

CONFERENCE ON  
BAUXITE GEOLOGY  
BUDAPEST, SEPTEMBER 4-8, 1969

*D. J. ...*

EXCURSION GUIDE

BAUXITE GEOLOGY  
OF THE TRANSDANUBIAN CENTRAL  
MOUNTAINS



A COLLECTIVE PROGRAMME OF THE HUNGARIAN GEOLOGICAL INSTITUTE  
AND THE HUNGARIAN TRUST OF THE ALUMINIUM INDUSTRY, ON THE  
OCCASION OF THE CENTENARY OF THE HUNGARIAN GEOLOGICAL INSTITUTE

*Handwritten signature and date: 4. 1969*

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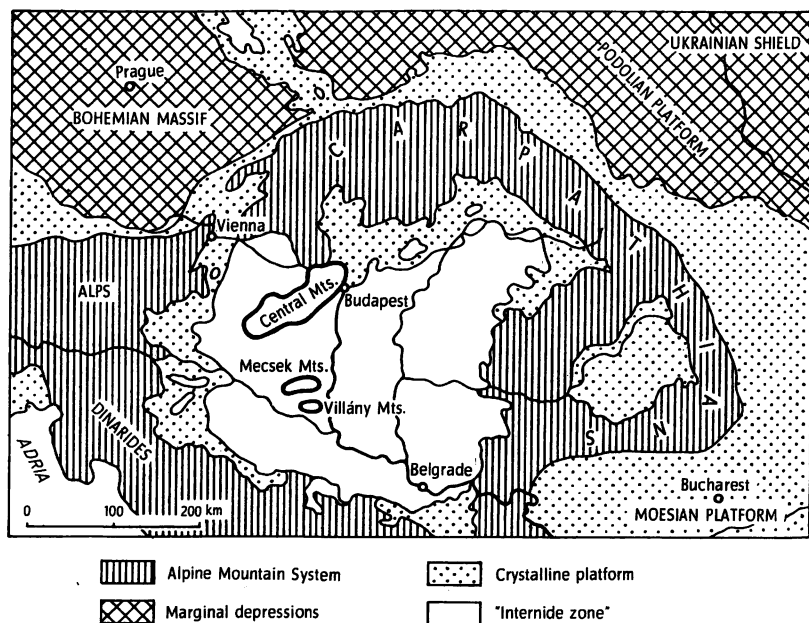
## I. MEGATECTONIC SETTING

The Transdanubian Central Mountains<sup>+</sup> are a part of the "Internide zone" of composite origin and structure lying between the Alps, Carpathians, and Dinarides. This zone is characterized by the small thickness of the lower crust, by its unusually low geothermal gradient, and by its faulted, fault-folded, and imbricated tectonics. Its genesis was originally interpreted in terms of the presence of a uniform mass consolidated during earlier tectonic phases ("Internides", "Tisia", "median mass") which played an active role in the formation of the Carpathians. Our present knowledge suggests that the peculiar and varied structural patterns of this zone owe their development to the "stress shadow" that existed between the crystalline masses in the foreland of the Carpathians (Fig. 1).

For the most part, the Central Mountains represent Mesozoic elements of "Mittelgebirge" type. They rise a few hundred metres above the flat or rolling (100-200 m relief) surface of the Transdanubian basins, filled with 1000-4000 m of Neogene sediments, and are separated by intermontane basins. They are believed to form an autochthonous, asymmetrical synclinorium affected by both tensional and compressional stresses, with some subordinate manifestations of flexing (Fig. 2).

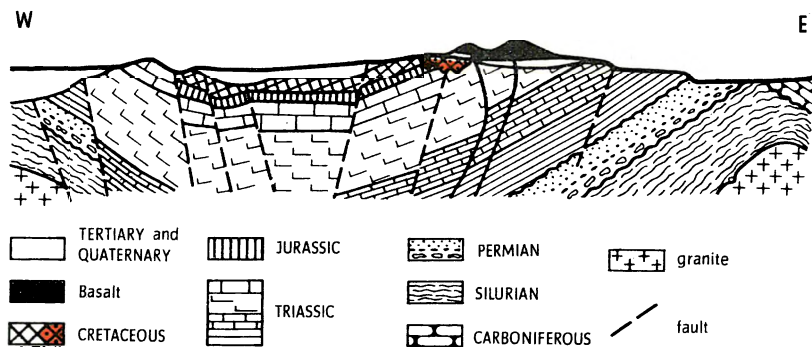
<sup>+</sup> Hereafter referred to as the Central Mountains.

In the southeast limb of the synclinalorium Paleozoic and Triassic rocks occur, generally in a monoclinial position. Along its axis there are Jurassic and Cretaceous formations. The narrow opposing limb consists of Trias-



1. Situation of the Transdanubian Central Mountains

sic rocks. In addition to the production of synclinal forms, compression is manifested in the piling up of blocks, thrust-sheets (imbrications), and horizontal en echelon faults. Their effect is reflected in the distribution of the sedimentary facies zones. The disjunctive tendencies that gradually became predominant in the Tertiary produced large longitudinal and transverse faults, youthful intramontane basins, and irregular tilting. These fractures provided paths for the manifestations of andesitic, rhyolitic, and basaltic volcanism.



2. Sketch of the geological structure of the Transdanubian Central Mountains



## II. GEOLOGICAL FORMATIONS

The oldest formations occur on the southeast border of the NE-SW trending mountains, on a line between Lake Balaton and the Velence Mountains.

**SILURIAN.** As indicated by its fauna, the oldest formation in the Central Mountains is the anchiepimetamorphic slate series exposed along Lake Balaton and around the Velence Granite Pluton. In this very thick series of metamorphosed sandy and argillaceous strata, three different lithologic sequences can be distinguished;

The oldest member consists of an unfossiliferous sequence of flagstones, quartzite and chlorite schists.

It is succeeded by sericite schists and flagstones with siliceous shale lenses and intercalations of quartz porphyry and diabase (phyllitic member). The black siliceous shale lenses contain the Monograptidae fauna which, associated with Hystriosphæridæ, chitinozoa, radiolaria, and silicospongia, dates the whole series as Silurian.

The final member consists of calcareous sericite and chlorite schists and flagstones with thin interbedded layers of quartz porphyry, quartz-porphry tuff, and tuffite. This Late Silurian or Early Devonian formation shows the least effect of metamorphism.

**DEVONIAN.** Besides the aforementioned member, there is an isolated exposure of crystalline limestone which can be considered Devonian (?). Its thickness may have been much greater than the exposures suggest, as indicated, on the one hand, by its presence among the pebbles in the Per-

mian conglomerates and, on the other, by its frequent appearance as xenoliths in the products of the Upper Pliocene basaltic volcanism.

CARBONIFEROUS. Similarly isolated are the dark calcareous and marly shales of the Viséan stage of the Lower Carboniferous with corals and brachiopods, faulted up near the surface.

South of Lake Balaton, deep drilling reached Upper Carboniferous, Schubertella- and Climacamina-bearing, yellowish-white limestones, underlying the Neogene and Paleogene formations at a depth of 956 m. Besides the calcareous shales and Schubertella limestones exposed on the southeast border of the Central Mountains, the Velence Granite Pluton is also considered to be Carboniferous (Sudetic phase of the Variscan folding). Its essential minerals are orthoclase, oligoclase, quartz, and biotite; its accessories are apatite, zircon, magnetite, and orthite. Associated with the pluton are numerous dikes of granite porphyry, aplite, and kersantite on the one hand, and pegmatitic, pneumatolytic, and hydrothermal veins (with fluorite and Pb-, Zn-mineralization), on the other. What was left of these Lower and Upper Paleozoic sequences after extensive Early Permian erosion makes up the Variscan basement of the Central Mountains.

PERMIAN. The Permian is represented by an Upper Permian continental red sandstone sequence which, as shown by the exposures on the southeast border of the Central Mountains, becomes more complete and thicker (from 200 to 700 m) from southwest to northeast. Beneath the Permian beds the eroded, rough surface of the Silurian (Upper Devonian?) anchiepimetamorphic schist series is covered by an intraformational breccia of variable thickness. At the base of the

Permian sequence there is a conglomerate member 50 to 150m thick. Its pebbles usually consist of shale, quartz, quartzite, quartz porphyry, and sandstone. The conglomerate member is followed by a sequence of red sandstones with graded bedding, becoming gradually finer upwards with rhythmic repetitions. The final member of the Permian is a fine-grained, grey sandstone with variegated intercalations. The cement of the sandstones is silica in the south, silica and carbonate in the north, and ankerite-dolomite locally. Kaolinite also is a characteristic constituent of the cement. The red sandstone is very poor in fossils. Silicified and carbonized plant detritus, tracks of mud-eaters, and the footprints of a terrestrial reptile (Chirotherium) have been found so far. The sequence is the result of continental, fluvial sedimentation during which the role of flood-plain and lacustrine sediments gradually increased; grain size changes from coarse at the bottom to very fine at the top. Members 20 to 30 m thick can be distinguished, some of them separated by erosional unconformities. In the upper part of the Permian of the southeast foreland of the Vértes Mountains there is a lagoonal anhydrite- and gypsum-bearing series overlain by marine limestones, dolomites, and marls.

TRIASSIC. The bulk of the exposed Central Mountains is made up of Triassic formations. The most complete Triassic sections can be found in the Balaton Highland and the Bakony Mountains. They can be readily correlated with the occurrences in the southern and eastern Alps, but they are considerably less disturbed, rich in fossils, and include marked subdivisions.

In the south the LOWER TRIASSIC rests on the Upper Permian with a hiatus; farther north, sedimentation was

continuous. The WERFENIAN sediments, more than 1000 m thick, were laid down in the shallow waters of the coastal plain of a continuously subsiding sedimentary basin. The SEISIAN consists of a 600 m thick sequence of grey and red micaceous sandstones, laminated shales, sandy marls, and thin dolomites. The ripple marks observable on the bedding planes and the eurythermal and euryhaline fauna suggest near-shore, shallow-water sedimentation. The appearance of thin-bedded oölitic limestones in the CAMPILIAN, the subsequent disappearance of coarser detritus, and the simultaneous appearance of the ammonite fauna indicate deepening of the sea and stabilization of salinity (Tirolites marl). The cellular-porous dolomites - which owe their texture to the removal of gypsum and anhydrite that once filled the cavities of the dolomite - and the stunted, dwarf fauna of the thin-bedded limestones overlying them are indicative of an evaporating, supersaturated marine environment. The basal member of the ANISIAN is the Megyehegy Dolomite, poor in fossils. On the basis of their brachiopod fauna the overlying limestones can be correlated with the Recoaro horizon of the southern Alps. Upwards, it grades into the Paraceratites trinodosus horizon of marls and limestones with an abundant fauna, which can be correlated with the Reifling Limestone.

In the LADINIAN the Protrachyceras reitzi horizon, composed of alternating siliceous limestones, tuffaceous marls, and diabase tuffs, can be correlated with the Buchenstein Beds of the southern Alps, while the red cherty Tridentinus limestone horizon can be correlated with the Wengenian Beds. The deeper-sea limestone facies of the Balaton Highland, characterized by tuff intercalations bearing thin-shelled pelecyp-

pods and ammonites, is replaced by Diplopora dolomites in the eastern part of the Bakony Mountains. This very thick (900 m) neritic succession of chemo- and biogenic sediments represents the Ladinian in the area of the Vértes, Gerecse, and Buda Mountains, as well.

The CARNIAN exhibits the marked heterogeneity of facies that is typical of the area of Triassic sedimentation of the Central Mountains. In the Balaton Highland the Füred Limestone was deposited first. It is overlain by a very thick marl sequence. The final member is a thin limestone group. This whole complex, some 700 m thick, becomes markedly thinner to the northeast and the aforementioned rocks are replaced by dolomites, dolomitic marls, marly dolomites, thin-bedded cherty limestones, and cherty dolomites.

The NORIAN is represented in the Balaton Highland and in the Bakony Mountains by the widespread Hauptdolomit of enormous thickness, containing a Megalodontidae fauna typical of the Norian stage. Proceeding from south to north across the northern Bakony, Vértes, Gerecse, and Buda Mountains, the Hauptdolomit is replaced by the Dachsteinkalk lower and lower in the stratigraphic column.

RHAETIAN. In the Balaton Highland, the southern Bakony, and on Mt. Keszthely, the Norian Hauptdolomit underlies a Rhaetian sequence of cherty dolomites and dolomitic marls of Kössen facies with Avicula contorta, whose upper part is represented by Pachyodonta (Conchodus) limestones. Toward the northeast it pinches out by the middle of the Bakony Mountains. Elsewhere the Rhaetian is represented by continuation of the Dachsteinkalk of the Norian stage. It is a neritic, oölitic facies containing algae, foraminifera, Paramegalodus, and Conchodus.

JURASSIC. In the Bakony Mountains the Hettangian follows the Triassic with no break in sedimentation, and its lithological features correspond to those of the Rhaetian Dachsteinkalk. In the Vértes and Gerecse Mountains there is a hiatus between the Triassic and the Jurassic. The absence of Jurassic formations on the southeast border of the Central Mountains and the lithologic features of the Jurassic of the central areas suggest a break in sedimentation from the end of the Triassic period to the end of the Jurassic. In the narrow Jurassic sedimentary basin surrounded by extensive coastal areas of Triassic limestones and dolomites, crinoid- and brachiopod-bearing limestones were deposited in the shallower parts, and red clayey limestones with ammonites and a planktonic microfauna, cherty nodular limestones, and radiolarites on the deeper sea bottom. A locally developed manganiferous formation, comprising workable accumulations of manganese carbonate and manganese oxide, was discovered here. The Jurassic deposits suggest that the basin gradually deepened from the Liassic to the end of the Dogger, and then became shallower again during the Malm. The near-shore representatives indicate discontinuous deposition of sediments, including clastic materials of local origin, in shallow agitated waters. The locally abundant ammonite fauna present in the continuous sedimentary sequences in the central part of the basin permits recognition of all stages of the Jurassic system. The majority of ammonite species are of Mediterranean type, but Central European forms are also represented.

The Jurassic member of the geologic section is only 50 to 60 m thick in the Gerecse and Vértes Mountains, and does not exceed 200 m in the Bakony Mountains. In the lagoonal

marginal facies zone it may locally be only a few metres thick.

CRETACEOUS. The Cretaceous is represented by various members of different facies, deposited in isolated basins and separated from one another by stratigraphic hiatuses.

NEOCOMIAN (Berriasian-Barremian). In the Gerecse Mountains a 200 to 300 m sequence, which can be correlated with formations in the northern Alps and Carpathians, shows a normal cycle of sedimentation: Berriasian basal breccia - Valanginian marls - Hauterivian-Barremian sandstones - Upper Barremian regressive conglomerates. In the Bakony Mountains it is less clastic, represented rather by cherty-nodular limestones (Biancone facies), and by marls and crinoidal limestones; relationships with the southern Alps are suggested. In the central basin areas the Berriasian, Valanginian, and Hauterivian stages consist of a 100 to 200 m sequence of cherty-nodular limestones with tintinnids and nannoplankton, and the Barremian is represented by sandy limestones 20 to 200 m thick. In the marginal areas, rocks of this age are represented by crinoid- and brachiopod-bearing limestones from a few metres to 20-30 m thick.

Simultaneously with the marine sedimentation, bauxite bodies were deposited on the land, on a limestone and dolomite surface of rough topography (coastal karst zone with conical elevations) in the zone that extended along the strike of the Central Mountains. Some of the ore bodies are overlain by Aptian sediments, the majority of them by later formations (Senonian or Eocene). A considerable part of the original bauxite deposits was subsequently eroded; another part was redeposited, but retained its bauxitic nature even in secondary form.

MIDDLE CRETACEOUS. In the Aptian a 20 to 80 m sequence of grey crinoidal limestones was formed along the whole length of the Central Mountains. These grey crinoidal limestones are overlain - transgressively and with an erosional unconformity - by the following sequence: Upper Aptian mottled clays with a mostly brackish fauna (500-600 m) - Albian limestones with Pachyodonta, Orbitolina, microfossils, mollusks, and echinoids (20-50 m) - Albian glauconitic marls (0-10 m) - Cenomanian turrilitic marls (50-500 m).

UPPER CRETACEOUS (SENONIAN) occurs in the southern Bakony Mountains. The Central Mountains were uplifted by Late Cenomanian-pre-Gosau movements, and blockfaulted in the Turonian; in the south, sedimentation started with Early Senonian submergence and ended with Late Maestrichtian emergence due to Laramide movements. At the base of the Senonian there is a continental variegated clay member up to 100 m thick containing pebbles of Mesozoic limestones, cherts, dolomites, and bauxites. This is overlain by freshwater limestones, calcareous marls, and clayey marls with a freshwater gastropod fauna and a rich assemblage of sporomorphs (40-100 m), which can be dated as Santonian. This member underlies a coal-bearing formation which shows limnetic feature in the lower part and paralic in the upper (20-120 m), of Upper Santonian-Lower Campanian age. Overlying the continental freshwater sequence, there are marine sediments - Campanian clayey marls and limestones of reef facies containing a characteristic assemblage of corals, mollusks, foraminifera, and sporomorphs (100-200 m).

The Maestrichtian is represented by a sequence



of calcareous marls, limestones, and clayey marls with a characteristic Inoceramus and Globotruncana fauna, together with the Pseudopapillopollis sporomorph assemblage (about 400 m).

E O C E N E. Although incomplete, the Lower, Middle, and Upper Eocene members are all represented in the area of the Central Mountains. Their facies suggest an epicontinental type of sedimentation. Near-shore (calcareous-detrital) archipelagic, and pelagic facies can be distinguished. The rough topography, the varied habitat, and the variable conditions of sedimentation gave rise to a number of varieties in addition to the principal types. Eocene sedimentation was interrupted by three periods of emergence (accompanied by erosion): one at the Lower-Middle Eocene boundary, one within the Middle Eocene, and one between the Middle and Upper Eocene. Stratigraphic subdivision is based on the larger foraminifera. The geologic evolution was controlled by differential movements of opposite sense (subsidence and uplift, respectively) at the northeast and southwest ends of the Central Mountains. This phenomenon did not cease until the Upper Lutetian - Upper Eocene transgression on a continental scale set in. The Eocene sedimentation was associated with andesitic and dacitic-rhyolitic volcanism, predominantly explosive, which produced tuff and tuffite layers. At the base of the Eocene sequence, lignite seams of economic value were deposited.

O L I G O C E N E. At the beginning of the Oligocene the area was uplifted and became the scene of very intensive erosion. Sedimentation began in Rupelian time. It produced variegated clays and sandstones, with lignite seams (1 to 2 m thick) deposited in former embayments. At Bodajk, a vertebrate fauna has been discovered in the 400 m thick con-

tinental sequence. During Rupelian time the sea invaded the Central Mountains area from the northeast. Its sediments, containing Cyrena, Melanopsis, Potamides, and agglutinated foraminifera, occur in the area between Budapest and Esztergom. The maximum thickness is 600 m. (In the Gerecse and Vértes Mountains only brackish-water deposits, and in the Bakony only continental freshwater deposits can be found.) The so-called Kiscell Clay containing Clavulinoides szabói is of more limited geographic range; it is more than 200 m thick. The Chattian is represented by a regressive sandstone member up to 400 m thick. Affected by simultaneous crustal movements, some parts of the Central Mountains were submerged for a short time, just in the Chattian.

MIOCENE. The Miocene can be divided into three members:

The BURDIGALIAN - LOWER HELVETIAN (?) sedimentary cycle is represented by a sequence of continental-fluvial conglomerates, sandstones, and variegated siltstones. Many of the pebbles in the conglomerate are derived from older members of the stratigraphic column. This sequence is overlain by lacustrine sediments with allochthonous lignite deposits.

UPPER HELVETIAN is represented by marine sediments such as fine-sandy clay and clayey marl of Schlier type, deposited in the central part of the basin and by brackish and lagoonal clayey marls (Congerina böckhi, Brotia escheri) formed in the marginal, near-shore zone. The volcanism that furnished the andesitic masses of the Dunazug Mountains and the northeast part of the Central Mountains began in Late Helvetian and attained its maximum in Early Tortonian time.

TORTONIAN - SARMATIAN. The sea advanced considerably in the Tortonian. In the near-shore shallow water zone coarse conglomerates, Pecten- and Lithothamnium-bearing limestones (Leithakalk), Heterostegina limestones, and sandstones were formed. Near Várpalota, the littorial molluskan sands are overlain by an autochthonous lignite formation. Farther off-shore molluskan clayey marls were deposited. The Sarmatian deposits constitute the final member of the sedimentary cycle that began in the Tortonian. In the area of the Central Mountains the Sarmatian is represented by coarse-grained molluskan limestones and clayey marls, and freshwater limestones. The presence of thin dacite tuff intercalations is evidence of continued volcanism.

PANNONIAN (PLIOCENE) formations have been developed on the border of the Central Mountains as well as in the inner basins of the Balaton Highland and Bakony Mountains. These are coastal and near-shore clastic sediments. Their lithologic and paleontologic patterns well reflect the break-up of the Pannonian inland sea, its subsequent filling up, and the establishment of a completely freshwater regime. A characteristic formation of the Lower Pannonian is the Melanopsis sand. Unconformably overlying the lower member, the Upper Pannonian is represented by the clay, clayey-marl and sandy-marl sequence of the Congerina ungula caprae horizon and by the sandy-clayey Congerina balatonica horizon with intercalations of lacustrine sediments and freshwater limestones. On the west border of the Central Mountains, argillaceous Lower Pannonian grades into arenaceous Upper Pannonian. At the end of the Uppermost Pannonian significant basaltic volcanism took place in the southern half of the Central Mountains, the Balaton Highland, and the Little Plain.

Completely emergent by the end of the Pliocene, the landscape was subjected to extensive erosion, with fluvatile-lacustrine accumulations.

QUATERNARY. The Quaternary is represented by continental, lacustrine, fluvatile, and eolian (loess) sediments of periglacial type. The formation of freshwater limestones had begun as early as Pliocene time; lacustrine limestones and travertines (spring deposited) are typical. The slopes of the more and more deeply dissected inner sections of the mountains were covered with talus, and extensive alluvial fans developed at the foot of the mountains. Glacial climatic changes and tectonic movements produced terraces along rivers and brooks. Some areas became covered with eolian sands. Loess formations containing fossil soil horizons and intercalations of rubble are common.

Their sand content is considerable. Of special importance are relics of early Paleolithic and Neolithic man's campsites and chert pits. The most valuable archeological records are known from the Tata, Érd, and Vértesszőllős sites.

### III. BAUXITE DEPOSITS IN THE TRANS-DANUBIAN CENTRAL MOUNTAINS

Bauxite is a typical formation of the Transdanubian Central Mountains and one of the economically most valuable mineral raw materials of the country. Beyond the Central Mountains area, bauxite occurs in the Harsány Mountains (South Hungary) and on the left side of the Danube (hill range of Nézsza), yet the characteristic and most important deposits are in the territory of the Central Mountains.

Concerning their geological development, these deposits can be considered karst-bauxite, because they overly dolomite or limestone paleoreliefs which underwent a karst evolution prior to bauxite formation. The foot-wall of the bauxites usually consists of Upper Triassic dolomites and limestones, rarely of Lower Cretaceous Requienia-bearing and Upper Cretaceous Hippurites-bearing limestones. The hanging wall is rather variable in geological age and lithology: in some places it is Lower Cretaceous clay, marl and limestone, sometimes Middle Eocene limestone. The higher sequences of the hanging wall are constituted by — locally changing — Upper Eocene, Oligocene, Miocene, Pliocene and Quaternary sediments.

The geological age of the bauxite can be determined only on the basis of the hanging wall, because in the bauxite bodies fauna was found only in one place—in the uppermost part of the Halimba deposit. This Upper Cretaceous fauna contains Pyrgulifera. Thus it can be concluded that the bauxite deposits are Aptian, Turonian and Senonian.

As a rule, the bauxite is not exposed to the surface, being usually under a sediment cover, sometimes above 400 m thick.

As for shape, we can distinguish the following types of deposits: stratiform bodies, blocks and lenses. Stratiform deposits have a large lateral extension (one or more km<sup>2</sup>), being relatively not very thick (1-30 m); blocks occur where faults have disintegrated the deposit into several small units; lenses are minor bauxite bodies. As a rule, the deposits show the following vertical succession: at the base there is a bauxitic clay with dolomite or limestone detritus; above it lie clayey bauxites of low quality; then follows a bauxite of good quality with a little silica; at the top there are again clayey bauxites or bauxitic clays. The marginal part of the deposit is usually of inferior quality. Because of the karstic erosion of the foot-wall, the bauxite bodies lie with an erosional unconformity on it; however, the top of the deposit is mainly conformable with the hanging wall, though sometimes it may show an erosional unconformity. The bauxite areas are often faulted by a fault system of SW-NE and SE-NW strike.

Mineralogically, the bauxite deposits of the Transdanubian Central Mountains are of gibbsite, boehmite, and mixed gibbsite-and-boehmite type. The two last-mentioned types are the most frequent. The characteristic chemical composition of these types is:

Type	Al <sub>2</sub> O <sub>3</sub> %	SiO <sub>2</sub> %	Fe <sub>2</sub> O <sub>3</sub> %	TiO <sub>2</sub> %	loss of ignition %
gibbsite	48-52	1-4	17-23	2.2-2.9	19-28
boehmite	50-57	1-6	20-26	2.3-3.1	11-13
mixed	49-53	1-6	16-24	2.3-3.0	18-22

The predominant colour of the bauxite is red to rusty, but brown, yellow and grey colours may also occur.

According to the most widely adopted theory, the bauxite of the Central Mountains was produced from an argillaceous source material -- accumulated in the karst sinkholes of a continental environment -- by physico-chemical processes comparable to tropico-subtropical lateritization.

The bauxite deposits of the Central Mountains stretch for 150 km in the Bakony, Vértes, Gerecse and Buda-Pilis Mountains. The largest deposits are in the first two areas.

The deposits of highest economic value in the Bakony region occur in the southern part of the mountains at Nyirád, Halimba, Szóc and Kislőd, in the northern part at Fenyőfő and near Bakonyszentlászló, and in the eastern part near Iszkaszentgyörgy. At Nyirád, Halimba, Szóc, Kislőd and Iszkaszentgyörgy, the bauxite is mined mostly underground. The major part of the country's bauxite output is furnished by these mines.

Nyirád. The bauxite deposit occurs in the region of Nyirád and Nagytárkánypuszta, in the northern foreland of the southern Bakony Mountains. Here the geological basement is constituted by Upper Triassic dolomite, which crops out in the south, but which northwards plunges gradually below the Upper Cretaceous, Tertiary and Quaternary sediments of the Little Plain basin. The latter are thicker to the north. The bauxite is represented by typical lenses filling the karstic depressions of the dolomite. The underground depth of the lenses increases northwards, to attain 150--180 metres at about 2 km north of the dolomite exposures.

The area occupied by the lenses varies between 0.1 to

10.0 ha, averaging 2.0 ha; the average thickness is 5.0 m (between extreme values of 1 and 30 m). The ore contains an average of 51.8%  $\text{Al}_2\text{O}_3$  and 5.8%  $\text{SiO}_2$ . The composition of the bauxite of good quality is:  $\text{Al}_2\text{O}_3$  55.5%,  $\text{SiO}_2$  2.4%,  $\text{Fe}_2\text{O}_3$  25.2%,  $\text{TiO}_2$  3.1%, loss of ignition 12.9% (boehmite 54.5%, gibbsite 1.8%).

The hanging wall of the bauxite lenses consists of Lower to Middle Eocene clays, marls and limestones, Upper Tertiary conglomerates, sandstones, clays and limestones, and Quaternary clastic sediments. In the northwestern part of the area some Upper Cretaceous (Senonian) marls and limestones also appear, the bauxite being locally developed at two levels—between Upper Triassic dolomites and Upper Cretaceous marls and between Upper Cretaceous Hippurites limestones and Lower Eocene clays.

The area has become an important bauxite-mining district, where karst-water causes significant technical difficulties. The greater part of the bauxite lenses are under the hydrostatic level of the so-called karst-water accumulated in Upper Triassic dolomite; therefore mining is threatened by water entries. To overcome this, the bauxite miners have lowered the water level on the regional scale by large-scale pumping. Thus the lenses are exploited after getting above the karst-water table as a result of its depression.

Halimba. The bauxite deposit of Halimba is the northeastern continuation of the Nyirád deposit, in the flat basin of the northern foreland of the southern Bakony Mountains. The basement is represented by Upper Triassic dolomites and Dachsteinkalk plunging northwards under the gradually thickening Cretaceous, Tertiary and Quaternary fill of the Little Plain basin.



The bauxite deposit lies on the karsted surface of Upper Triassic dolomites and limestones at a depth of 50—400m, over an area of 6—7 km<sup>2</sup>. The thickness of the deposit varies between 1 and 30 m, depending on the karstic topography of the foot-wall. The average thickness of the deposit is 6—8 m. High quality bauxites generally occur in the centre of the deposit. The chemical composition of such a bauxite is: Al<sub>2</sub>O<sub>3</sub> 56.1%, SiO<sub>2</sub> 2.7%, Fe<sub>2</sub>O<sub>3</sub> 24.3%, TiO<sub>2</sub> 2.7%, loss of ignition 12.6% (boehmite 54.8%, gibbsite 0.6%).

In the south the deposit is overlain by Lower to Middle Eocene clays, marls and limestones, in the north by Upper Cretaceous conglomerates, coal bearing clays, marls and limestones, Lower and Middle Eocene clays, marls and limestones, Upper Eocene marls and limestones, Upper Tertiary sands, clays, marls and limestones, and various Quaternary clastic sediments. Prior to the development of bauxite, Senonian sediments had been deposited, but these had eroded before Eocene ingression occurred in the southern part of the region.

S z ő c . South and southeast of the large bauxite deposit of Halimba, at a distance of about 2—4 km, there are a bigger bauxite block and some smaller bauxite lenses of different size, partly exposed, partly at a depth of 10 to 100 m under the surface. The foot-wall is Upper Triassic dolomite, the hanging wall Lower and Middle Eocene clay, marl and limestone, Miocene conglomerate, Pliocene clay and Quaternary clastic sediment. The thickness of the bauxite varies between 1 and 20 m, averaging 5 to 6 m. The chemical composition of the ore of good quality is the following: Al<sub>2</sub>O<sub>3</sub> 48.6%, SiO<sub>2</sub> 1.5%, Fe<sub>2</sub>O<sub>3</sub> 22.6%, TiO<sub>2</sub> 2.8%, loss of ignition 24.9% (gibbsite 41.7%, boehmite 5.4%).

Kislőd. A large bauxite lens near Kislőd, 11 km north-east of the Halimba deposit (this direction corresponds to the characteristic strike of the Transdanubian Central Mountains). Its mean thickness is 9 m (varying between 1 and 30 m). The foot-wall is Upper Triassic dolomite, the hanging wall Lower Eocene clay and marl, and Middle Eocene limestone. The thickness of the hanging wall is maximum of 100 m. The high-grade bauxite of the deposit shows the following characteristic composition:  $\text{Al}_2\text{O}_3$  56.7%,  $\text{SiO}_2$  3.3%,  $\text{Fe}_2\text{O}_3$  20.1%,  $\text{TiO}_2$  2.7%, loss of ignition 15.9% (boehmite 41.8%, gibbsite 12.6%).

Fenyőfő-Bakonyszentlászló. Farther northeast, 45–50 km away from the bauxite area of Nyirád and Halimba, in the northern part of the Bakony Mountains, several bauxite deposits are known to occur. Among them those of Fenyőfő and Bakonyszentlászló are most important. In this region, beside lenticularly distributed masses, there is again a large block of bauxite, at 10–200 m under the surface. The thickness of the bauxite is variable, locally 50–60 m, on the average 6–7 m. The foot-wall is Upper Triassic dolomite, the hanging wall Lower Eocene sand, clay and clay-marl, Middle Eocene limestone, and various Upper Tertiary and Pleistocene-Holocene detrital materials. The quality of the bauxite is very unsteady, and redeposition is a frequent phenomenon. On the average, the ore is of inferior quality:  $\text{Al}_2\text{O}_3$  50.2%,  $\text{SiO}_2$  8.7%; among the ore types gibbsite, boehmite and their mixtures are equally represented.

Alsópere. South of the former bauxite deposit in the Magas-Bakony, near Alsóperepuszta lies a bauxite deposit of

geological interest, though rather insignificant from the economical point of view. The foot-wall is Upper Triassic Dachsteinkalk, directly overlain by the Upper Aptian clay and marl. Accordingly, it can be supposed that the bauxite developed during the Lower Aptian, thus being the oldest bauxite of the Transdanubian Central Mountains. The deposit is stratiform, commercial ore being represented only by some small lenses. The thickness varies between 1 and 9 m, averaging 2 to 3 m. Generally, the bauxite contains plenty of silica:  $\text{Al}_2\text{O}_3$  53.2%,  $\text{SiO}_2$  7.8%,  $\text{Fe}_2\text{O}_3$  19.6%,  $\text{TiO}_2$  2.6%, loss of ignition 15.9%.

In the hanging wall, besides the afore-mentioned clay and marl, there are also Albian limestone, Cenomanian marl, and various Eocene and Miocene sediments.

Iszkaszentgyörgy. Important bauxite deposits are known to occur in the eastern Bakony Mountains, and near Iszkaszentgyörgy in the Mór Graben, separating the Bakony and Vértes Mountains. Occupying an area of 6 to 7 km<sup>2</sup>, the bauxite deposit is stratiform. On the average it is 6—7 m thick, locally attaining even 16 m. The foot-wall is Upper Triassic dolomite, the hanging wall Lower Eocene coal-bearing clay, marl and limestone, Middle Eocene limestone, Miocene gravel, Pliocene limestone and sand (glass sand), and Quaternary clay and loess. The thickness of the hanging wall is locally 300 to 350 m.

For the most part, the bauxite is of mixed gibbsite-and-boehmite type, the ore of good quality is of the following composition:  $\text{Al}_2\text{O}_3$  52-56%,  $\text{SiO}_2$  1-6%,  $\text{Fe}_2\text{O}_3$  16-24%,  $\text{TiO}_2$  1.8-2.9%, loss of ignition 15-23%. The ore reserves are considerable. They are worked in two underground mines with a regional lowering of the karst water table.

The bauxite range can be farther traced in the Vértes Mountains beyond the Mór Graben, reaching a significant development on the southern slope of the mountains, near Gánt.

Gánt. A stratiform deposit, it can be encountered in several isolated units over an area of 3 to 4 km<sup>2</sup>. Its thickness is very variable, attaining a maximum of 25 m.

The foot-wall is Upper Triassic dolomite; the hanging wall, Middle Eocene clay, marl and limestone, with a maximum of 75 m thickness.

The bauxite is of boehmite type and the composition of the good-quality ore is: Al<sub>2</sub>O<sub>3</sub> 55-61%, SiO<sub>2</sub> 2-4%, Fe<sub>2</sub>O<sub>3</sub> 17-22%, TiO<sub>2</sub> 2.2-2.6%, loss of ignition 13-15%. These are the earliest-known bauxite deposits of Hungary, ever since being exploited in opencast pits. All that which has remained from the original ore resources is a highly siliceous bauxite.

Advancing northeastwards in the Central Mountains strike, the bauxite range can be traced even within the Gerecse and Buda-Pilis Mountains, but it occurs there only sporadically in the same stratigraphic level as at Gánt.

In the Gerecse Mountains at Nagygyháza, Ó- and Uj-barok, the bauxite rests upon Upper Triassic dolomites and is overlain, near the surface, by Quaternary sediments or by different Tertiary horizons. The original Eocene cover has been removed for the most part, and only small lenses of bauxite could escape to erosion.

In the region of the Buda-Pilis Mountains, the bauxite deposits are scarcer and smaller. A bauxite lens worth mentioning is only that near Pilisszántó. There the foot-wall is of Upper Triassic Dachsteinkalk; and a part of the bauxite lens is exposed, the rest being overlain by a thin Tertiary cover.

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## V. FIELD GUIDE

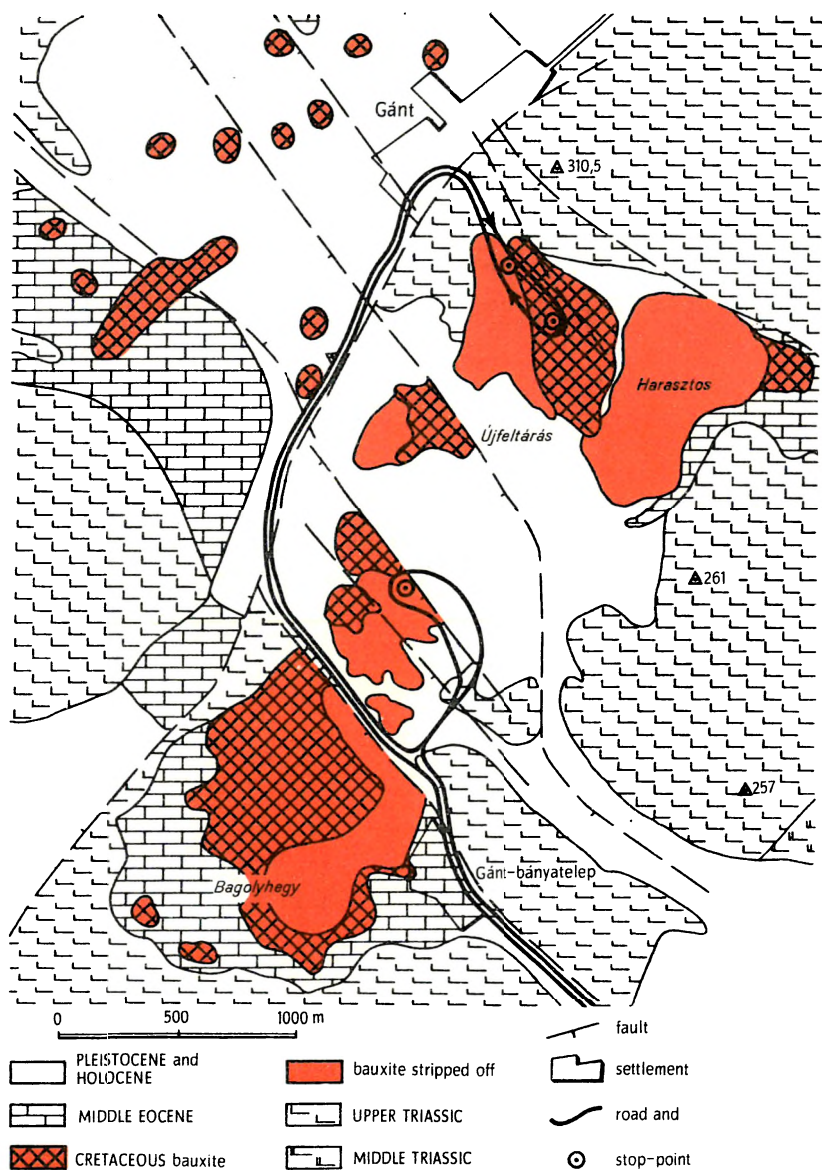
### 1. Gánt

The bauxite pit of Gánt is in the southeastern part of the Vértes Mountains (Fig. 3). Since 1926 it has been exploited with interruptions in opencast pits. The stratiform bauxite is dissected by NW-SE trending faults into the following units: Bagolyhegy, Angerrét, Meleges, Harasztos-Ujfeltárás. The NW-SE striking main faults are combined with faults perpendicular to them.

The foot-wall of the bauxite bodies is represented by Carnian and Norian Hauptdolomit. Bauxite was deposited on a rough karsted surface. The boundaries of the bauxite body are defined by gradual pinch-out or by tectonic lines. The tectonic boundaries suggest that the bauxite body may have been originally larger. Therefore, the existing bodies can be taken to be remainders of a contiguous bauxite bed.

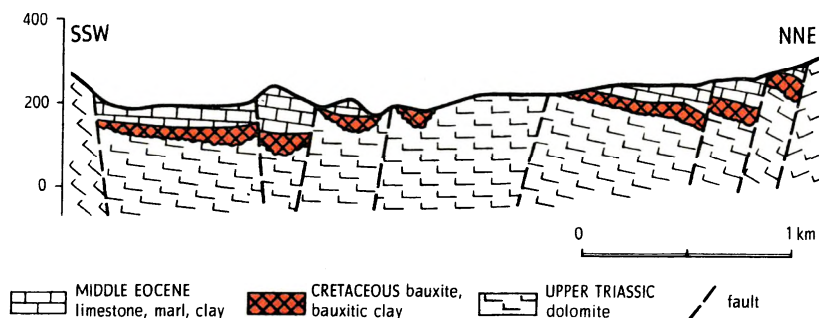
The clayey bauxite, found at the base of the bauxite body, also makes up the pinching margins. The central part of the bauxite formation is constituted by a brick-red to light-brown, pisolitic, concretionary ore of good quality. In the upper horizon there is a bauxite reworked and supplemented by some foreign material in Middle Eocene time. The bauxite is predominantly boehmitic, though it contains varying quantities of gibbsite too.

The Middle Eocene sequence overlies the bauxite with an apparent conformity. Its lower member is a fresh- and brackish-water Melania marl and calcareous marl interrupted



3. The Gánt bauxite deposit





4. Profile across the Gánt bauxite deposit

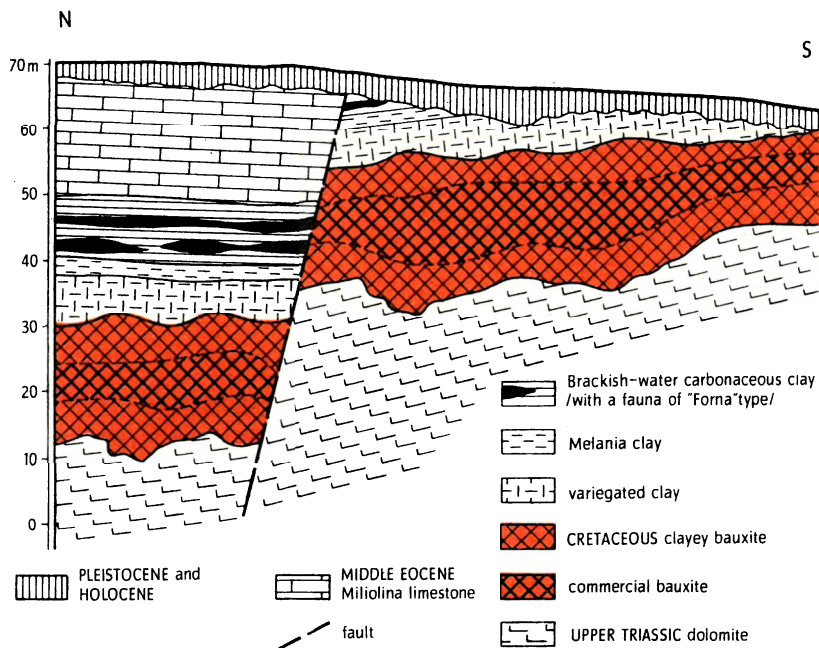
by coal-bearing clay beds. The upper part consists of brackish-water sediments with *Miliolina* and mollusca. The Eocene formations were deposited in well-sheltered, minor bays or in lagoons. The Nummulites limestone shows a grading of fresh- and brackish-water sediments into marine ones.

#### Ujfeltárás, bauxite pit

The exposed part of the deposit backs—in the NE, along an antithetic fault—the southwestern dolomite block of the Gémhegy. Between the dolomite foot-wall and the superincumbent bauxite there is a 10- to 25-cm-thick transitional zone. Descendent Mn and Fe solutions infiltrated into the upper level of the loose, pulverulent, clastic dolomite and cemented it, developing a characteristic hard crust of red-brown, or black hematite and lithiophorite. Above the foot-wall follows a yellow, yellowish-red, or pale purple bauxite, then a yellowish-red, reddish-yellow to red-brown pisolitic bauxite. Pisolite may be enriched in some levels. The next member is a yellow- to red-brown-mottled, variegated ore.

In the upper part of the bauxite formation concretionary bauxites are common. The light red, yellowish-red, clayey bauxite and bauxitic clay, immediately underlying the hanging wall, grade to Middle Eocene variegated clays.

The mineralogical and chemical compositions of the bauxite formation and their changes are presented in Fig. 5. According to this, the bauxite is predominantly of boehmite type, gibbsite is subordinated, but always present (in a maximum of 18%). Among the iron ores, goethite is predominant; the percentage of hematite is generally about 1 to 3%, being enriched only in the red-coloured bauxites (6—9%).



5. Geological section of the bauxite pit of Gánt

### Ujfeltárás, paleokarst

Tectonics played a considerable role in the development of the karst, as it controlled the dissolving effect of water. It is clearly visible that the rows of both sinkholes and pinnacles are arranged according to the main tectonic trends. Karst morphology is largely responsible for the extension and the thickness of the bauxite bodies.

### Meleges II, bauxite pit

This body lies in the central part of the Gánt deposit. The foot-wall is again typically karsted. In this opencast pit all the characteristic bauxite types of Gánt are present. On the NE boundary of the deposit an antithetic fault of more than 20 m throw occurs, with straight, oblique and arched slip-markings. The recurrent post-Eocene tectonical activities are manifested, beside simple slides, by both horizontal displacements and strike-slip faults.

## 2. Székesfehérvár

Leaving the area of the bauxite pits of Gánt, the road leads through the Zámolyi basin to Székesfehérvár, where we pass lunch time. This city is an important communication centre with important industrial plants, of which the radio and TV factory and the light-metal-processing works are the most prominent. The city is noted for its history. Chieftain Árpád, leader of the Hungarian tribes at the time of the Conquest, settled here. The city later became the centre of the new unified Hungarian Kingdom. It was the scene of the most important

governmental ceremonies such as royal coronations, weddings, and burials, Parliament meetings, etc. It did not lose its prominence until the second half of the Middle Ages.

### 3. Iszkaszentgyörgy

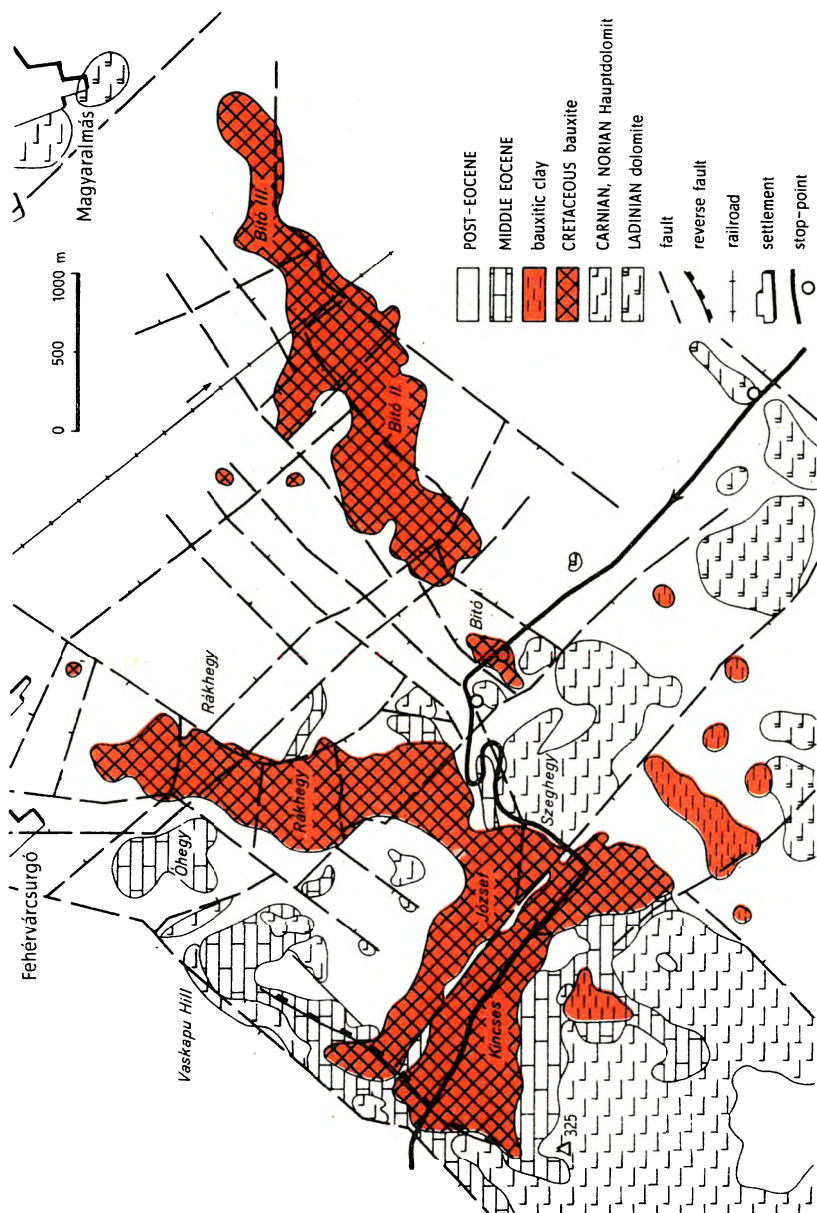
The bauxite deposit of Iszkaszentgyörgy lies on the north-eastern margin of the Bakony Mountains. At present four major bauxite beds are known: Kincses, József, Rákhegy, and Bitó.

The bauxite is stratiform. Characteristic feature is, that with the gradual pinching-out of the bauxite, the quality of the ore will grow worse towards the margin. Thus we can find the best-quality bauxite in the central part of the Kincses and József beds. The average thickness of the bauxite beds is 6 to 7 m. Although the average thickness of the Bitó bed is greater (8 to 9 m), the quality of the bauxite is inferior. The predominant dip is north to northeast.

Characteristic bauxite types (from top to bottom):

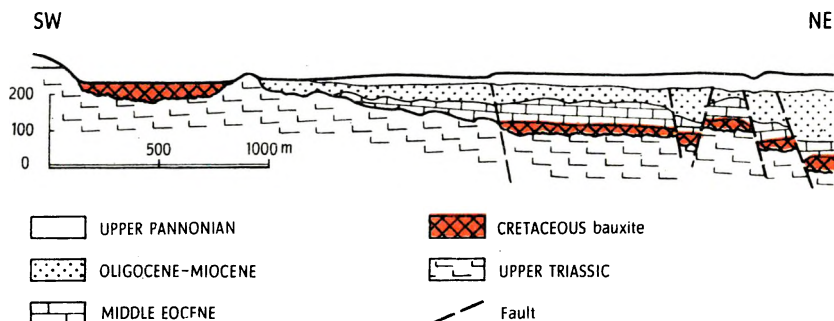
1. Grey pyrite-bearing bauxite of roughly the same extension as the superincumbent coal formation. Quality low for the most part.
2. Purple bauxite, a reoxidized representative of the grey type.
3. Light-yellow, brown-mottled, sometimes brecciated or pisolitic bauxite.
4. Mottled bauxite, dark red, with yellow and purple streaks.
5. Red bauxite, yellow-mottled in the upper part, homogenous in the lower part, and clayey near the foot-wall.

Characteristic of the mineralogical composition of the bauxite beds is that in the Kincses and József beds gibbsite



6. The Iszkaszentgyörgy bauxite deposit

is dominant and boehmite is subordinate and that the Rákhegy bed is of mixed, gibbsite-and-boehmite, the Bitó bed of boehmite type. As for the iron ores, goethite is usually abundant, while hematite rarely attains the quantity of goethite. In the grey bauxite pyrite and marcasite are the predominant Fe minerals.



7. Geological section from the Bitó pit as oriented towards the Mór Graben

In the northwestern part of the Kincses bed, near the grey bauxite, a green, chloritic bauxite type also occurs. The  $\text{SiO}_2$  content of the bauxite is usually fixed in kaolinite.

#### Ladinian Diplopora dolomite quarry

The quarry lies about 2 km southeast of Iszkaszentgyörgy. The dolomite represents the Ladinian stage of the Middle Triassic. It grades northwestwards into Carnian Hauptdolomit.

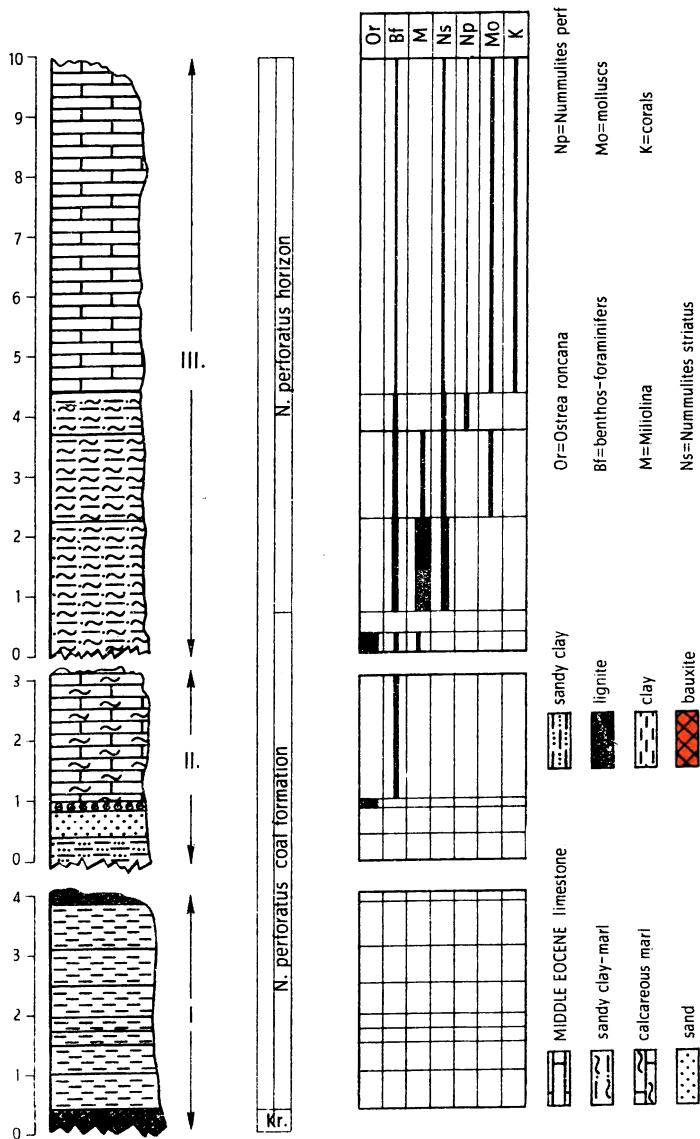
The Paleo-Mesozoic basement of the region strikes NE-SW. Perpendicularly to this strike, a lateral succession of zones, partly exposed, partly buried by younger (Tertiary and Quaternary) deposits, has been recognized. The zones lying

NW of the quarry represent gradually higher Triassic members, those SE of it being respectively of Lower Triassic, Permian, and Silurian age.

The Ladinian dolomite exposed in the quarry is the oldest known foot-wall of bauxite beds in Hungary (Bitó bed, Iszka-szentgyörgy deposit). Its thickness is 800 to 1000 m. As a rule, the dolomite is distinctly stratified, forming thick beds. It dips NW at angles of 30 to 45°. Characteristic fossil is Diplopora annulata (Schaffh.) accumulated in certain beds or lenses.

#### Opencast bauxite pit Bitó I.

In the SW part of the Bitó bed, the bauxite is near the surface. The bed dips predominantly NE. In this direction its depth in the area of the Mór Graben is more than 300 m. The deposit is dissected by longitudinal and strike faults. The foot-wall is partly Ladinian *Diplopora* dolomite, partly Carnian dolomite. The hanging wall consists of Middle Eocene beds exposed also in the pit. NE of the pit the higher levels of the hanging wall include Oligocene, Miocene, Pannonian and Pleistocene formations. In the Pannonian sequence glass sands of good quality are known to occur. The bauxite body, compared with the other bauxite beds of Iszka-szentgyörgy, is of lower quality, though thicker. It is predominantly of boehmite type. Gibbsite occurs mainly in the SW part of the bed, being enriched in the best-quality bauxites (max. 14%). Diaspore occurs sporadically and in a very low percentage. Among the iron ores, goethite is predominant. Si is present in kaolinite and, subordinately, in sudoite.



8. Middle Eocene bauxite-hanging sequence in the Bitó pit



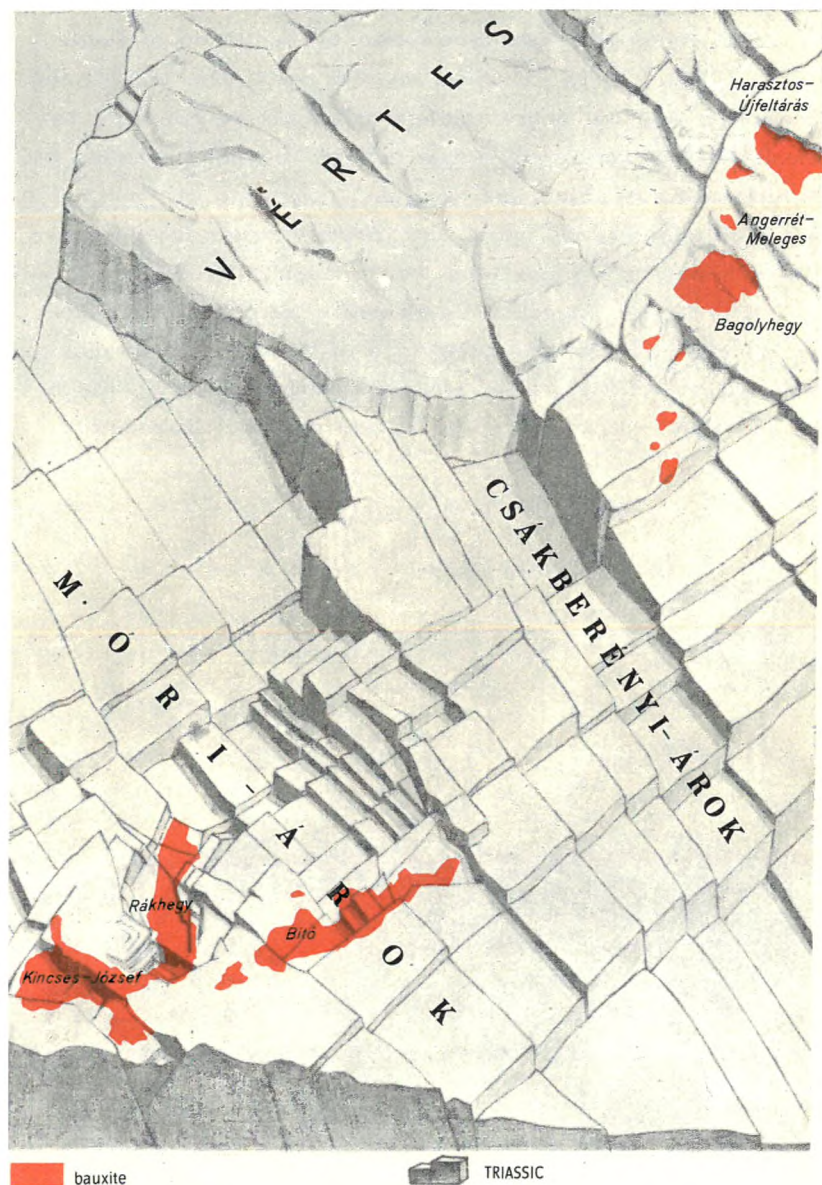
## Panorama of the Mór Graben

In the so-called Mór Graben, which separates the Bakony and Vértes Mountains, NW-SE faults are predominant. These have produced the graben system. The structure is asymmetric. Away from the Bakony Mountains, the graben is dropped down by several comparatively small faults being separated from the Vértes by a larger fault. In the Mór Graben the strike faults have also played an important part. Both NW and SE of the Bitó bed, we find deeper down-dropped fault-blocks. Parallel to the Mór Graben runs the Csákberény Graben of similar structure.

Owing to the discontinuity of the sequences an accurate dating of the faults is rather difficult. Zonality is likely to have been developed before bauxite deposition (as a result of the Late Cimmerian, Austrian and sub-Hercynian movements). The final accumulation of bauxite is supposed to be connected with the Laramian or post-Laramian movements. In the disintegration of the deposits the Pyrenean orogenic phase also played a significant role. Finally, Styrian and Attic movements, mostly confined to reviving ancient faults, must have been involved in the final development of the present-day structure.

### 4. Bakonycsérnye. Tűzkövesárók

Along the strike of the Transdanubian Central Mountains the asymmetrical synclorium was axially filled up with Jurassic and Cretaceous marine sediments. The geological structure of this area was unfavourable for bauxite deposition, although in the northern Bakony Mountains a significant hiatus can be shown to occur in the Lower Cretaceous, a fact suggesting an emergence of the area.

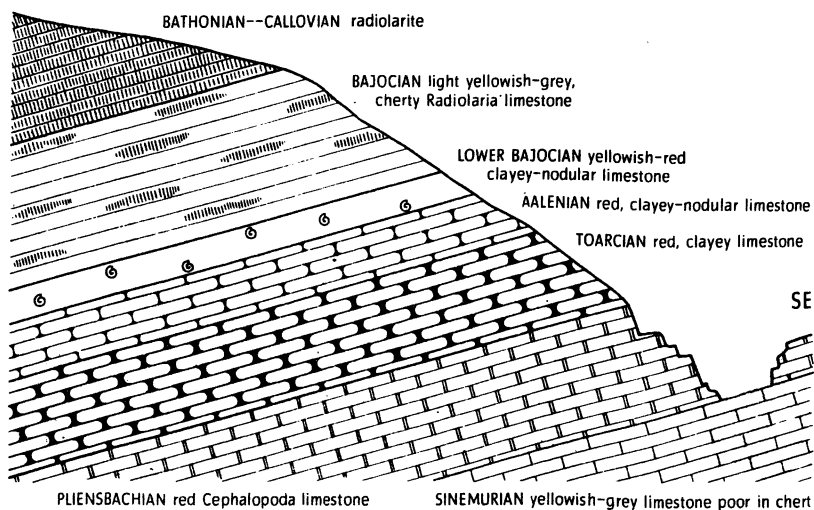


9. Tectonic setting of the Mesozoic basement of the Mór and Csákerény grabens

The Hettangian and Sinemurian are made up of Dachsteinkalk with cherty, crinoidal intercalations. The top of the Sinemurian and the entire Pliensbachian are represented by limestones of Ammonitico Rosso facies. They are overlain by the Toarcian, Aalenian, and Bajocian composed of Ammonitico Rosso represented by marls and clayey-nodular limestones. The abundant ammonite fauna was treated in classical studies.

The Upper Dogger is represented by cherty limestones and radiolarites. At the upper edge of the ravine the radiolarites are overlain by 4- to 5-m-thick Malm limestones which are followed, with a hiatus, by Aptian crinoidal limestones.

NW



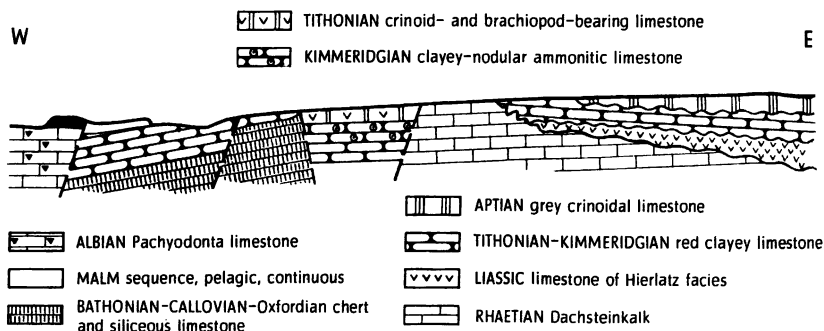
10. Geological section of the Tuzkövesárók at Bakony-csernye

## 5. Zirc, arboretum

The park, of about 36 acres, is only a very little fracture of the virgin forest which used to cover the entire Bakony Mountains. The Zirc Abbey fenced this park in 1759 and from 1782 on, supplemented its stand with various plant species, including rarities from abroad. The plant-assemblage, with its 620 species of trees and shrubs, represents one of the most famous arboretums of Hungary. In 1421 an artificial fish-pond was established here, which ponds up the Cuha brook. The 380-m-long, double linden alley was planted in 1809, along the track of the former Roman military road.

## 6. Olaszfalu. Eperkéshegy

During the Jurassic and Cretaceous, characteristic discontinuous sequences were deposited in the marginal zones of the marine and continental sedimentary basins. A pretty example of them can be studied on the Eperkéshegy by Olaszfalu. Just a few kilometres beyond the hill, lies an area which emerged and was karsted after the Triassic period, and bauxites were deposited in the karst dolines (Alsópere).



11. Geological section of the Eperkéshegy at Olaszfalu

The hanging wall of the bauxite bodies is an Upper Aptian Munieria clay. To W-SW, towards the ancient marine sedimentary basin, complete Jurassic and Lower Cretaceous sequences are known. Both the near-by bauxites of Perepuszta and the Lower Cretaceous marine sequences of Zirc-Lókút are heteropic facies. The Eperkéshegy at Olaszfalu represents a transition between the two developments.

## 7. Veszprém

The city has a rich historical past. During the Árpád dynasty it was mainly the residence of the queens. Most of the city's historical and architectural monuments are in the castle area. (Under the castle-gate, on a table, a short bilingual summary commemorates the city's history.)

On the left side of the castle-gate there is a fire-watch tower, at right the Castle Museum. Going northwestwards, the main street is bordered by baroque mansions. Leaving behind the Renaissance column called "Vetési kő", our way leads to a little square surrounded by the episcopal palast, the canon's houses and the Gizella chapel. In the middle of the square is the castle well, sunk uncased into the compact Raiblian dolomite. In the Middle Ages it was used as water reservoir.

To the northwest the square is closed by the cathedral's undercroft, which preserved its original, time-honoured form.

Throwing a glance at the castle garden and the chapel ruins exposed near-by, we can take delight in the sight of the landscape north of the city, standing—near the statues of the first Hungarian king, Stephen I (1000—1038), and his wife Gisela— at the rock-wall rimming the escarpment of the castle hill. The white rocks immediately below us are of Raiblian dolomite.

The city has been built partly on Norian Hauptdolomit, partly on Carnian rocks. The thickness of the Carnian varies between 500 and 800 metres. In the sequence of unusually rich facies an abundant fauna can be studied (Daonella reticulata, Halobia rugosa, Carnites floridus, Trachyceras austriacum, Megalodus carinthiacus, Ostrea montis caprillis, Placochelys placodonta etc.)

#### 8. Balatonfüred

It is an internationally known spa, famous chiefly for its natural carbonic acid waters. Since more than two centuries, its spring-waters have been used for curing heart diseases. Monuments and self-planted linden-trees keep the memory of Rabindranath Tagore and the Italian Nobel-Prize-winner poet, Quasimodo. The spa was developed in the 19th century. During the reform period it became a symbol of the Nation's efforts. The first Hungarian stone-theatre was built here in 1831. The famous "Ann balls" date from this period. The introduction of steam navigation on Lake Balaton is also connected with the name of Füred. Aquatic sports, nice parks, historical and artistical monuments, and amusement places make it attractive and suitable for accomodating international conferences.

#### 9. Tihany Peninsula

Concerning landscape and geology, this is one of the most beautiful and interesting areas of Hungary. As shown by drilling and by xenoliths in basalt tuffs, the basement of the Tihany Peninsula consists of Paleozoic anchiepimetamorphic

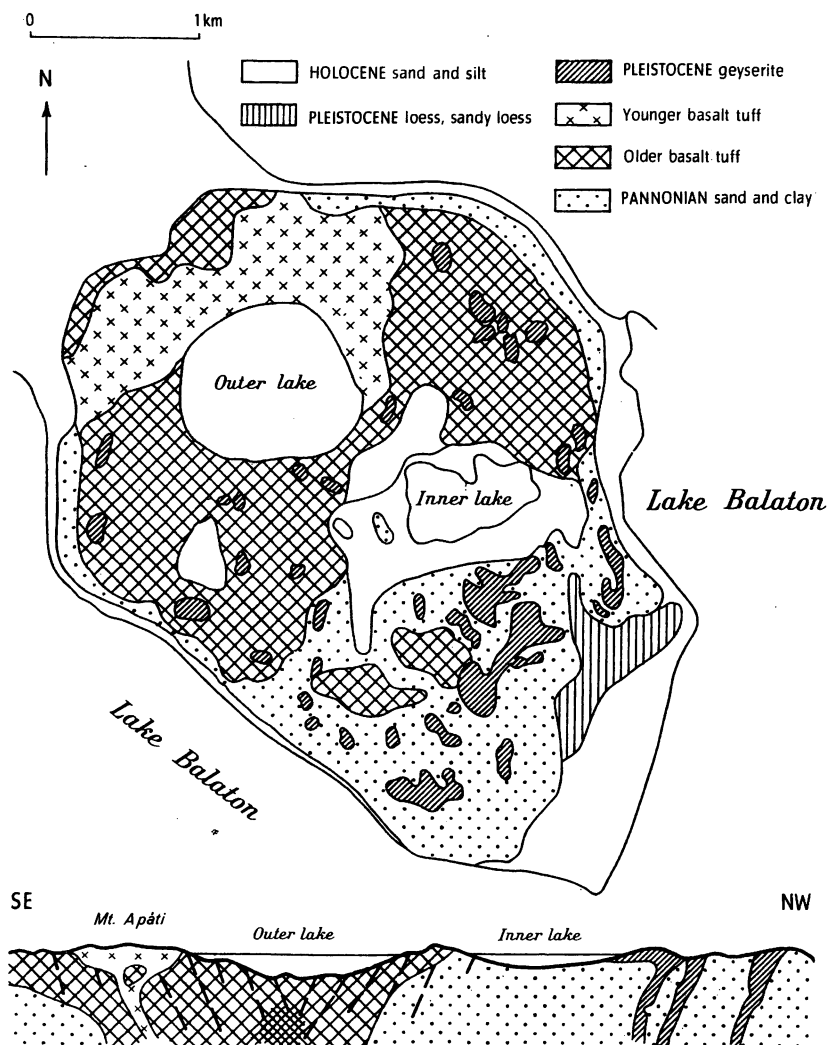
rocks and of Permian red sandstones. They are overlain by a Pannonian sequence, the final member of which is the Congeria triangularis horizon. Tectonic disturbances at the end of the Pannonian opened up channels for basaltic volcanism. The volcanic vent was in what is now the Outer Lake, a hypothesis warranted by prominent magnetic highs. This was the crater that furnished the basalt tuffs, rich in xenoliths. After the crater collapsed and the caldera had developed, coarse-grained lapilli and bombs were ejected in the northern part of the caldera, giving rise to independent cones of basaltic tuff. The development of numerous geyserite cones was contemporaneous with the second phase of volcanism. The afore-mentioned formations of the Peninsula are associated with Pleistocene loess and loessic sand and with Holocene deposits.

#### Templómdomb

The Tihany Abbey was founded in 1055 by King Andrew I. Its charter contains the first written record of the Hungarian language. The founder is buried in the Romanesque crypt. Above the crypt a baroque style church crowning the hilltop was built between 1719 and 1754. The ruins of the former church, monastery, and castle were used in its construction.

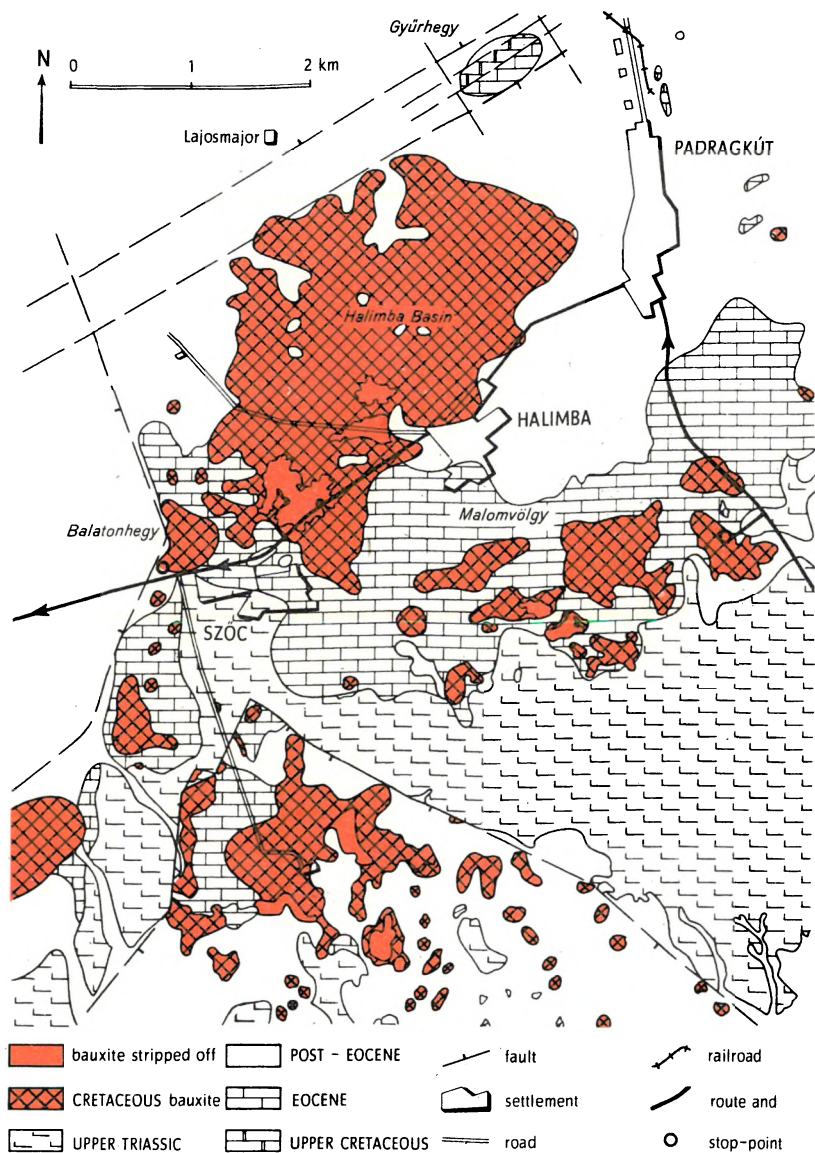
In 1954 a geophysical observatory (geomagnetic, gravimetric, and telluric measurements) was built on the Peninsula. In addition, there is a Biological Research Institute founded earlier.

#### 10. Halimba. Malomvölgy bauxite pit



12. Geological map and section of the Tihany peninsula





13. Halimba-Szóc bauxite deposit

## 10. Halimba. Malomvölgy bauxite pit

South and southeast of the village Halimba is the so-called Malomvölgy bauxite lens group. The size of the lenses varies between 0.1 and 0.6 km<sup>2</sup>. To the south, east and west of the lenses the Upper Triassic Hauptdolomit is exposed in several places. Close to these outcrops the bauxite is also exposed in a number of places. At present, both prospecting and mining are going on in this area. The lenses are mostly at shallow depth and are suitable for opencast exploitation. Their dip shows in most cases a northern trend. The oldest geological formation is the Norian Hauptdolomit, it is on its karsted paleorelief that the bauxite was deposited. The hanging wall consists of Lower and Middle Eocene continental, brackish-water and marine sediments.

In the vicinity of the dolomite outcrops the Eocene sediments were eroded, the bauxite was partly redeposited, degraded, and covered by Pleistocene clastic-clayey deposits. In the region, NW-SE and NE-SW trending faults are predominant, which were developed before the accumulation of the bauxite or simultaneously with it. The younger faults are, for the most part, renewed ancient faults.

In the eastern part of the bauxite deposit is the lense No. XI. In NW-SE direction its length is 760 m, the breadth, 600 m. The average thickness of the bauxite is 10 m. In the southern dolomite area the bauxite crops out from beneath the Pleistocene sediments. In the north its depth is more than 80 m.

Vertically, the bauxite formation can be divided into three parts: the upper member is a clayey bauxite poor in iron, the middle one is a commercial ore, and the lower clay-

ey bauxite has no economic value. One part of the bauxite deposit was several times redeposited, partly before the Eocene, or in Lower and Middle Eocene time, partly in Pleistocene time. Redeposition—especially that which occurred in Pleistocene time—was followed by a significant worsening of quality. Mineralogically, the bauxite is predominantly of gibbsite type (max. 76.6%); boehmite is subordinate (max. 36.5%). Among the iron ores both hematite and goethite are significant, hematite perhaps a little more. Si occurs in kaolinite, but the allochthonous parts include quartz, too.

Bauxite is partly overlain by Lower Eocene sediments. As a consequence of infra-Lutetian denudation the L. Eocene beds were partly eroded and only minor rags have been preserved. Comparatively larger contiguous Lower Eocene masses are encountered only in the northern half of the lens. Here the 6-m-thick silty marl is parted by clay beds and the 10-m-thick limestone has a coarse crystalline texture. The Middle Eocene Assilina spira horizon (originating lithologically from the reworking of older Eocene members) consists of conglomerate and limestone. The limestone beds are interrupted by yellowish-brown, sandy clay stringers of bauxitic origin.

Beside the representatives of Assilina, characteristic forms are: Nummulites baconicus, Alveolina elongata, Operculina sp., Orbitolites sp. and the species of Miliolina. In the southern and middle part of the lens, the bauxite is directly overlain by Middle Eocene beds. In such cases the unconformity between the bauxite and its hanging wall is conspicuous.

Higher Eocene members occur only in the less eroded northern area, where the Nummulites perforatus horizon has an over-all extension.

## 11. Szóc, Balatonhegy

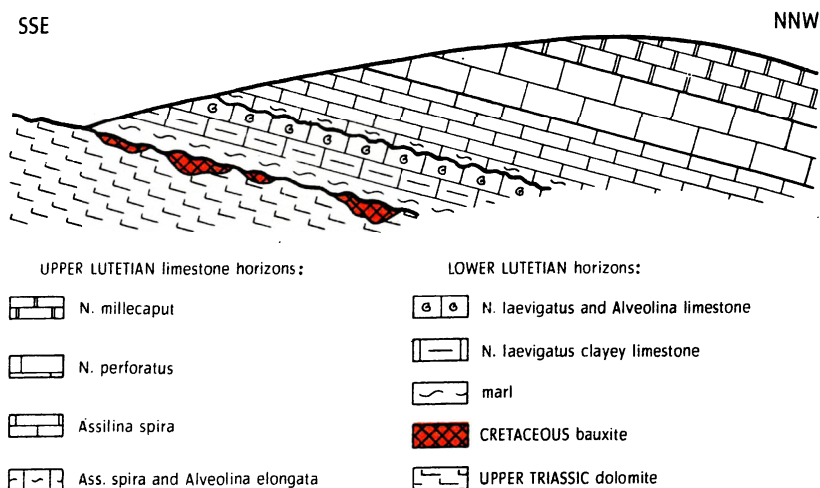
On the karst surface of the Upper Triassic (Norian) Hauptdolomit there are remnants of a Cretaceous bauxite deposit. They are overlain by the lowermost member of the Middle Eocene (Lower Lutetian) brackish-water *Milliolina*-molluscan marls and marly limestones. Locally, this formation contains coal lenses. The *Milliolina* marls grade, with continuous sedimentation, into clayey-marly limestones characterized by *N. laevigatus* Lamarck, in which molluscs and echinoids can be collected, in addition to the larger foraminifera. The upper part of the limestones contains *Alveolina*. The top of the sequence shows traces of redeposition due to emergence (intra-Lutetian erosion). This unconformity is overlain by Upper Lutetian limestones with *Alveolina elongata* and *Assilina spira*. As an extension of the geological section, limestones with *N. perforatus* and *N. millecaput* can be traced on the hilltop.

From the hilltop the magnificent landscape of the Halimba basin unfolds before our eyes. The bauxite is stratiform, lying between Upper Triassic dolomite or partly Dachsteinkalk (foot-wall) and Eocene and Upper Cretaceous sediments (hanging wall). On the southwestern margin of the basin there are also Kössen beds in the foot-wall and the Lower Liassic Dachsteinkalk was also preserved in some deep-seated tectonic grabens sheltered from erosion. The lower levels of the bauxite body are of red clay with limestone and dolomite detritus. The marginal parts of the ore body are characterized by similar bauxite formation of no economic value. In the southern part of the basin the bauxite is overlain by Lower Eocene, in the central and northern parts by Upper Cretaceous coal-bearing sequences.

## 12. Nagytárkány. Darvastó bauxite pit

The lenticular bauxite body lies in the southwestern part of the Nagytárkány bauxite area. In the opencast pit we can see well the karsted paleorelief which at the contact with the bauxite is intensively weathered and pulverulent. Ferruginous and manganous precipitations are frequent.

Lithologically, the bauxite is essentially a light or dark brick-red body, variegated in the upper and lower levels. Sporadically, near the hanging wall, the bauxite is grey, containing many pyrite-marcasite (partly hematitic) concretions and fragments of plant roots.



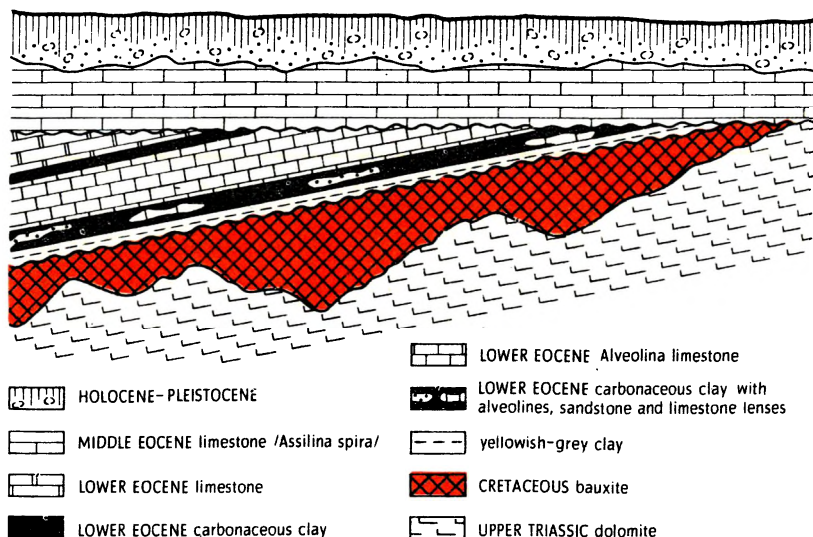
14. Geological section of the Balatonhegy at Szőc

The principal mineral of the bauxite is gibbsite; boehmite is subordinate. In the red-coloured bauxite types hematite is dominant, and the quantity of goethite is only 4-5%. The Si of the bauxite is fixed in kaolinite.

This bauxite body is immediately overlain by the Lower Eocene Alveolina oblonga horizon, made up of lignite, carbonaceous clay and Miliolina-Alveolina limestone. It is overlain unconformably by Middle Eocene Assilina- and Nummulites-bearing limestones. The Eocene beds show atectonic bends.

N

5



15. Geological section of the bauxite pit at Darvastó

Not only the higher Eocene members were affected by post-Eocene erosion, but sometimes the bauxite as well. In the area of the lens the erosion reached, in some places, down to the upper level of the bauxite formation. In such a way, the ore body remained in situ, without any worsening of quality. In Hungary it is relatively unfrequent to find a bauxite of a good quality under Pleistocene sediments.

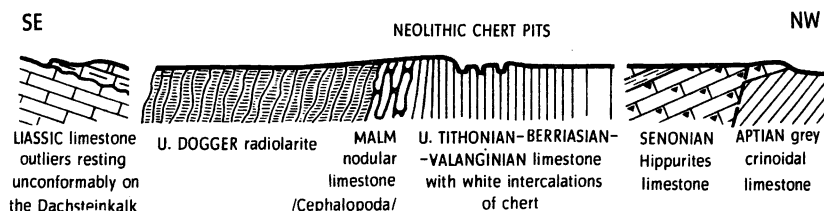
The faults are abrupt, either controlled by pre-existent faults, or developed simultaneously with the bauxite, or post-Eocene.

### 13. Sümeg

Situated below a mediaeval castle which crowns a horst of grey crinoidal Aptian limestone, the town has a rich historical past. Neolithic chert pits have been discovered in the Berriasian limestone member of the Mogyorósdomb; the tops of the steep Cretaceous and Eocene limestone hills rising above the town were prehistoric campsites. Artifacts of the Copper, Bronze, and early Iron Age have also been found. There are records of Illyrian, Scythian, and Celtic residents, and of Roman occupation from the early years of our era to the end of the 4th century. After the Roman legions withdrew, Huns, Eastern Goths, and Longobards replaced each other, and then there were invasions by the Avars, Franks, and Slavs. The Hungarians built a castle here after the Mongol invasion of Hungary, which became an important stronghold in the fights with the Turks and during R á k ó c z i's insurrection. In 1713 it burned down and was abandoned. Worth of mention are the baroque and neoclassic buildings and the frescoes of the parish church painted by M a u l b e r t s c h.

## Mogyorósdomb

Thick chert-nodule-bearing Radiolaria marls (Dogger), cephalopod-bearing clayey-nodular limestones (Oxfordian--Kimmeridgian), and then Biancone limestones (Tithonian--Berriasian--Valanginian--Hauterivian) exemplify the continuous marine sedimentation of this area. During geological excavations, the traces of an important Neolithic chert mining were uncovered. In the vicinity, on the edge of Kövesdomb hill, a Senonian Hippurites limestone sequence is exposed.



16. Geological section of the Mogyorósdomb and Kövesdomb at Sümeg

## Gerinci quarry

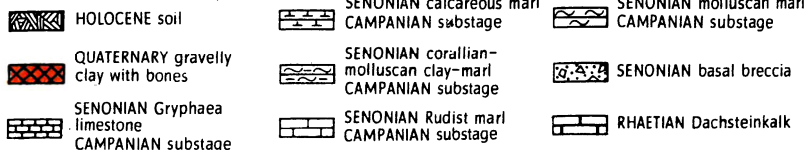
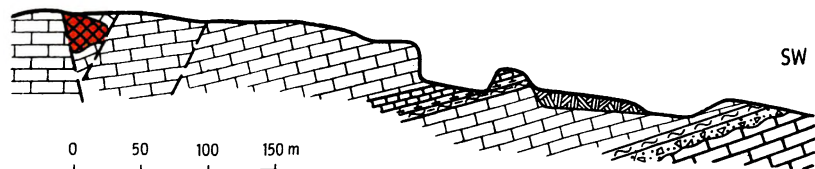
The Senonian Hippurites limestone sequence is above Upper Triassic Dachsteinkalk. Taking into account that a totally different geological development is on the near-by Mogyorósdomb, we can observe a magnificent example of the block-faulting tectonics of the Transdanubian Central Mountains.

In the dolines of Hippurites limestones bauxite bodies were discovered. Their material may have been redeposited from the adjacent Triassic limestone and dolomite areas. This is supported by both textural characteristics and composition of the bauxites.



NE

SW



17. Sümeg, Gerinci quarry

#### 14. The bauxite deposit of Nyirád

The Nyirád deposit of 30 km<sup>2</sup> area is on the southwestern margin of the Bakony Mountains.

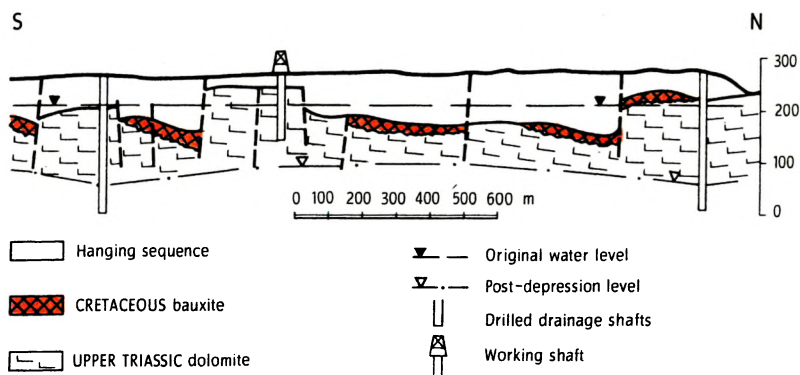
The foot-wall of the bauxite is usually Upper Triassic dolomite, the hanging wall is constituted by Eocene, Helvetian, Tortonian and Sarmatian limestones, calcareous marls, sandstones, sands, pebbles and clays. Impermeable formations are thin and laterally discontinuous.

The area was strongly affected by tectonic stresses. Many pre- and post-bauxite faults can be traced. As a result of post-bauxite denudation processes, the bauxite has been preserved in form of lenses only in the tectonically controlled depressions of the karst relief.

The carbonate rocks of the area—the Triassic dolomites and the Eocene and Miocene limestones—are strongly karsted, heavily water-bearing. Therefore, bauxite deposits under karst-water level are threatened by water hazard. Water hazard is

due to the presence of a so-called main karst water system which is continuous throughout the Transdanubian Central Mountains. The water is accumulated primarily in the Upper Triassic dolomites and limestones, and Jurassic limestones. In the younger sequences "inherited karst-waters" are present. The original karst water table is at 176 m a.s.l. The greater part of the bauxite lenses lie sometimes by more than 100 m below the static level of the main karst-water system. Bauxite mining was handicapped and sometimes even jeopardized by karst-water entries. Therefore, prior to the extraction of bauxite, the karst water table is lowered to ensure the working of dry ore.

The beginning of active karst-water control can be dated from the time of suddenly increased water extraction in 1963.



18. Geological section of the Nyirád bauxite area

The active water control was developed by investigating the locations and equipments and means of drainage workings and by a consideration of the available karst-hydrological evidence.

The information about the location of tapping (tapping by shafts and drifts, or scattered wells) and about the means of water extraction (underground pumping cells or plunger pumps) has shown several possibilities for drainage.

In the first period of active water control the sinking of drainage shafts, with drainage drifts radiating from them and equipped with plunger pumps, seemed suitable. However, their execution was faced by great difficulties because of the great water hazard.

In addition to this, such an approach is disadvantageous because the drainage shafts have to be sunk to a great depth owing to the steepness of the lower part of the depression funnel. Because of the encountered difficulties and with a view to economy, the drainage method was finally modified and a bore-well system of water control was adopted. According to this, shafts (wells) are sunk by drilling technology in the barren interspaces of the bauxite bodies and karst water is extracted by plunger pumps. During this procedure karst-water entries cannot cause difficulties, and the scattered wells produce—because of interference—a more favourable depression area. Thus the volume of water to be extracted and the emplacement of the bauxite lenses have been decisive for the determination of the location and number of wells.

The rate of pumping necessary for controlling the dynamic water recharge is about  $70 \text{ m}^3/\text{min}$ . As regards the annual amount of static water reserves to be extracted, it depends on the rate of drainage. With the gradual drainage of the sta-

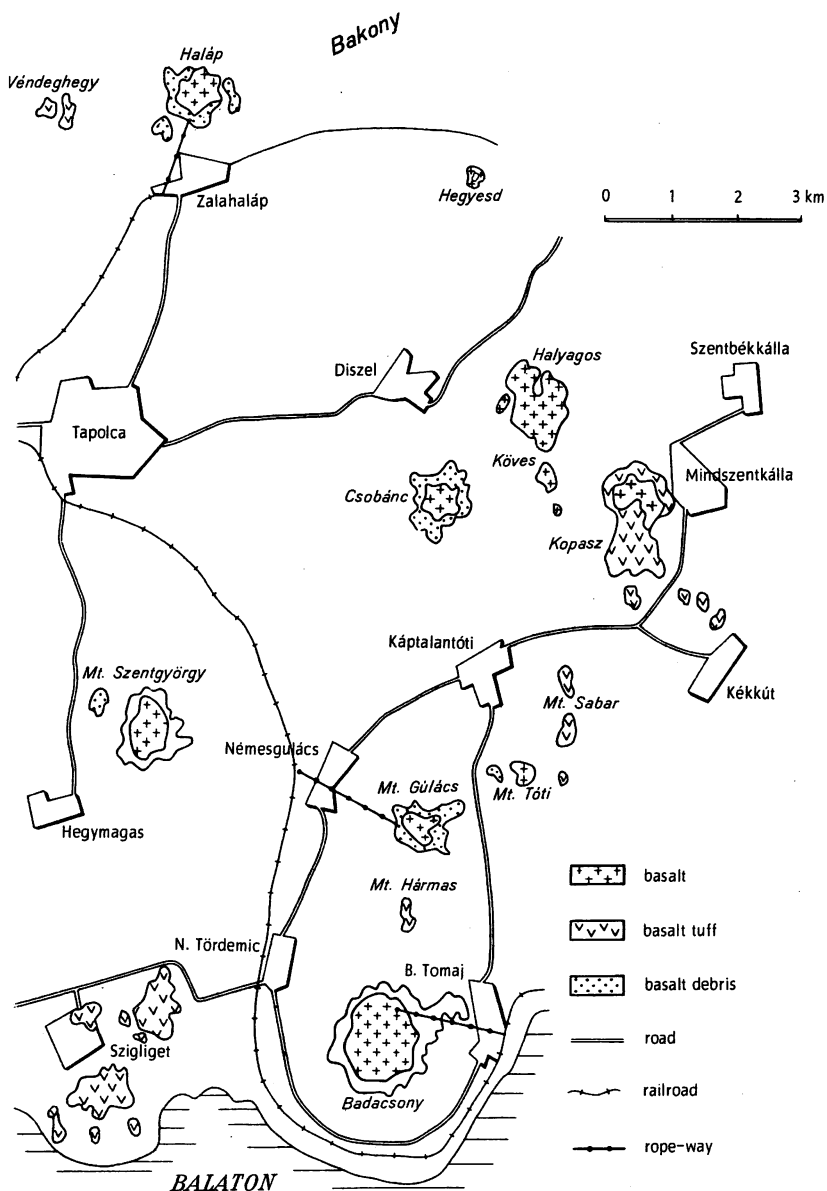
tic water reserves the volume of extracted water gradually approaches the calculated value of dynamic water recharge. In Hungary the first experimental drill-shaft was sunk in 1963. Since the technology of drill-shaft sinking is continuously improved, the output gradually increases and the execution expenses decrease.

### 15. Basaltic volcanoes of the Tapolca Basin

The most scenic portion of the Balaton Highland is the Tapolca Basin. The basalt cones of Mounts Badacsony, Szigliget, Gulács, Csobánc, Tóti and Szentgyörgy are real gems of this volcanic lakeshore. Their characteristic shape, harmony and combination with the adjacent Lake Balaton, have been from time beyond recall the source of beautiful stories and folk-tales, and the favourite subjects of artists.

The basalt cones of the Tapolca Basin were built up by explosive and effusive eruptions. Volcanic activities began with eruption of ashfall tuffs, continued with lava flows and locally ended with vesicular scoriaceous lava flows. Their structure and development are rather uniform. The volcanic activity took place on the Upper Pannonian sand and sandy clay relief. Later the loose sands were mostly eroded around the basalt mounts and they have been preserved only where the steep walls of the basalt cover protected them, thus forming the gently sloping base of the basalt cones.

The basalts forming the volcanic mounts of the Tapolca Basin, are partly stratified-bedded, partly exhibit columnar jointing. The frequent forms of jointing are the so-called "stone sacs" —typical irregular basalt columns of 1.5 to 2 m diameter— whose typical representatives occur on the slope of the Badacsony.



19. The basalt cones of the Tapolca Basin

The basalt types of the Tapolca Basin have a compact texture and are first-class road-materials, because of their good cleavage characteristics. They can be well used for masonry, too. Consequently, significant basalt quarries have been developed here. For the sake of nature conservation, extraction was stopped in most of them, only some quarries on Mounts Haláp and Halyagos are still active.

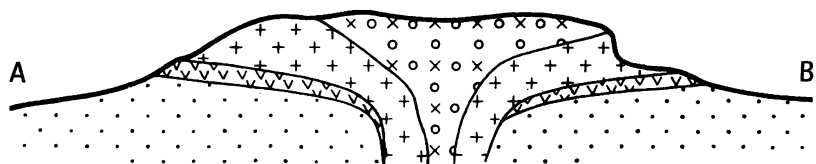
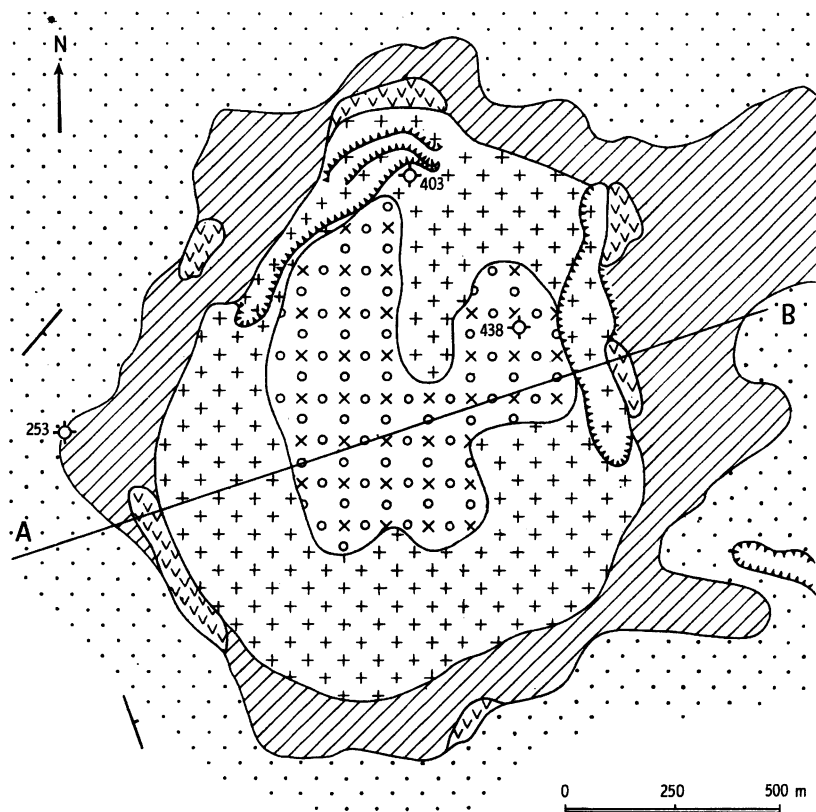
#### 16. The Badacsony

The best-known basalt mount in the Tapolca Basin is the 439-m-high Badacsony on the Balaton shore. The scenic beauty, historical past, literature and artistic relations and far-famed wines make it the country's pride.

The basal part of the gentle hill-side up to 300-310 m is constituted by Upper Pannonian sand and clayey sand sequences. Here there are carefully cultivated vineyards. The upper steep, forest-covered part of the mountain consists of volcanic rocks. At their base a pyroclastic layer represents the beginning of volcanic activity, it is followed by a dark grey, compact basalt of columnar jointing, which was greatly exploited between 1905 and 1964 because of its first-class road-material characteristics. The brownish-red vesicular basalt represents the last product of the volcanism, forming gentle projections on the hilltops.

#### 17. Balatonalmádi. Enterprise of Bauxite Prospecting

This prospecting enterprise of the Hungarian Trust of the Aluminium Industry was founded in 1954 with the task of regular and large-scale bauxite prospecting, mainly in the Transdanubian Central Mountains. It had a considerable part in the



- |   |  |
|---|--|
|  Basalt talus     |  Basalt pyroclastics                  |
|  Vesicular basalt |  UPPER PANNONIAN sand and clayey sand |
|  Compact basalt   |  |

20. Geological map and section of the Badacsony

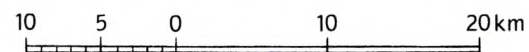
conclusion of the Hungaro-Soviet Aluminium Agreement (15th October, 1962), which ensures an economically favourable industrial utilization of the extracted bauxite. Between 1950 and 1959 the mean annual drilling metrage was 30,000 m. Since 1959 it has shown a gradual increase and in 1963 it exceeded 100,000 m. At present the activities of the Enterprise include: drilling operations; geodesic locating of prospect workings; regular analyses of geological materials as a result of the putting into operation of the Enterprise's laboratory in 1966; geological interpretation of field results and estimation of bauxite reserves. In the bauxite pits of the prospected area, hydro-geological observations are made. In addition, the Enterprise deals with drill-shaft sinking and with the production of equipment for supporting underground workings.

Sokszorosította: a M. Áll. Földtani Intézet  
120.pld.-ban. Fv.: Balogh Ernő  
Eng.sz.: 21/1969



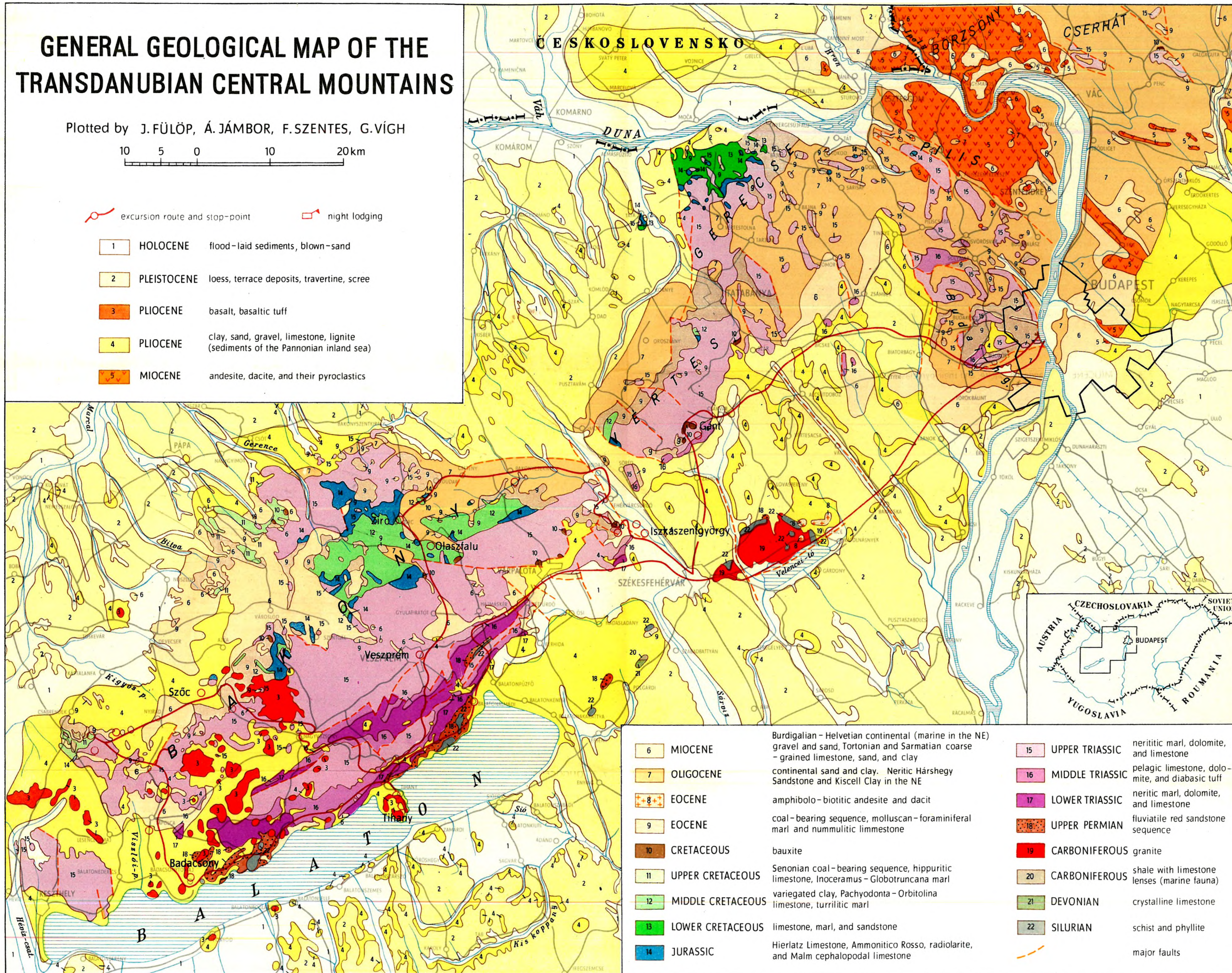
# GENERAL GEOLOGICAL MAP OF THE TRANSDANUBIAN CENTRAL MOUNTAINS

Plotted by J. FÜLÖP, Á. JÁMBOR, F. SZENTES, G. VÍGH



excursion route and stop-point night lodging

- |   |             |   |
|---|-------------|---|
| 1 | HOLOCENE    | flood-laid sediments, blown-sand  |
| 2 | PLEISTOCENE | loess, terrace deposits, travertine, scree  |
| 3 | PLIOCENE    | basalt, basaltic tuff   |
| 4 | PLIOCENE    | clay, sand, gravel, limestone, lignite<br>(sediments of the Pannonian inland sea) |
| 5 | MIOCENE     | andesite, dacite, and their pyroclastics  |



6 MIOCENE

7 OLIGOCENE

8 EOCENE

9 EOCENE

10 CRETACEOUS

11 UPPER CRETACEOUS

12 MIDDLE CRETACEOUS

13 LOWER CRETACEOUS limestone, marl, and sandstone

14 JURASSIC

Burdigalian - Helvetian continental (marine in the NE) gravel and sand, Tortonian and Sarmatian coarse-grained limestone, sand, and clay continental sand and clay. Neritic Hárshegy Sandstone and Kiscell Clay in the NE

amphibole-biotitic andesite and dacite

coal-bearing sequence, molluscan-foraminiferal marl and nummulitic limestone

bauxite

Senonian coal-bearing sequence, hippuritic limestone, Inoceramus - Globotruncana marl variegated clay, Pachyodonta - Orbitolina limestone, turrititic marl

Hierlatz Limestone, Ammonitico Rosso, radiolarite, and Malm cephalopodal limestone

15 UPPER TRIASSIC

16 MIDDLE TRIASSIC

17 LOWER TRIASSIC

18 UPPER PERMIAN

19 CARBONIFEROUS granite

20 CARBONIFEROUS shale with limestone lenses (marine fauna)

21 DEVONIAN crystalline limestone

22 SILURIAN schist and phyllite

major faults





## KEY MAP

