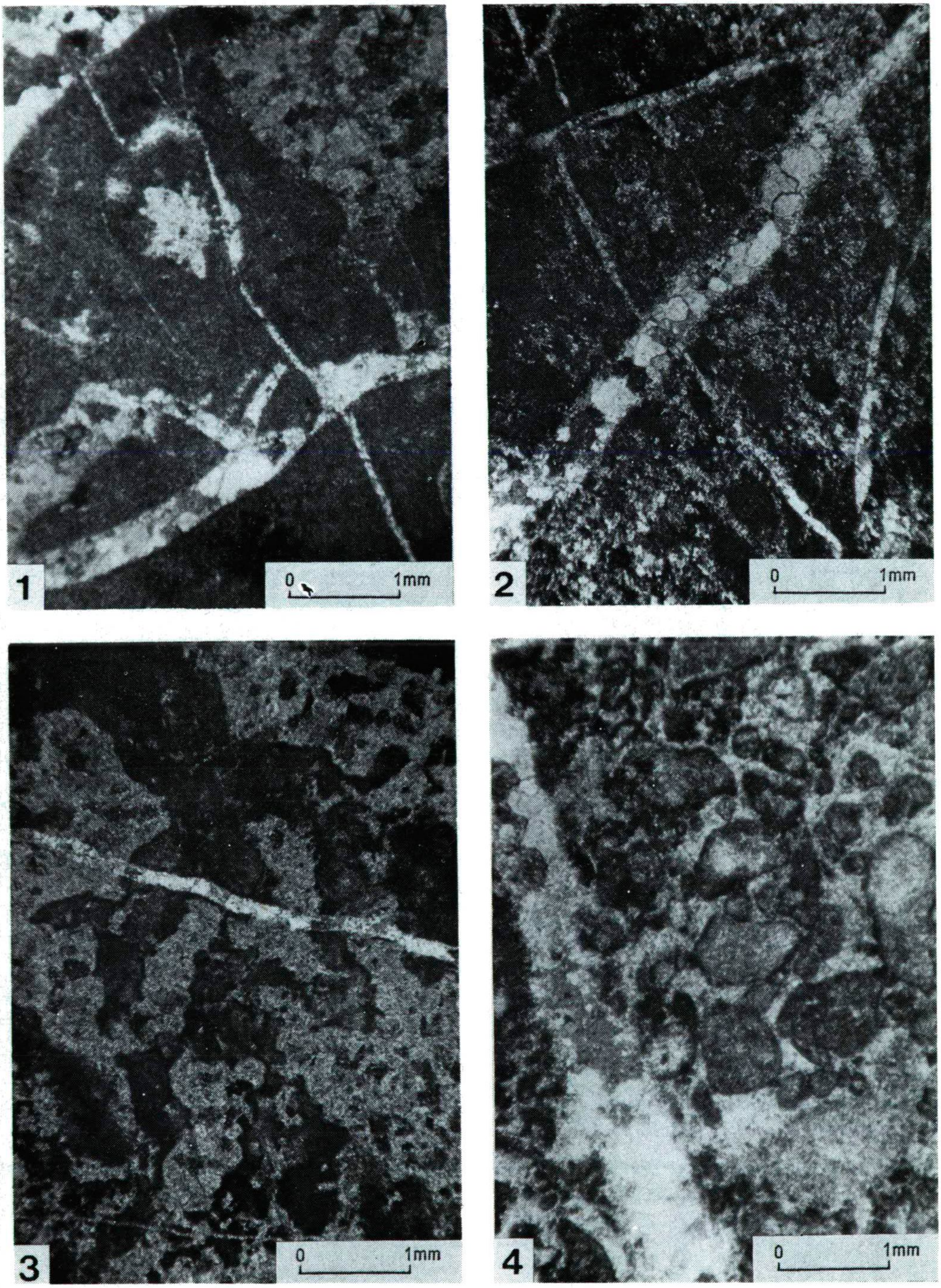
Of the thin-section, photographs bringing best into relief the genetic characteristics of the hydrothermal rock alterations, are shown. The pictures shown represent partly the individual phases of the hydrothermal phenomena, partly — by covering several areas — the process of the phenomena taking place on both sides of the andesite mountain of the Danube. The explanation of the rock thin-sections is given below.

PLATE I

Photomicrograph 1. Fine-grained limestone broken under more intensive dynamic effect. The network of veins consists of coarse crystalline calcite.

Photomicrograph 2. Pellets hidden in pelitic micrite basic material. The entire material is crossed by a network of calcite and siliceous diffuse veins.

PLATE I. *1.* Thin-section of hydrothermally decomposed limestone (Dorog, Mount Strázsa); *2.* Thin-section of hydrothermally decomposed limestone (Dorog, entrance of the cave of Sátorkőpuszta) *3.* Striated, dolomitic limestone (Pilisszántó, limestone quarry of Pilis Mountain) *4.* Thin-section of dolomitic limestone (Dorog, Mount Kis Strázsa)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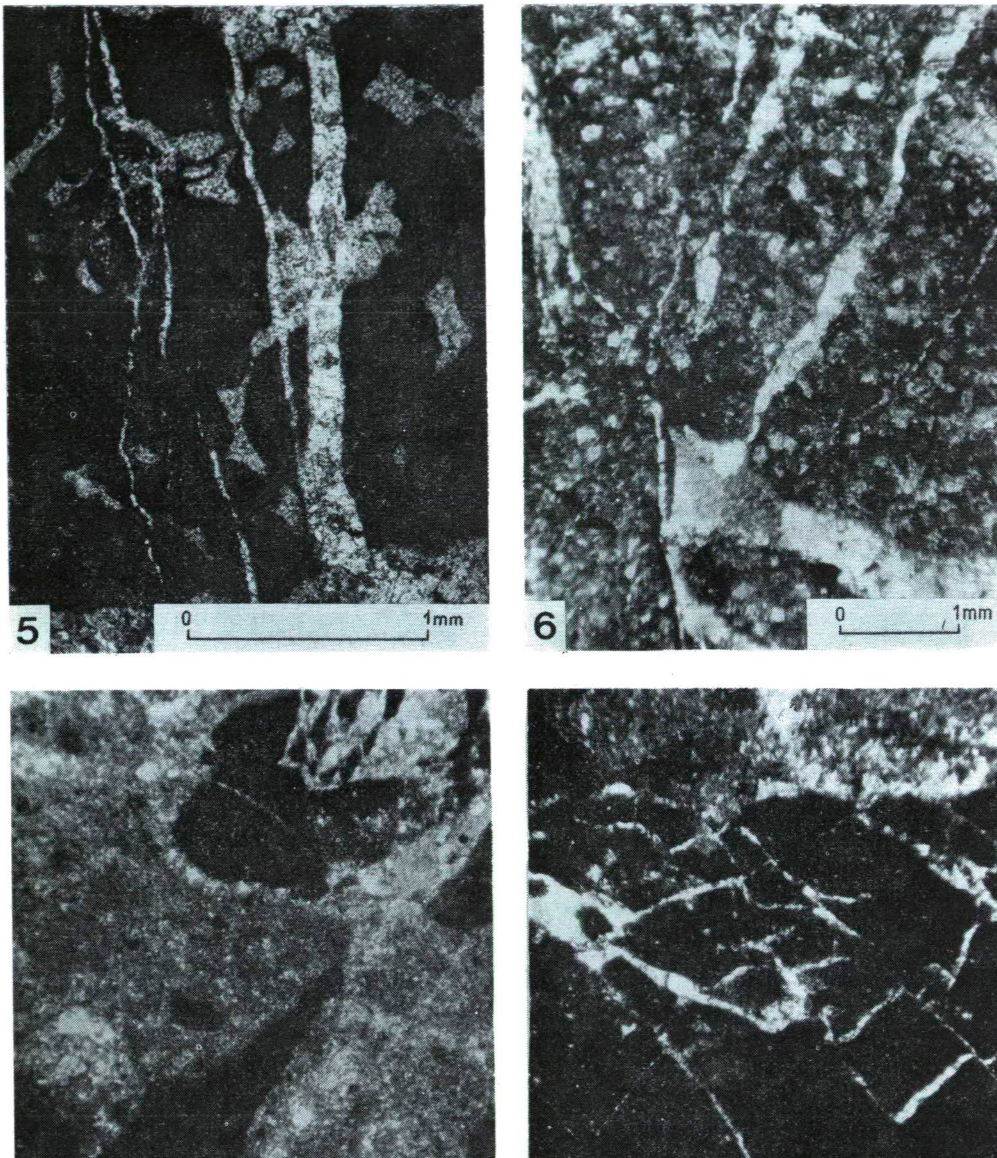
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Photomicrograph 3. Pelitic, microcrystalline limestone with lithographic structure transformed under hydrothermal effect, with reabsorptive and recrystallized structural marks.

Photomicrograph 4. Pelletic biomicrite with epigenetic calcite filling, with a finer network of veins in some places.

PLATE II

Photomicrograph 5. Oopelletic, algaic biomicrite with a string network of spathic veins, with cavernous, nesty pore cement.

Photomicrograph 6. The basic material was transformed into coarser-grained dolosparite along the diffuse vein network.

Photomicrographs 7 and 8. In basic material consisting of pelitic dolomicrite, darker intraclastic inclusions, interwoven with coarse crystalline calcite veins. In some places, the microbreccias of the intraclastic details and their resorption, respectively, can be observed.

The microphotographs demonstrate the alterations caused by the hydrotherms, the epigenetic calcite and siliceous filling and dolomitization well.

Metasomatic dolomitization manifests itself first along fissures, then penetrating into the inner parts of the rock, in widening, nesty, bossy impregnations. Its dimension varies in a wide range (from microscopic to metric order of magnitude). The most varied structural character is displayed by the intermediate rock types (e. g. dolomitic limestone varieties).

It should be also noted in connection with the material tests that the higher CaO content of the andesite samples from the Diós Mountain of Vác are indicative of the carbonation of the andesite group. The K_2O quantity of the hydrothermally decomposed andesite originating from the region of Pilisszentlélek (2,36 and 2,57%) falls between the normal (intact) andesite and the hydrothermally intensively decomposed andesite (Table 1). These provide data for studying the petrometallogenetic evolution of the area, too. The epigenetic dolomitization of the Triassic limestone, as well as the carbonation of the Neogene andesite and its presumed potassium metasomatism are pre- and synmetallogenetic.

PRACTICAL CONCLUSIONS

The following practical conclusions are drawn from the comparison of geological observations and the results of material testing.

Metasomatic dolomitization is indicative of hydrotherms originating from a greater depth, whereas simple hydrothermal decomposition is possible from thermal water originating from a smaller depth, too.

Metasomatic dolomitization is completed by the end of the Pliocene period, the thermal springs causing simple hydrothermal rock alterations are most intensive in the Pleistocene period. The former is connected with volcanic post-activity, the

PLATE II. *5.* Thin-section of dolomitic limestone (Keszeg, bore No. 6, 14,2 m) *6.* Thin-section of dolomitic limestone with saccharoidal structure (Dorog, Mount Strázsa) *7.* Thin-section of calci. .rous dolomite (Dorog, Mount Kis Strázsa) *8.* Thin-section of calciferous dolomite (Dorog, Mount Kis Strázsa) latter ones indicate the activity of first hot, then lukewarm karst springs and thermal springs mixed with cavern water, respectively.

In the Mesozoic basement areas *(Fig. 1)*, the areas suitable for the development of thermal water can be allocated by means of the traces of one-time thermal springs. Of these, thermal water can be developed at a smaller depth below the surface in the region of Dorog and at a greater depth below the surface in the other areas.

On the basis of the appearance of calciferous dolomite, active zones can be allocated from the point of view of metasomatic dolomitization. It can be concluded from the fact of dolomitization that metasomatic sulfide mineralization is possible on the border of the Mesozoic limestone and Neogene andesite groups, e. g. similar to the one of Óradna. The borders of the prospective areas (on the basis of taking the active zones known so far from the point of view of metasomatic dolomitization and the large structure into consideration) are indicated on a reconnaissance geological map *(Fig. 1)*.

Attention is called to hydrothermal mineralization probably located at a greater depth below the surface by the limonite segregations of the carbonate rocks (Szendehely, Csővár, Pilisszentkereszt, etc.), by the pyrite scatterings of the andesite (Dömös, Mt. Tábla), as well as by the sulfide mineralizations (Nagybörzsöny, Irtáspuszta), moreover by the trace elements of the thermal spring deposits and hydrothermally decomposed rock varieties.

In the industrial utilization of limestone, the fact of metasomatic dolomitization — with special regard to the irregular seam conditions — deserves attention in any case.

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