# GEOLOGY OF IPOLYTARNÓC*

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## HISTORY OF RESEARCH

The northern tributaries of the Csapás-völgy merging with the Ipoly river, the Botos- and Borókás-árok ravines and the ,,Kőmedence", owe their worldwide fame to the preservation within this restricted area of almost all the phenomena of one-time life. The rich fossil plant finds, the diversified marine micro- and megafossils, the fossil traces of birds and mammals and even of rain droplets preserved in their paleoenvironment represent a unique collection of Nature's treasures.

This natural geological museum of Ipolytarnóc is to be thanked first of all to the habitat that had resulted from the exceptional paleogeographical setting, to the rhyolite tuff blanket that played a role similar to the case of Pompeii. Its exposure was provoled by post-volcanic tectonic movements, while the effects of active erosion have been enhanced, regretfully enough, by man's activities which have led to irretrievable damages.

The history of the Ipolytarnóc finds has been a chain reaction of discoveries traceable back to nearly one century and a half ago. The history of exploration of the silicified tree-trunks, the footprint sandstone, the shark teeth and the fossil flora is reviewed in the chronological order of discoveries.

### The silicified tree-trunk

Edited by P. BUGÁT and F. FLÓR, the publication "Proceedings of the Field Symposium of Hungarian Physicians and Naturalists" was the first to announce, in a paper by F. KUBINYI (1842), that in 1836, while strolling along the Ipoly's bank, the author observed, "at a distance of a quarter of hour's walk from the village Tarnócz..., where countless ravines empty into the river, the giant-sized petrified tree in question." The shepherds of the region alleged "to have crossed the ravine several times in their young days, by walking along the so-called Gyurtyánkő bench". Buried with sand, the wood trunk was then visible in a length of 3 fathoms. On October 6, 1841, he had the trunk unearthed and dragged out of the ravine by "11 pairs of oxen". The trunk then broke into pieces. A number of the resulting fragments were then transported, upon KUBINYI's orders, to Losonc (now: Lučenec, Slovakia). The wood fragments totalled 132 feet in length, i.e. 22 fathoms (42 m) in the pit called Kőmedence which lay where now the concrete basin of the Conservation Hall (1983) is situated. **1842.**

KUBINYI named the silicified trunk "*Petrefactum giganteum Humboldti*" which he supposed to have been oak or Austrian oak.

Eager to conserve the 9-fathom-long petrified wood left at the site, KUBINYI had it covered with earth, "lest it fell prey to vandal hands, that are lamentably so common in this country and that let the so-called stone-bench come to nothing". He concluded that "the hills of the neighbourhood are made up of sandy and argillaceous apoka (molasse) accumulated by running water".

B. JANKOVICH, "chemistry assistant at the Mining Academy of Selmecz", having analyzed the petrified log, identified the following components:

| | | |
|---|---|---|
| "Silex | 86 00 | per cent |
| Water | 9 22 | per cent |
| Coal | 2 78 | per cent |
| Clay-earth | 1 32 | per cent |
| Red | 0 54 | per cent" |

And KUBINYI was really not mistaken as far as the behaviour of the later generations is concerned. Scarcely a few well-preserved fragments of silicified wood could escape devastations by vandal hands and even these owed their preservation only to being buried under the ruins of a collapsed conservation house built in the last century.

* Manuscript completed in September, 1983

**1854.** F. KUBINYI,* then one of the editors of the publication "Hungary and Transylvania in Pictures", re-publishes, with some slight modifications, his paper on the petrified tree-trunk and appends a superb drawing of K. MARKÓ Sr. as an illustration. Judging by the picture and the description, just a few pine trees were rubbing along the then barren landscape lacking any trace of the acacia trees now dominating the area.

**1865.** The petrified tree-trunk of Tarnócz is visited by J. SZABÓ, professor at the University of the town Pest. He estimates its length at 40 m, its perimeter, in the thickest part, at 3 m. Locating it stratigraphically between the "apoka and the basalt tuff" (=rhyolite tuff), he notes that the roots of the one-time tree penetrated into Miocene sandstones of marine origin that had been exundated. In his opinion, the broken tree-trunk fragments weighed an estimated 1600 quintals!

**1901.** J. TUZSON presents his paper "The petrified tree of Tarnócz" at a meeting of Division III of the Hungarian Academy of Sciences.

The thicker part of the log, 24 m long, was still available in the conservation house. As stated by H. BÖCKH, professor of the Mining Academy, and shown in the afore-mentioned paper, "the tree-trunk lies at the boundary between the Lower and Upper Mediterranean stages, being buried by biotite andesite tuff. In one level with the location of the trunk, there is a sandstone bed with leaf imprints and footprints, underlain immediately by a gravelly layer and then, yet deeper by clays."**

Result of detailed phytological examination by J. TUZSON: the petrified tree represents a coniferous species having neither fossil, nor living representative. Describing the locality too, he described the petrified trunk as Pinus tarnocziensis. The anatomical description of the pine tree by J. TUZSON is a superb, classical work of international standard.

**1949.** R. KRÄUSEL assigns the tree of Tarnócz to the genus Pinuxylon, the group of Pinuxylon succiniferum.

**1954.** P. GREGUSS determines several kinds of petrified wood from Ipolytarnóc, including six different coniferous species. Among these, F. KUBINYI's giant petrified tree was described as Pinuxylon lambertoides n. nom. on evidence of the extraordinary size (at least 56 m tall with the crown included), the five-needled leaves and the xylotomical pattern of the tree-trunk.

**1963.** E. VADÁSZ considers the name Pinuxylon tarnocziensis (Tuzson) Greguss to be scientifically most correct.

**1964.** By examining the annual rings of the silicified fossil conifer, and the excellent paper by M. BAKTAI—I. FEJES—A. HORVÁTH bears witness to a 7-year cyclicity of Early Miocene sunspot effects, as opposed to the present-day 11-year periodicity. The shortened cycles provide another reason accounting for the climatic peculiarities of the Early Miocene.

**1983.** Three comparatively large fragments of the trunk of the one-time pine-giant are known at Ipolytarnóc. One of them is found, disintegrated by cryofracturing, in the preserved part of the original conservation house, the second one is buried under the collapsed vault (about 4 m) in a relatively good state of preservation, the third one being the fragment exposed in the Conservation Hall in which the footprint sandstone is conserved. This one is regarded, for the moment only with a question mark, as belonging to the fossil pine.

The devastations, as already referred to, began in the year of discovery and they intensified rather than diminished as the reputation of the locality grew. Unfortunately, neither F. KUBINYI's efforts, nor the building around 1860 of the conservation house could save the trunk of the petrified tree of Tarnócz of an estimated weight of 160 tons or so from being reduced by swarms of "souvenir collectors". Tourists sampled what they called the "Gyurtyánkő" for souvenirs, ornamentals, while more practically-minded local residents used it as whetstone.

Deposited at the headquarters of the Hungarian Geological Institute, the Hungarian National Museum and the Kubinyi Ferenc Museum of Szécsény, a few larger well-preserved fragments are available to the public.

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* The lifework of the KUBINYI brothers was reviewed by L. MAJZON (1974). At present F. KUBINYI's name is borne by the museum of Szécsény, where splendid portraits commemorate the initiators of geological research in Hungary.

** If the andesite tuff is identified with the rhyolite tuff and the clays are identified with marine Eggenburgian sandstone- and sand-bearing clays, the stratigraphic position of the tree-trunk is determined in terms of the present-day nomenclature.

The main attraction that has compelled people to visit Ipolytarnóc has been the huge petrified tree-trunk. Most specialists came to study the tree-trunk or just to see it. Thus the "Kőmedence" (Stone Basin) has become a meeting point for geologists and paleontologists. In fact, to list the names of last-century scientists who paid visits to Ipolytarnóc would not be easy.

Guided by J. Tuzson, H. Böckh, then professor of the Mining Academy of Selmec, and his students were shown round the conservation house and the rest of the locality where they saw what had been left over from the fossil already identified as a pine species. This trip ended with an enormous surprise, as it was then that the footprints of Proboscidea and other animal species on the sandstone surface underlying the tree-trunk were discovered. Local people said that the bedded sandstone had not been unknown to those who frequented the forest: in fact, some people had been even mining it for casing dug wells.* **1900.**

J. Tuzson writes: "on the afore-mentioned sandstone bank, in summer, we found even footprints of fossil mammals which makes the region even more interesting to visit and is another reason for public efforts to have the valuable paleontological material at this locality conserved with utmost care for science." **1901.**

J. Böckh has a part of the "Lower Mediterranean" footprint sandstone transported to the Geological Institute. The cost involved is borne by A. Semsey.

K. Papp reports, still in terms of highest praise, on the footprints still just partially visible: "where the volcanic ash is removed from the solid sandstone, wonderful imprints are visible on the sandstone surfaces. These are the fingerprints of rhinoceros, fossil deer and fossil birds which, by freaks of chance, have been so nicely preserved for millions of years up to these days." **1910.**

Eager to save the sandstone that has acquired a rapid fame, F. Nopcsa has two large stone plates extracted and transported to the Geological Institute in Budapest, where he places them to ornament the wall in the first floor corridor of the headquarters. **1920.**

In October 1928, J. Noszky Sr. shows the footprints, now exposed over a larger area, to participants in a field-trip to Ipolytarnóc organized in conjunction with the Budapest meeting of the "Paläontologische Gesellschaft". The specialists participating in the field-trip declare the fossil footprints to be unmatched on a worldwide scale. The excited paleontologists cannot help staying on and on, though time passes quickly. In their opinion, the footprint sandstone is "a unique and irretrievable value of nature" which to conserve and to save is an urgent duty. So it is desirable "To save it from destruction by human vandalism!" **1928.**

Doing his military service, the present writer visits the locality several times, admiring the excellently preserved and large sandstone plate on which the limonite-coated footprints are glittering in the sunshine. **1930.**

J. Noszky Sr. is appalled to see that the sandstone plates "have been damaged by careless human hands, after being exposed, in 1928, over an area of a few square metres. So the only thing we can do is to pick them up". **1931.**

T. Szalai, in his "list", quotes traces of turtles he observed in Aquitanian beds. **1933.**

In a note on the excursion of 1928, O. Abel refers to Ipolytarnóc as "eine Art Pompeji", taking into consideration the hundreds of footprints on the "grossen Fahrtenplatte" and the rhyolite tuff overlying this. In his opinion, the fine-grained sandstone with plant moulds and footprints was burnt into brownish-red terracotta by the glowing volcanic ash. He also mentions that the rock slab composed from broken fragments and deposited at the museum of the Hungarian Geological Institute in Budapest does not correspond to the original state. Eventually, after removing the "biotite andesite tuff", he has a large contiguous plaster mould made, in 6 separate portions, to cover the area richest in footprints and he sends the moulds to the Paleontological Institute of the University of Vienna. He quotes, in writing, traces of birds, rhinoceroses and arctiodactyla he observed at the site. **1935.**

Miss M. Hermann and Mr. K. Emszt carry out detailed petrographic and chemical analyses of the footprint sandstone. This excellent work, even though requiring some re-evaluation, is a fundamental contribution to our knowledge of the locality. **1940.**

A. Tasnádi Kubacska writes the first of a series of his popularizing articles on the footprints. Picking out only the most important ones, in our bibliographic list, we could only partly follow the chronology of these works of his.

* Amid the ruins of the collapsed conservation house with the tree-trunk in, fragments of the sandstone are observable, moreover, some fragments are recognizably built in within the vault still intact.

1948. R. THENIUS describes a predatory animal's footprints from the locality.

1950. In a discussion on the Chattian—Aquitanian problem, M. KRETZOI writes on the stratigraphic assignation of the locality as follows: "the finds in question (Anchiterium-Cervida) need not be assigned to the Lower Miocene", but, even though not precluding an Oligocene age, he does not speak in favour of it either.

1952. O. S. VIALOV and K. K. FLEROV commence their description of Tertiary vertebrate footprints from the Carpathian foreland with the locality Ipolytarnóc. They are basing their remarks on research by A. TASNÁDI KUBACSKA.

1958. The popularizing articles of A. TASNÁDI KUBACSKA arouse interest among tourists. Misunderstanding the scientific appraisal of the world-famed finds, tourists, armed with chisels and picks, swarm the locality, seeking to "sample" the footprint sandstone bed.

1968. L. BOGSCH, in his textbook, presents the locality Ipolytarnóc in its palaeogeographic setting.

1974. A. TASNÁDI KUBACSKA publishes his first systematic treatise of his preceding works.

At the same time, in the April 19 issue of the newspaper Népszabadság, T.B. gives a perfect critical assessment of the devastations. His conclusion: "enormous, irretrievable values are being waisted".

1977. Setting it in part in a vulgarized frame, A. TASNÁDI KUBACSKA gives a superb illustrated account of the footprint sandstone. This posthumus work of his landmarks the completion of a stage of research.

1979. A review by F. SZABÓ V. is the first indication of rescue efforts on the part of National Nature Conservancy Office.

1980. The excavation of the footprint sandstone over a large area and the construction of the Conservation Hall are completed. Detailed mapping, preparation and conservation of the footprints are becoming continuous.

Thus 80 years had to elapse until the preserved part of the once splendid footprint sandstone was declared a nature conservation area. This achievement is the result of pioneering initiative, vigorous and exemplary cooperation and funding by the Central Office of Geology, the Hungarian Geological Institute, the National Environment and Nature Conservancy Office, the Nógrád County Council and the Salgótarján Tourist Office.

## The shark teeth

The huge petrified pine trunk and the footprint sandstone attracted increasing numbers of scientists and tourists to Ipolytarnóc, where, at the railway station, children and grown-ups were selling petrified "bird's tongues" at a price depending on the size of the fossil in question. These "bird's tongues" were shark teeth chiefly belonging to the group of Lamna.

1903. As A. KOCH puts it, he found hundreds of shark teeth while studying the unconsolidated, fine-grained sandstone. Determined in terms of size and shape, the shark species listed in his work exceed twenty in number. Three new species are described too (in our opinion, this work of 80 years ago needs to be revised for several reasons).

1904. As pointed out by A. KOCH in a paper discussing shark teeth collected at Felső-Esztergály, in the western part of the Ipoly valley (Slovakia), from beds corresponding to the locality Ipolytarnóc, both the Ipolytarnóc and the Felső-Esztergály faunas

— are of Lower Mediterranean age,

— at the beginning of Miocene time, both the southern foreland of the Central Carpathians and Central Europe as a whole, i.e. the bays of the contemporaneous Mediterreanean Sea and its shores were inhabited by similar, though not fully identical, animal associations and these interesting mixed faunas partly persisted even in Mid-Miocene i.e. Late Mediterranean times.

## The fossil flora

1842. First to report on the leaf-imprinted tuff, F. KUBINYI writes as follows: "close to the petrified tree, moulds of tree leaves are found; these are observable, in a more perfect shape and in greater quantities, on the other side of the hill adjacent to the petrified tree" (in opinion of the present writer, in the Botos-árok ravine).

Later, M. STAUB determined plant moulds from the footprint sandstone, but he did not list the flora.

J. JABLONSZKY carried out the determination of his own collection and that sampled by J. NOSZKY. In fact, this work marks the beginning of the development of a systematic inventory and description of the Ipolytarnóc plant moulds. His final sentence reads: "the vegetation of Tarnóc is dated as post-Oligocene to pre-Late Miocene, its life having required, in addition to a wet soil, a fair amount of rainfall and a subtropical coastal climate".* **1914.**

A paper by K. RÁSKY lists 92 known and 11 new species. Following the concept generally adopted that time, she places the Lower Rhyolite Tuff at the Oligocene—Miocene boundary. **1959.**

B. GÉCZY mentions Ipolytarnóc as the most significant locality of Early Miocene flora in Hungary, noting that most of the sites were "exploited" already prior to conservation. In our opinion, this statement concerns first of all the site of recovery of JABLONSZKY's floral finds (map symbol: B-14, in Fig. 4), only two of the eight major sites having been preserved in relatively intact state. **1972.**

As pointed out by I. PÁLFALVY, the flora of the sandstone with coniferous needles known from deeper parts of the footprint sandstone implies varied, humid to arid, subtropical climatic conditions and an environment close to the coastline. **1974.**

L. KORDOS outlines the paleoclimate of Ipolytarnóc by relying on earlier authors. **1979.**

## Underlying strata

Because of the controversial question of the Oligocene—Miocene boundary, the disputes about the Chattian and Aquitanian problem and the different biostratigraphic scales based on the flora, the marine megafossils, the microfossils or the vertebrate fauna, the age determination of the sedimentary sequences underlying the fossiliferous beds of Ipolytarnóc was for tens of years pregnant with contradictions.

F. KUBINYI outlines the stratigraphy of Ipolytarnóc as follows: "hills composed of sandy and argillaceous "apoka" (molasse) accumulated by water partly in an undulate, partly in a level pattern extend for a little distance." On the next page he continues his observations as follows: "The hilltops overlooking the stone-basin pit are overlain by masses of silex placers (sandstones with tuff pebbles) which are followed by grass-earth underlain by argillaceous apoka consisting of micas, argillaceous particles and pumice (=rhyolite tuff), and the argillaceous "apoka" layer is followed by a sandstone placer. The basal terrain ends with bluish sandstone in which valves of gastropods are found." **1842.**

As far as the subsequent publications concerning the age of the sedimentary sequence are concerned, we will not enter into details up to the year 1900, to avoid repetitions.

In his paper, already referred to, on the shark teeth of Ipolytarnóc, A. KOCH produces megafaunistic evidence testifying to a Lower Mediterranean (Gaudendorfian = Eggenburgian) age of the sandstone. **1903.**

In his field-survey report and even in papers preceding it, J. NOSZKY Sr. assigns the marine formations to the Lower Mediterranean (= Burdigalian). **1917.**

T. SZALAI, in a study on megafossils, determines an Aquitanian (Miocene) age of the marine sandstones-conglomerates. **1924.**

J. NOSZKY Sr., in his monograph on the Cserhát Mountains, does not discuss the marine deposits of Ipolytarnóc, but unlike to the case of his earlier papers, he assigns all "beds underlying the terrestrial formation or its time equivalent" in the Zagyva and Ipoly valleys to the Oligocene. It is this concept that launches a quarter of a century of debates on the Oligocene—Miocene (or Chattian—Aquitanian) boundary problem. **1940.**

Studies of the microfauna by L. MAJZON lead to a division of the chronological problem: the fauna of Fehér-hegy is declared to be latest Chattian, that of Botos-árok to be of earliest Miocene. Thus the lack of a firm chronological standpoint is obvious and, on top of that, the uncertainty about what is meant under the name Fehér-hegy adds further complications to the problem. Supposedly, it is the roadside ridge between the ravines of Botos-árok and Borókás-árok that is referred to as Fehér-hegy. In our opinion the difference in fauna between the two sites is due to changes in facies. **1950.**

Based on megafossils, the stratigraphic research carried out by I. CSEPREGHY-MEZNERICS is an example of "classic" work. A host of papers by her provide sound foundations for the revision of the Hungarian Miocene. She fixes the age of the underlying marine beds in the Burdigalian. **1967.**

* In our opinion, the list of flora composed of about 30 species, including 5 new ones, enables an assessment of the age of the rhyolite tuff. Consequently, JABLONSZKY's conclusions are still valid today, i.e. 70 years after the appearance of his work.

In a study on Foraminifera, R. Nyírő describes a rich fauna consisting of 96 forms from the conservation area and its immediate vicinity. The fine-sandy, grey argillaceous marls and the sandstones with shark teeth exposed at the foot of Botos-árok and the foraminiferal species from the argillaceous marls exposed at the Botos-árok waterfall correspond, in two-thirds part, to Foraminifera from the Eggenburg Basin, being well-correlable with S Slovakia's microfauna of similar stratigraphic position as well.

**1974.** As pointed out by I. Korecz-Laky and Á. Nagy-Gellai, the results of a detailed study of the microfauna recovered from the exploratory borehole Ipolytarnóc-9 agree with the results obtained by R. Nyírő for Sampling-Point 5. The Foraminifera are of Eggenburgian age, though the underlying sequence intersected in the 146 to 195 m interval of the borehole contains several species known from the Oligocene too.

**1981.** On evidence of the analysis for Nannoplankton of a sample taken from the underlying beds exposed in the surface key section, Theodoridis (Utrecht) assigns the enclosing rock to the (Eggenburgian) NN3 Zone (personal communication).

## Pre-Neogene formations

*Crystalline basement, Paleozoic*

No borehole hitting the pre-Cenozoic basement has been spudded in the Ipolytarnóc area. At a distance of 15 to 18 km north of Ipolytarnóc, the crystalline, metamorphic rocks of the Veporides are exposed. In the intermediate area, in borehole Lučenec H-6, the crystalline basement was already reached under a 200-m-thick Oligocene sequence.

At Balassagyarmat, the Oligocene-covered basement was hit at a depth of 650 m, while the hydrocarbon exploratory wells at Szécsény hit it in the interval of about 800 to 1,000 m.

At Ipolytarnóc the crystalline basement composed of phyllites, gneisses and amphibolites lies at an estimated depth of 600 m or so. At any rate, the presence of a fault-graben structure, the lack of Mesozoic formations and the paleomorphology produced by the Oligocene transgression should be taken as factors of uncertainty into consideration.

## Paleogene

### Eocene

Put down to the west and southwest of the Ipolytarnóc area, boreholes Sóshartyán-2, -3 and -4 cut, in the 1,500 to 1,600 m interval, Lithothamnium limestones. The hydrocarbon exploratory wells of the Szécsény area have provided similar data. As far as our present-day knowledge goes, the formations in question are of Late Eocene age and 50 to 150 m thick.

Between the fault-blocks of the study area some fargments of Eocene marine or continental deposits may have escaped erosion too. Such an assumption is justified by borehole GK-4 spudded near the village of Bzovik in S Slovakia (D. Vass 1979).

### Oligocene

To the southwest to south of the study area a complete Oligocene sequence (about 1000 to 1500 m) is composed of the Rupelian Kiscell Clay Formation and the Egerian Szécsény Schlier Formation and Pétervására Sandstone Formation. Let us note in this context, that the age of the last two formations is placed by T. Báldi and M. Horváth in the Egerian—Eggenburgian interval. In the Ipolytarnóc area only the Szécsény Schlier Formation is supposed to be developed from among these. The Oligocene in this area is developed in an estimated thickness of 300 to 400 m.

Novel approaches to Miocene research are characterized by regional studies based on interregional correlations developed since 1958 by international cooperation. Although the nomenclature of lithostratigraphic units is not definitively finalized yet, the rightness of the principles adopted is confirmed by their growing acceptance. The lithostratigraphy of Ipolytarnóc has been developed by adapting the Miocene lithostratigraphic classification proposed by G. Hámor and will be presented hereinafter accordingly.

## Neogene

### Miocene

*Szécsény Schlier Formation (Eggenburgian)*

The oldest Miocene formation in the study area is represented by a sequence of bluish-grey clays, fine-grained, micaceous sandstones with glauconitic intervals and argillaceous sands (schlier) that evolved by continuous sedimentation in Egerian and Eggenburgian times. In the old literature it is referred to as "Chattian schlier" or "Lower Schlier". It is best exposed, within the study area, by the Botos-árok and Borókás-árok ravines (Fig. 6).

Farther away, it is known to occur in a morphological trench between the Karancs and the Kercseg-tető, in the vicinity of Sóshartyán and in the clay pit of the abandoned brickyard of Szécsény. Water exploratory wells in the vicinity of Salgótarján reached this monotonous formation after intersecting the "glauconitic sandstone" (Pétervására Sandstone Formation).

Evolved along faults, erosion in the two afore-mentioned ravines has exposed the formation in a thickness of 5 to 15 m varying in dependence on the degree of tectonic deformation. On evidence of borehole It-9, its thickness is estimated at 150 to 200 m in the marginal part. In the central part of the basin, a substantially thicker sequence must be reckoned with.

The site of borehole It-9, spudded for stratigraphic purposes in 1971, is indicated by an effluent well near the present-day Conservation Hall. The borehole was put down with the aim of exploring the formation. The cumulative geological log of the borehole is given in Fig. 7.

Showing but very little variation, the sedimentary sequence is characterized by an average of 30% by weight of the frequency of the 0.000 to 0.0002 mm grain size and by 68% of the 0.002 to 0.06 mm fraction (analyses performed by É. Kovács at the Petrographic Laboratory of the Hungarian Geological Institute).

Commonest representatives of the heavy mineral fraction (Gy. Lelkes) are muscovite, chlorite, leucoxene, pyrite, garnet, biotite, epidote, tourmaline and zoisite. The number of muscovite and chlorite grains shows a marked increase in the 6 to 128 m interval. In the light mineral fraction quartz (40—50%), oligoclase and chlorite are conspicuous.

The $CaCO_3$ content varies between 5·5 and 9·4%. Most of the minerals are metamorphic, magmatic derivatives being subordinate.

Thin-shelled megafossil remains and shell fragments (Leda sp., Arca sp.) were observed in core samples. The Foraminifera were studied by I. Korecz-Laky and Á. Nagy-Gellai who assigned the rock of the 3 to 195 m interval into the Lower Miocene Eggenburgian stage in spite of the appearance of several Oligocene species (Table 1) in the basal 49 m (146—195 m). Neither lithological, nor paleontological studies have enabled us to draw the Oligocene-Miocene boundary. The older microfossils are of transitional character suggestive of the Egerian stage.

In Borókás-árok, at sampling points $D_1$, $D_2$ and $D_3$ along the ravine section leading to the Conservation Hall of the footprint sandstone (Fig. 8), R. Nyírő (1967) identified the following microfossils.

**Sampling-point $D_1$:** *Dentalina punctata* d'Orb., *Nonion boueanum* (d'Orb.), *Bulimina elongata* d'Orb., *Rotalia beccarii* (L.), *Cassidulina crassa* (d'Orb.), *C. oblonga* Reuss, *Globigerina praebulloides* Blow, *G. woodi* Jenkins, *G. ciperoensis* Bolli, *Cibicides lobatulus* (W.—J.) as well as Ostracoda and Mollusca shell detritus, spines of echinoderms, sponge spicules and sponge skeletons.

From the same sampling point, I. Csepreghy-Meznerics (1967) sampled and identified the following megafossils:

*Megaxinus bellardianus* May, *Pitaria chione* L., *Solen marginatus* Phil., *Turritella vermicularis tricincta* Schaff., *Trochocyathus* sp., *Bryozoa* sp.

**Sampling point $D_2$:** The nicest exposures and the best possibilities for samplind are provided by the surfaces in front of the steep-walled waterfall of Borókás rivulet. Here the sandstone intercalation typical of the flysch facies and the argillaceous sand is richer in glauconite than it is the case with the other sampling points:

*Globulina gibba* d'Orb., *Nonion granosum* (d'Orb.), *N. boueanum* (d'Orb.), *Elphidium ortenburgense* Egger, *Bulimina elongata* d'Orb., *Rotalia beccarii* (L.) *Globigerina praebulloides* Blow, *G. woodi* Jenkins, *Cibicides lobatulus* (W.—J.) and *C. tenellus* (Reuss) have been recovered from the site in question.

On the sandstone bedding planes there is a very great deal of calcareous-shelled fossil fragments. The important role of the surfs and wave action in the littoral zone is proved, among other things, by the pinching out of sands and clays.

Because of disintegration the Mollusca fauna here is poor, only *Miltha suessi* Kautsky, *Megaxinus bellardianus* May, *Flabellum* sp. and *Bryozoa* detritus have come into the fore.

**Sampling point $D_3$.** Foraminifera of the sandy clay exposed by shaft-sinking in Borókás-árok: *Nonion boueanum* (d'Orb.), *Bulimina elongata* d'Orb., *Bolivina antiqua* d'Orb., *B. fastigia* Cushm., *Rotalia beccarii* (L.), *Cassidulina crassa* d'Orb., *C. oblonga* Reuss, *Cassidulinoides bradyi* (Norman), *Globigerina ballii* Cita-Premoli Silva, *G. praebulloides* Blow, *G. woodi* Jenkins, *Cushmanella nitida* Thalm.

This exposure is the richest—in terms of both species and individuals—foraminiferal locality of the schlier. In sampling point $D_3$ no identifiable megafossil has been found.

Irrespective of a slight deviation, the foraminiferal fauna studied by R. Nyírő (1967) from the sampling points $D_1$ and $D_2$ agrees with the material of I. Korecz-Laky. R. Nyírő determined 96 foraminiferal taxa from the conservation area and its neighbourhood, but these taxa include the foraminiferal species recovered from the lower beds of the glauconitic sandstone and its argillaceous facies as well.

On evidence of the available results, let us conclude with full conviction that

— part of the formation exposed in the study area is of Eggenburgian age;

— both the foraminiferal and the molluscan faunas bear witness to the presence of a littoral, hemipelagic facies;
— the Eggenburgian fauna is identifiable with the fauna of similar formations in S Slovakia.

*Pétervására Sandstone Formation* (Eggenburgian)

*Budafok Sand Formation* (Eggenburgian)

In the Nógrád—Cserhát area the Pétervására Sandstone Formation (referred to as "apoka", "glauconitic sandstone", "Chattian cross-bedded glauconitic sandstone" etc. in the relevant literature) and the Budafok Sand Formation (referred to as "Pectunculus Beds", "Grosspecten Beds" etc. in the literature) are readily distinguishable. Upon a new stratigraphic revision, G. HÁMOR assigns the first one to the Egerian stage, the second one to the Eggenburgian stage. T. BÁLDI believes both formations to be of Eggenburgian age.

In the Ipolytarnóc area the problem is even more complex: elsewhere developed in a total thickness of 400 to 600 m, the two formations here are represented between the Szécsény Schlier Formation and the Zagyvapálfalva Formation, by a condensed sequence of overwhelmingly psammitic to psephitic (often glauconitic) and subordinately pelitic sediments attaining a total of only about 50 to 60 m in thickness. Since the correlation based on the nannoplankton, Foraminifera and Mollusca is more convincing with the Budafok Sand Formation and since, in terms of the chronostratigraphic evaluation, these beds are of Eggenburgian age, the deposits in question are presented here under this formation name.

The underlying Szécsény Schlier Formation is overlain by fossiliferous sandstones with tiny pebbles and of an arched cross-bedding that are followed, higher up the section, first by bedded sandstones and then by "gömbköves" sandstone, thinly laminated, argillaceous sands, sandstones and micaceous sandstone. The sequence ends with bluish-grey argillaceous sands not exceeding 10 m in thickness.

In the heavy mineral fraction of the 0.1 to 0.2 mm ∅ part of the cross-bedded sandstone, biotite is represented in 1%, garnet in 2% and glauconite in 97%. The glauconite grains are surprisingly rounded. In the light mineral fraction oligoclase (andesine) is 2%, orthoclase (microcline) 1%, quartz 87%, argillized grains 8%, volcanogenic plagioclase 2%.

On the basis of the mineralogical composition, the source area must have been made up of crystalline rocks. From these beds, R. NYÍRŐ (1967) determined, from the vicinity of the shark teeth-bearing site (ravine B-13), the following foraminifers:

*Robulus cultratus* (MONTF.), *R. inornatus* (D'ORB.), *R. limbosus* (REUSS), *Marginulina hirsuta* D'ORB. and *Nonion scaphum* (F.—M.).

Agreeing with L. MAJZON (1950), she assigned the microfauna to the Lower Miocene (Burdigalian).

Likewise a Burdigalian age was attributed by I. CSEPREGHY-MEZNERICS (1967) to the megafossils sampled from the gravelly sandstones of Botos-árok, namely:

*Leda fragilis* LAM., *Glycymeris pilosa* group, *Diplodonta rotundata* MONTF., *Megaxinus bellardianus* MAY, *Abra alba* WOOD., *Spisula subtruncata triangula* BR., *Lutraria sanna* L., *Solen marginatus* PHIL., and *Natica burdigalensis* MAY.

The higher beds are very poor in fossils. In the washing residue of the topmost pelitic sediment, dihexahedral quartz and biotite suggestive of a weak volcanic activity (or redeposited) were identified. Rounded glauconite is abundant.

The microfauna of this formation is extremely poor, a few Foraminifera suggest redeposition. Spines of sea urchins and spicules of Spongia are more frequent. The sandstone sequence is characterized, among other things, by its including the shark teeth locality of Botos-árok.

A. KOCH (1903, 1904) collected from ravine B-14, in an hour's time, more than 100 shark teeth specimens from the gravelly sandstone. He lists 25 species belonging to eight genera in his work, including 3 new species described by him (*Notidanus paucidens*, *Oxyrhina neogradensis* (Fig. 9) and *Lamna tarnocziensis*).

Bones of marine mammals were found to be admixed to the shark teeth assemblage represented, in its bulk, by species of Lamna, Oxyrhina, Carcharias, Galeocerdo, and Notidanus. It would be time to carry out a revision of the fauna.

The fish teeth from Ipolytarnóc largely agree with the species known from the localities of the Eggenburg area and S Slovakia (Rapovče). Despite some cosmopolitan forms and species that had persisted from earlier periods or survived the Eggenburgian, the "shark-teeth-bearing beds" seem to have been deposited in Early Miocene (Eggenburgian) time.

As stated by R. BRZOBOHATÝ and O. SCHULTZ (1971) the Eggenburgian marine vertebrate fauna implies a tropical-subtropical climate.

The abundance of shark teeth at Ipolytarnóc and the sandstone with small gravels enclosing these fossils testify to the immediate vicinity of the shoreline and to a sandy beach of a gentle slope (beach facies). The shark corpses were piled up at the site in question by wave action, by the surfs attacking the beaches. And it was primarily their teeth that would be fossilized.

Regardless of a thin interbedded argillaceous marl layer, the marine sandstone in the Botos-árok is a homogeneous formation. On the contrary, on the northern side of the road of Csapás-völgy, as far as the ravine marked with C-1, both the loose sandstones and the harder sandstone beds overlying them alternate with gravelly and sandy clays. In the ravine marked with C-2 the sandstone sequence is replaced eastwards by brown sandy clays that continue on the western side of the Borókás-árok.

Near the building "Alkotóház", in the road-cut, light grey marl rags are found. Growing thicker and well-exposed, these can be studied at the base of the motor vehicle road leading to the Conservation Hall of the footprint sandstone. The fauna recovered from here is as follows:

*Nucula fragilis* CHEMN., *Myrtea spirifera* MONTF., *Megaxinus bellardianus* MAY., *Turritella vermicularis tricincta* SCHAFF., *Dentalium* sp., as well as corals and bryozoans.

Interbedded with the marly fine-grained sandstones of the formation, the lumachelle was first reported by T. SZALAI (1924) from the Csapás-völgy. Carrying out complementary samplings and a revision of the fossils in question, I. CSEPREGHY-MEZNERICS (1967) determined a fauna consisting of 33 species of Bivalvia and Gastropoda almos totally conformable to the fauna of Gaudendorf—Eggenburg.

Let us list the Mollusca fauna as identified by I. CSEPREGHY-MEZNERICS:

*Arca fichteli* DESH., *Glycymeris pilosa* group, *G.* cf. *fichteli* I. a.m., *Ostrea* cf. *fimbriata* I., *Anomia ephippium pergibbosa* SACCO, *A. ephippium aspera* PHIL., *Mytilus haidingeri* HÖRN., *Pedalion (Isogonum) rollei* HÖRN., *Pecten hornensis* DEP.—ROM., *P. holgeri* GEINITZ, *Chlamys gigas* SCHLOTH, *Cardita zelebori percostata* SCHAFF., *C. zelebori planata* SACCO., *Isocardia werneri* HÖRN., *Cardium ,,edule"* var. *commune* MAY., *Laevicardium tenuisulcatum* NYST, *Pitaria erycionides* LAM., *P. gigas* LAM., *P. polytropa* ANDERSON, *Abra alba* WOOD, *Turbo carinatus* BR. (operculum), *Turritella turris rotundata* SCHAFF., *T. vermicularis tricincta* SCHAFF., *T. riepeli* PARTSCH, *T. desmarestiana* BAST., *Aporrhais pespelecani* PHIL., *Natica burdigalensis* MAY., *Polinices olla* DE SERR., *Euthriofusus burdigalensis* BAST., *E. burdigalensis depressa* SCHAFF., *Pirula condita* BR., *Tudicla rusticula alterspirata* SCHAFF., *Xenophora cumulans* BRONG. var.

Similar conglomerates with fossil detritus were found by the author in the upper reaches of Botos-árok.

*Pecten hornensis* and *Chlamys gigas* are found in the upper member of the Budafok Sand Formation in the vicinity of Nagybátony (Szoros-patak), Kisterenye (Arany-hegy) and Salgóbánya, etc. This "Grosspecten" Sandstone is overlain by terrestrial conglomerates and the so-called "Lower Variegated Clay".

In the Ipolytarnóc area too, the above fossil-rich beds are covered by continental beds of the Zagyvapálfalva Formation. Consequently, the mode of superposition and biostratigraphic evaluation of these suggest the following possibilities:

— the lower part of the succession is assigned to the Pétervására Sandstone Formation and is dated as of Egerian age;
— the upper part of the succession may belong to the Budafok Sand Formation, being of Eggenburgian age. This seems to be corroborated by the frequency of interbedded layers of coarse detritus (gravel, conglomerate, breccia) (beginning of a new sedimentation cycle) and by the new Indopacific faunal elements.

### *Zagyvapálfalva Mottled-Clay Formation (Eggenburgian)*

The name of the formation was proposed by G. HÁMOR (1974) for the second phase of the Eggenburgian sedimentary cycle, the terrestrial deposits between the marine Eggenburgian beds (Budafok Sand Formation) and the Gyulakeszi Rhyolite Tuff Formation (these are referred to as "Lower Mottled-Clay", "terrestrial beds", etc. in the relevant literature). As key beds within the formation, he distinguished the footprint sandstones which he called the "Ipolytarnóc Beds".

In the Ipolytarnóc area the basal part of the formation is constituted by gravels and conglomerates, its upper part taken in a strict sense being represented by the "footprint sandstone".

#### Gravel and conglomerate beds

Growing thicker to the east from Ipolytarnóc in the Nógrád Basin, the gravel and conglomerates are characterized by varying grain size and interbedded sand and clay layers. The gravel sequence there varies between 50 and 60 m in thickness. In the conservation area, in ravine B-3/b, its thickness attains a maximum of 8 to 10 m, but generally it varies between 1 and 6 m. The gravels show a southward reduction in pebble size and thickness which bears witness to a transport from a northern to northwestern direction.

At Ipolytarnóc, in the tributary ravines of the Borókás-árok and Botos-árok, the gravels are observable in excellent exposure over a large distance along the length of the section. In the tributary B-3/b of the Botos-árok is its typical section: it overlies the undulate, erosional surface of the "glauconitic sandstone", being overlain by sandstone and rhyolite tuff. In the middle and lower parts of the gravel sequence, the lack of sorting and the presence of interbedded sand layers are conspicuous. Grooves are filled with sandy small-grained gravel overlain by partly sorted pebbles of a nut's size to a fist's size (Fig. 10). Along with the abundant pebbles, their composition includes quartz porphyry, diabase, arcose and magmatite pebbles, these latter being unidentifiable with more precision. No limestone pebble has been found yet. In the northwestern, upper tributary of the ravine the gravels are characterized by a uniform grain size distribution and the absence of intercalations.

In the Csapás-völgy, west of the ravine shown by symbol C-1 on the map, at the bottom of a small non-labelled gully, among compressed pebbles, the author found a black nummulitic chert pebble too (Fig. 11). Characterized by a lithological composition rather peculiar in the Hungarian Eocene, such pebbles had been encountered, in a few specimens, north of Budapest up to the Danube Bend (L. Bartkó 1939) and from the Ipoly valley up to the nation's border. On some of the pebbles of Eocene age, segments of gastropods and bivalves are visible. In Hungary, no chert pebble with such Eocene fossils is known to us from localities of pre-Lower Miocene age. The paleogeographic source area of these rare and conspicuous pebbles was in what is now S Slovakia.

Ipolytarnóc owes its fame to the silicified pine trunk reported by F. Kubinyi (1842, 1854) and J. Tuzson (1901) and to other petrified tree remains published later by P. Greguss (1954, 1967). Some of these siliceous log remnants are enclosed in the gravel-conglomerate beds. Let us call attention to the fact, however, that the silicified tree fragments figuring in the works of P. Greguss derived not only from the conglomerate bed. The pine of Tarnóc is the only find for which the original site is completely cleared and exactly assessed stratigraphically. More complicated is the case with the tree fragments, for the "mother rock" was disregarded when the fossils were being sampled. In fact, the tree remains enclosed in the gravels, sandstone and rhyolite tuff were regarded as being of identical stratigraphical value. Hence the strange situation that the tree species recovered from the gravel cannot be correlated with their counterparts enclosed in the overlying rhyolite tuff, with the finer vegetal parts—twigs, leaves and fructifications. The tree-fragments are angular. A huge silicified tree-trunk may weigh as much as several quintals, so the original tree must have lived in the immediate vicinity.

P. Greguss identified the following silicified tree-remains:

*Sequoioxylon* sp., *Pinuxylon lambertoides* Greguss = *Pinus tarnociensis* Tuzson, *P. albicauloides* Greguss, representatives of *Pinuxylon*, *Keteleeria* (?), *Palmoxylon Sabal*) (?), *Carpinuxylon* (?), *Laurinoxylon aniboides* Greguss, *L. müller-stolli* Greguss, *Dryoxylon silvaticum* (Tuzson) Greguss.

Some taxa of the listed flora correspond to the flora of the footprint sandstone and of the rhyolite tuff, respectively.

Silicification poses another group of problems. E. Vadász (1963), for his work devoted to the petrified wood remains from Hungary, took advantage of *X-ray* diffractometric results by Gy. Bárdossy (1962) who, when examining the relationship between geological age and silicification, found that the younger the fossil tree was, the less quartz it contained. In this novel kind of work Ipolytarnóc is represented by the silicified pine, the material being assigned to the fibrous-radiaxial chalcedony series, composed as it is, in its bulk, of quartzose matter.

## Ipolytarnóc Beds ("footprint sandstone")

Since the silicified giant pine trunk has been almost totally lost to unwanted collectors, it is the "footprint sandstone", i.e. the upper limonitized and silicified bed of the sandstone overlying the gravel and conglomerate that is still guarding the reputation of Ipolytarnóc. Because of the varying thickness, the heavy block-faulting of the region, its being hidden by a contiguous overburden and the absence of good exposures, the sandstone has heretofore been regarded as being of local occurrence confined to the footprint-dotted area.

The best exposure is found in the upper reaches of the precipitous tributary gully B-3/a of Botos-árok. Here the sandstone bed is about 4 m thick. Regarding lithology, vegetal remains (pine-needles and deciduous leaves) and the silicified sandstone bed, the site is an equivalent of the classical Borókás-árok site. At the outcrop no footprint has been found.

East of the outcrop, up to the fault indicated by the springs and in the corresponding zone of the Borókás-árok, mainly under a thick overburden, the sandstone is supposed to form a continuous rock body. An informative and partly cumulative list of the results of mineralogical analyses of samples taken from the middle part of the sandstone in the Borókás-árok and Botos-árok is given in Table 2.

In addition to the minerals listed in the tabulation, both samples contain rutile, zircon, titanite, clinozoisite, hornblende, glaucophane, chloritoid from the heavy mineral group and K-feldspar, oligoclase and andesine from the light mineral assemblage.

The mineral grains deriving from granite, granitoids and metamorphic rocks are more rounded, testifying to repeated redeposition.

In our opinion, the footprint sandstone is an erosional product. This is proved by the examination of the sandstone by M. Herrmann and K. Emszt (1940) who drew the following conclusion: "the glauconitic sandstone (i.e. footprint sandstone) is a sedimentary material derivable from gravel debris of the Palaeo-Vepor and from glauconitic Oligocene sandstones of Palócföld." The authors refer to the upper silicified sandstone bed as quartzite sandstone (II) and to the rock type deriving from the less silicified, deeper part as silicified sandstone (I). (Roman numerals indicate the horizon of sampling within the sandstone sequence.) The silica in the sandstone is ascribed to the effect of silicic acid solutions that were ascending along faults.

In our petrographic analyses there is no essential difference between the two types, for the samples derive from points of little difference in vertical level. Let us quote the results of chemical analyses of the two samples:

| | I. | II. |
|---|---|---|
| | *Sandstone of low degree of silicification* | *Quartzite sandstone* |
| | Specific weight: 2.559 | Specific weight: 2.447 |
| $SiO_2$ | 84.85% | 86.36% |
| $TiO_2$ | in traces | in traces |
| $Fe_2O_3$ | 1.25% | 1.21% |
| FeO | 0.80% | 1.17% |
| MnO | in traces | in traces |
| $Al_2O_3$ | 7.14% | 6.01% |
| CaO | 0.33% | 0.39% |
| MgO | 0.89% | 0.60% |
| $K_2O$ | 1.73% | 1.07% |
| $Na_2O$ | 1.13% | 1.14% |
| $CO_2$ | 0.27% | — |
| $P_2O_5$ | 0.00% | in traces |
| $H_2O^{+110}$ | 1.34 | 1.25% |
| $H_2O^{-110}$ | 0.81% | 1.16% |
| Total | 100.54% | 100.36% |

The overlying quartzite sandstone bed is not the result of siliceous solutions ascending along faults. As can be proved in several vertical sections, the basal surface of the sandstone bed is undulating, with no manifestation of rock silicification observed underneath. What can be seen in a comparatively large exposure is that the upper footprint quartzite sandstone and the striking change in hardness between the overburden and the underlying rock were brought about by descendent flow of ferruginous-siliceous solutions.

Silica and iron are derived from the immediate overburden of the sandstone—the rhyolite tuff and the biotite tuff. The quartzite sandstone is overlain by 0.2 to 0.6 m of siliceous limonite coating which, after erosion of the protecting tuff layer or its peeling off, will be partly dissolved and blister. This was exactly what happened to major part of the footprint-dotted bedding surface now exhibited in the Conservation Hall. In such places the outlines of the imprints have grown blurred.

The footprint sandstone in the Conservation Hall strikes northwest—southeast, showing up an undulating and rough surface. A. Tasnádi Kubacska observed even traces of bathing and creeping of animals. Morphological, palaeontological and palaeobotanical interpretations suggest quite convincingly the pre-existence of a site of spring of low water yield here.

Considering the present-day microtectonics, the gravelly and footprint-dotted surface at the entrance to the Conservation Hall is taken to have represented the vicinity of a fault-controlled spring.

The cracks of regular rhombic to rhomboidal shape visible on bedding surfaces on the field or in museums are desiccation phenomena (Fig. 12). Under the upper footprint-dotted, hard sandstone bed, in the grey micaceous sandstone, another footprint horizon is known to us in which imprints of leaves and traces of roots abound too (Fig. 13).

The habitat of Pinuxylon tarnociensis—the petrified ancient pine—is exactly known to us. The tree lived on a sandy soil (the present-day sandstone), its cones and needles having come down to us in the footprint sandstone too (Figs. 14, 15). As suggested by P. Greguss, the living tree may have been 56 m tall.

The disappearance of the bios of the Ipolytarnóc area was caused by the active rhyolite-dacite volcanism, the ejecting of pyroclastics and their accumulation. Stratigraphical and climatological interpretation of the flora from the rhyolite tuff gives values corresponding to the time of birth of the footprint sandstone, for this was the habitat of the plants, while the tuff was the means of their destruction.

The fossil plant remains and the traces of vertebrate life also attest a Lower Miocene age for the sandstone. In an indirect way, the Eggenburgian age of the sandstone can be verified by the marine fauna as well. In the vicinity of Mátraszele and Kazár in the centre of the Nógrád Lignite Basin, sandstone lenses with an Eggenburgian marine fauna are enclosed in the Lower Variegated Clay (I. Csepreghy-Meznerics 1953, Kadosa Balogh 1966, p. 47).

A detailed processing of the paleoflora is reported by L. Hably, an evaluation of the vertebrate fauna being given by L. Kordos' comprehensive paper, both in the present volume.

All in all, let us conclude: the Ipolytarnóc Beds (="footprint sandstone") were formed on the sloped surface of sands and muddy sands accumulated on land, in a fluviatile and, more precisely, in an alluvial facies. Birds and mammals left their footprints in this formation in its prediagenetic state, supposedly around a spring they had been using as a watering spot. The site was fixed and conserved "in statu nascendi" by an acid volcanic blanket. The event took place in latest Eggenburgian time.

*Gyulakeszi Rhyolite Tuff Formation* (Ottnangian stage)

The Gyulakeszi Rhyolite Tuff Formation has become familiar under the name of "Lower Rhyolite Tuff" in the relevant literature. The rhyolite tuff has been a good marker, a key horizon, in mineral exploration, mapping and mining development in the Nógrád basin. Called "fehérkő" (white stone) and also „fejírkő" (the same in local dialect), it has been a valuable rock commodity in Nógrád areas poor in building stone resources. Local names like "Fehér-hegy" (White Mountain) or "Puhakő-bánya" (Soft Stone Quarry) are references to the surroundings of the one-time rhyolite tuff quarry of Ipolytarnóc. On a regional scale the tuffs gets more and more reduced in thickness as one proceeds from the south to the north in Nógrád County, the volcanism being controlled by graben structures. In both ridges traversing the conservation area the acid pyroclastics are exposed in varying thickness (2—30 m), being traceable as far as the national border and characterized by varying lithology and, from there they can be traced on in NNW direction for a distance of 15 km, up to St. Halič (Slovakia).

At Ipolytarnóc, the best exposures of the formation occur in Puhakő-bánya on Fehér-hegy, in the initial stretch of Botos-árok and the ravines and gullies labelled B-9, -10, -12 and -14 (J. Jablonszky's plant-imprinted locality, Fig. 4).

The formation varies in morphological appearance and lithological composition pending on the distance from the eruption site, the depositional palaeoenvironment and possible postvolcanic effects. Decomposed, bentonitic and bedded—pumiceous intervals alternate within the sequence, with a redeposited rhyolite tuff at the top. In Nógrád, lignite intercalations of varying extension and quality are frequent in the upper part of the sequence; these form the so-called Seam IV or "Teríték Seam". Its traces in the upper tributary of the B-3/a ravine are indicated by 5 to 8 cm of carbonaceous, argillaceous, silty tuffs and by charred and silicified fossil wood remains.

The rhyolite tuff or Ipolytarnóc is presented here by a combined columnar section, and by the results of three microscopic studies with the pertaining chemical analyses of rocks (Fig. 16). On the columnar sections the tuff varieties, the complementary occurrences other than the D-2 ravine, and the chemical analyses are indicated uniformly by a, b, c letters.

As evidenced by L. Ravasz-Baranyai's analyses, the amount of $SiO_2$ in tuffs deposited in an aquatic environment and redeposited is by 10% less compared to the 66 to 69% value obtained for the tuffs of subaerial accumulation.

The so-called „fehérkő" („White Stone") of Tarnóc is specified here by the results of petrographic analyses of three tuff varieties recognizable even on the field and by the corresponding chemical analyses (Table 3).

*Sample c) Bentonitized rhyolite tuff*

Upper (redeposited) tuff horizon
Location: Gyurtyános oldal, vicinity of Trinfis kút (Trinfis well)

The rock is represented by stratified, largely altered pyroclastics. Originally characterized by a vitroclastic fabric, the rock has lost the bulk of its glass matter (the pumice totally) to montmorillonitic decomposition. The remaining minerals include a low amount of glass fragments with corroded edges and pre-explosion mineral detritus such as plagioclase, biotite and a little bit of quartz. Plagioclase is zoned and twinned, its composition varying from oligoclase to andesine. Quartz is resorbed on its edges, biotite is bleached. From among the accessory minerals, zircon and lamprophyllite are observable. The crystal fragments vary between 0.04 and 0.3 mm in grain size, though sometimes a grain size attaining 1 mm (in the case bitotite) is also observed. The rock is a product of deposition of airborne pyroclastics.

*Sample b) Pumiceous rhyolite tuff*

Middle, blocky, pumiceous flood tuff
Location: Botos-árok, Fehérkő-oldal, abandoned quarry

The pyroclastite is of a crystallovitroclastic fabric. The volcanic detritus vary between 0.06 and 3.5 mm in grain size. Present in larger quantity, the glass detritus is composed of more coarse-grained pumice and vesicular glass, while the glass clastics of a peculiar concave shape is usually less than 2.0 mm in diameter. Accounting for smaller quantity in terms of percentage by volume, the crystal fragments are represented by plagioclase, quartz and biotite, while the accessories include sanidine, some magnetite, garnet, green hornblende and zircon. From among the pre-explosion mineral products, zoned and twinned plagioclase, represented even by complex twins, is most abundant. Quartz is characterized by resorbed edges. Biotite is fresh, intact, light greenish-brown to brown, pleochroic. Xenoliths in the rock include rhyolite of hyalopilitic texture, phyllite and a metamorphic rocks of enstatite-muscovite-biotite-quartz composition which is impossible to identify with more precision. Microcline has been recorded as mineral xenolith. The rock is slightly decomposed, containing some montmorillonite.

*Sample a) Altered rhyolite tuff*

A transition from altered, biotitic tuff with plant imprints into airfall dust tuff
Location: Botos-árok, gully B-14

The rock is of crystallo-vitroclastic texture with an overwhelming predominance of crystalloclastic matter. The volcanic detritus is represented by pumice and volcanic glass varying in size between 0.04 and 0.5 mm. The crystal fragments are represented by plagioclase, less biotite and quartz. Zircon, apatite, magnetite are recorded as accessories. The rock is stratified, containing sporadical fragments of Spongia. Fallen into a wet environment, the fine-grained airborne pyroclastics show a medium degree of decomposition.

*All in all*, the Gyulakeszi Rhyolite Tuff Formation was emplaced as a result of a single eruption (explosion) along tension faults generated in graben structures. Connecting it with the Savian orogeny, G. Hámor (1976), relying on the Bratislava convention of 1975, fixes its age at the base of the Ottnangian. On evidence of *K/Ar* dating by Kadosa Balogh, its radiometric age is $19{\cdot}6 \pm 1{\cdot}4$ Ma.

The overwhelming majority of rhyolite tuff flowed onto the ground surface as a viscous material and buried the terrestrial, fluviatile to alluvial environment in the form of tuff flow or flood-tuff, thus blanketing the entire floral assemblage of the paleoenvironment and conserving the footprints and other traces of life of the animals that had fled from the disaster. These traces and the half-charred plant remains would then be cemented by silica of tuff origin deposited from subsequent descending solutions thus providing further prerequisites for their preservation.

## *Salgótartján Lignite Formation, Nógrádmegyer Member* (Ottnangian)

The terrestrial formations subsequent to the rhyolite tuff in the Ipolytarnóc area are difficult to review.

The Nógrádmegyer Member of the Salgótartján Lignite Formation is represented, in the conservation area, by three types of lithofacies (the diagonally stratified rhyolite-tuff-bearing sandstone, the "Upper Variegated Clay" and the small-grained quartzite gravel conglomerate), forming, as local miners call it, the "immediate deep-footwall" of the lignite sequence.

The lower part of the member is well exposed at Gyurtyán-tető and in the upper tributaries of the ravine leading to the Conservation Hall with the footprints (D-5 and -6). Its thickness in the tectonically uplifted units is estimated at 10 to 12 m, in the ravines and gullies at 15 to 20 m. The gravelly sandstone contains redeposited, angular clastic fragments deriving from the tuff. The sandstones vary in hardness and thickness, being devoid of fossils. As suggested by L. Ravasz-Baranyai's microscopic results, two types of rhyolite pebbles are distinguished.

*a) Rhyolite flood tuff pebble*

The rock is of crystallo-vitroclastic texture, the pre-explosion minerals attaining a maximum of 3 m in size. Because of the high temperature of the pyroclastics the pumiceous to glassy groundmass was melted so that the origin of the rock now can only be reconstructed by the disintegrated nature of the crystals.

In the fused glassy groundmass plagioclase laths attaining a maximum of 0.1 mm, though commonly less than 0.05 mm, in length and corresponding to oligoclase in composition are disseminated. The glass is a little bit recrystallized. The crystal fragments of oligoclase-andesine composition are represented by zoned and twinned plagioclase, sanidine, resorbed quartz and subordinate quantities of biotite. Zircon and magnetite are observed as accessory minerals.

*b) Rhyolite foam-lava, rheoignimbrite pebbles*

The glass matter of the banded pyroclastite of fluidal texture is recrystallized into micro- or cryptocrystals, respectively, oligoclase laths attaining a maximum of 0.1 mm in diameter being dispersed in the glassy groundmass. The glass matter is characterized by vesicular, perlitic features, being montmorillonitized in small measure. The microscopic cavities attaining a maximum of 0.15 mm accross are frequently filled with spherolitic chalcedony. The mineral fragments are represented by zoned and twinned oligoclase-andesine, sanidine and subordinate quantities of biotite. The crystal fragments attain a maximum of 1.5 mm in diameter. Zircon of 0.1 mm is recorded as an accessory mineral.

Over the rest of the Nógrád brown-coal area this sandstone facies is unkown. In southern direction it does not seem to extend beyond the Dobroda-völgy. This sandstone too is an evidence in favour of fluviatile erosion transporting debris from a northern source area of varied morphology.

Youngest formation in the conservation area of Ipolytarnóc is the so-called ,,Upper Variegated Clay'' exposed in the upper reaches of Botos-árok and cut by boreholes It-10 and It-11.

The "Upper Variegated Clay" sequence is composed of alternating red to grey silty clays and interbedded sands and sandstones. Boreholes It-10 and It-11 have intersected the sequence in respectively 50 and 65 m thickness (Fig. 17). Lacustrine intercalations are indicated by fragments of sponge spicules.

The only megafossil recovered from these sediments of continental origin is the jaw of a mouse-sized rodent found in the material extracted from borehole It-10.

Put down in the clay pit of the brickyard, borehole It-11 (Fig. 18) intersected the underlying lower rhyolite tuff, the sandstones and the gravel-conglomerates and penetrated 11 m deep into the marine deposits as well.

The formations belonging to the Nógrádmegyer Member are indicative of a paludal, lacustrine and fluviatile palaeoenvironment that had a semi-arid climate.

The well-sorted, small-grained, silicacemented conglomerate blocks between Fehérkő-oldal quarry and gully B-3 being slumped towards Botos-árok ravine are also assigned to the Nógrádmegyer Member. Extremely hard and attaining several cu metres in volume, the boulder slabs are of unknown origin, their original, in situ position has so far been impossible to determine.

In the conservation area, younger Miocene to Pliocene formations are absent which is partly due to palaeogeographical causes, partly to Quaternary erosion.

### Quaternary

A typical Pleistocene formation in the study area is the freshwater limestone deposited around palaeo-springs located at the intersections of faults, coating mosses, twig fragments and leaves. The best and most spectacular occurrence of this limestone is found in Botos-árok, at the end of gully B-3.

The Holocene is represented by an annual total of about 1,000 cu metres of debris being removed by erosion from Fehér-hegy and Gyurtyános-oldal.

## GEOLOGY OF THE EXTENDED NEIGHBOURHOOD OF IPOLYTARNÓC

In the chapter on the geology of the conservation area the geological column was discussed from the basement up to the Nógrádmegyer Member of the Salgótarján Lignite Formation of Lower Miocene Ottnangian age. Southwest of the conservation area, in the so-called "Etesi-árok", isochronous facies equivalents of the afore-mentioned formations and younger deposits overlying them are also developed.

### Ottnangian Stage

*Salgótarján Lignite Formation, Kisterenye Member*

The Kisterenye Member of the Salgótarján Lignite Formation is characterized, for the most part, by lignite seams of paludal-lagoonal facies or traces of lignite seams. West to southwest of the conservation area, in the vicinity of Litke, Etes and Mihálygerge, the Nógrádmegyer Member ("Upper Variegated Clay") and its isochronous facies equivalent, the Kisterenye Member, are laterally interfingened in the transitional zone. This is proved by the appearance of Seam IV ("Teríték Seam") in the rhyolite tuff of the conservation area, by the sandstone with plant imprints within the "Upper Variegated Clay", by the scattered mollusc shell fragments and sponge spicules, the redeposited clay boulders and carbonized tree trunk- and root remains occurring in the gravelly sands above the clay pit of the brickyard of Ipolytarnóc.

The Kisterenye Member is constituted, in a succession proceeding from the bottom to the top,

— by Lignite Seam III and its overburden
— by diatomaceous silts (traces of Seam II)
— by grey clays with fish scales (traces of Seam I).

The stratigraphic position of the Kisterenye Member is known owing to borehole It-10, where it is situated between the "Upper Variegated Clay" and the rocks underlying the lignite sequence forming a gradual transition between the two.

*Lignite Seam III* is underlain by limonitic sands, and grey to greyish-blue clays with traces of plant roots. The lignite seam plus the rocks immediately under- and overlying it attain a total thickness of about 16 m. The lignite seam varies in thickness and is ramified.

The typical section of Seam III is exposed near the abandoned clay pit of the brickyard in Nagyvölgy at Mihálygerge, at the base of a gully.

Let us list the detailed cross-section of the seam in a succession starting from the top:

9. kaolinitic, carbonaceous clay, 5 cm
8. carbonaceous clay with coal stringers, 15 cm
7. grey clay, greasy to the touch, 15 cm
6. soft (bagós) lignite with bright coal stringers and kaolinite bands, 20 cm
5. carbonaceous clay, 19 cm
4. soft lignite with bright coal stringers
3. grey carbonaceous clay, 24 cm
2. soft lignite, 22 cm
1. brown clay, 10 cm

The seam is underlain by bluish-grey clays with interbedded limonitic sandstone layers. It is overlain by greyish-brwon clay with vegetal detritus.

E. Nagy reported, from Beds 3 and 9, a rich spore-pollen assemblage. The age of the material studied is Ottnangian.

Sporomorphs recovered from Bed 2: Mushrooms, mosses, *Crassosphaera concinna* Cookson et Manum, *Cooksonella* sp., *Ovoidites ligneolus* (R. Pot.) R. Pot., *Gleicheniidites* sp., *Leiotriletes maxoides* W. Kr. subsp. *maximus* (Pf.) W. Kr., *Leiotriletes* sp., *Polypodiaceoisporites muricinguliformis* Nagy, *Bifacialisporites* sp., *Verrucatosporites alienus* (R. Pot)., Th. et Pf., *Pityosporites labdacus* (R. Pot.) Th. et Pf., *Abietinaepollenites micoalatus* (R. Pot.) R. Pot., *Piceapollenites* sp., *Taxodiaceaepollenites* Kremp, *Coniferae* sp., *Sciadopityspollenites* sp., *Podocarpidites* sp., *Ephedripites* sp., *Acerípollenites* sp., *Araliaceoipollenites* sp., *Caprifoliipites* sp., *Tubulifloridites anthemidearum* Nagy., *Artemisiacpollenites* sp., *Chenopodipollenites* sp., *Ulmipollenites undulosus* Wolf, *Ulmipollenites* sp., *Tricolporopollenites hedwigae* Pflanzl, *Tr. microhenrici* (R. Pot.) W. Kr., *Salixipollenites* sp., *Caryapollenites simplex* (R. Pot.) R. Pot., *Engelhardticoidites* sp., *Myricipites myricoides* (Kremp.) Nagy, *M. rurensis* (Pf., et Th.) Nagy, *Monipites* sp., *Graminidites media* (Cookson) R. Pot., *Laevigatosporites* sp.

In Bed 9, in addition to the above forms, the following floral elements appear: *Echinatispores* sp., *Ginkgoretectina neogenica* Nagy, *Cyrillaceaepollenites exactus* (R. Pot.) R. Pot., *Malvacearumpollenites* sp., *Sapotaceoidaepollenites* sp., *Ostryapollenites* sp., *Alnipollenites* sp., *Tricolporopollenites cingulum* subs. *oviformis* (R. Pot.) Th. et Pf., *T. liblarensis* (Thoms.), *Arecipites tranquillus* (R. Pot.) Nagy, *Laevigatosporites* sp., (quantitatively predominant). Both samples abound with vegetal detritus and tissue remains.

As shown by the results of spore-pollen analyses, the flora forms a transition between the Eggenburgian of Tarnóc and the Badenian of Nógrádszakáll.

In borehole It-10 the third lignite seam (Seam III) is divided, by a grey clay intercalation, into two beds, the upper one being 0.8 m thick. This part of the deposit was worked by "manganese miners" equipped with rather primitive instruments. Lignite Seam II is represented only in traces. A peculiar country rock associated with the seam is silt.

*Diatomaceous silt.* Seam III in the study area is covered by a thin clay layer, overlain in a thickness of about 40 cm, by diatomaceous silts of low $CaCO_3$ content (called "púder" = powder by local people). From this formation, M. Hajós (1974) determined a diversified floral assemblage she had sampled at sites Ipolytarnóc S, Csahir, Szőlő-hegy (Wine Hill) above the brickyard, Mikó and Boglyalyuka (Table 4). In addition to predominant Diatoma, Chrysiomonas and Silicoflagellata, the remains of siliceous skeletons of a few Perifera also occur. Sessile epiphytic species as well as euryhaline forms living in freshwaters and watts at river mouths imply a coastal, lagoonal formation.

The assemblage is represented, in 40.2%, by modern taxa. 12.4% of these were recorded in the northern seas of Europe. Most of the species known from Ipolytarnóc have been recorded in S Slovakia, the vicinity of Modrý Kameň (Kékkő), as well.

The *grey fish-scale-bearing clay* is the final formation constituting the Salgótarján Browncoal Formation and the Kisterenye Member. Its best exposure was observed in gullies entering the Lom rivulet from an eastern direction near Mihálygerge village. In the washing residue of the basal 20 to 25 m of the clay sequence sponge spicules, fish bones and scales occur. Overlying the former, Lignite Seam I is characterized by thin lignite stringers and carbonized remains of driftwood. The upper 10 to 15 m of laminated clay strongly resemble to the underlying beds, being reminiscent of the "Cardium Shale" of the Nógrád area. No molluscs and foraminifers are contained in the washing residue.

These formations in the Modrý Kameň area of Slovakia are referred to as "overlying clay", attaining even hundreds of m in thickness there.

## Karpatian Stage

On the northern margin of Etesi-árok on the margin of the Ipolytarnóc area, the older Miocene rocks are overlain, transgressively, by marine deposits. At the base of the Karpatian, the Egyházasgerge Sandstone Formation is found, being overlain by the Garáb Schlier Formation.

### *Egyházasgerge Sandstone Formation*

Known under different names in the geological literature (Pecten Sandstone, Chlamys Sandstone. Manganiferous Sandstone), the Egyházasgerge Sandstone Formation is superimposed on the Salgótarján Lignite Formation and varies between 60 and 80 m in thickness in the study area.

The lower part of the formation is characterized by a banded alternation of micaceous sandstone and argillaceous sandstone; the middle part by sandstones with interbedded manganese oxide bodies and a uniform grain size; the upper part by diagonally stratified, bedded sandstones of varying grain size. The rock colour is yellowish-brown, that of the hard sandstone intercalations being grey to bluish-grey. The rhyolite tuff spheres and tuff bands within the sequence testify to abrasional redeposition of the Lower Rhyolite Tuff. The best exposure of the formation is in a ravine running downslope in the western part of the Kopasz-hegy at Litke village. Here three manganiferous sandstone interlayers occur within the sandstone, the thickest manganiferous layer being about 1 m thick. At Mihálygerge, in the abandoned sandstone quarry of the Templom-domb, a series of manganiferous sandstone bands of 2 to 3 cm thickness is observable.

The manganiferous, limonitic sandstone with small pebbles exposed in the ravine of Kopasz-hegy at Litke was studied mineralogically-petrologically by J. Gatter (Department of Mineralogy of Eötvös Loránd University, Budapest).

The small-grained manganese-coated pebbles are composed of metamorphic quartzite. Identifiable in thin sections, feldspars (plagioclase and sanidine) attain 15 to 20% in quantity. Among the mafic minerals, muscovite and biotite are frequent, zircon and garnet being less so. Among the larger grains, manganese is associated with opaque minerals, the smaller ones are cemented by limonite. According to micromineralogical results, the quantity of the heavy minerals in the 0.1 to 0.2 mm ∅ fraction is 9.85% by weight. Spectral analyses have shown the presence in the sample of high amounts of *Mn*, and *Fe*, of fair quantities of *Sr*, *Ni* and *Zn* and *low* quantities of *Ce*, *Zr* and *Ba*. In the manganiferous sandstone of greater grain size the presence of waad and lepidocrocite too could be identified by powder preparation techniques. Manganese is attached to the cement of the sandstone, its origin being so far unclear, a polygenetic origin being probable. So for example, it may derive from mafic minerals, though a terrigene origin may be supposed too. Manganese may have been precipitated from stagnant waters as well, but a bacterial segregation is contradicted by its uniform distribution.

In Nógrád County, only the Chlamys-bearing sandstone north of Dobroda-völgy contains a stratiform accumulation of manganese.

As observed on the field by the author, manganese-free sandstones (e.g. those exposed in the Egyházasgerge quarry) contain strikingly more molluscs than the occurrences north of Dobroda-völgy. This is an evidence of synsedimentary manganese genesis.

At Litke, in the good exposures of the Kopasz-hegy, identifiable fossils are scarce, Chlamys (Aequipecten) opercularis, Ch. scabrella, Ch. scabriuscula and Arca sp. fragments being most frequent among them.

In the lower part of the formation its continuous development (with banded clay intercalations) from the underlying fish-scale clays is observable. The transition to the overlying Garáb Schlier Formation too is continuous with a decrease in the grain size of the sandstone and an intertonguing of sandstone and argillaceous marl.

Boreholes spudded near Modrý Kameň in S Slovakia have cut a "Chlamys Sandstone" sequence of varied lithology varying between 35 and 40 m in thickness. A sequence of identical facies with sublittoral megafossils is described by A. Ondrejičková (1967).

### *Garáb Schlier Formation*

On the northern edge of Dobroda-völgy, erosional remnants of the Karpatian schlier bear witness to marine deposits of normal-salinity that have extended well beyond their present-day distribution.

The formation on the Kopasz-hegy of Litke and the Piliske-tető is represented by silty marls overlying the Chlamys-bearing sandstone. In its washing residue sponge spicules, Rotalia beccarii and Globigerina sp. are found.

On the southeast confines of Mihálygerge village, the Nagy-völgy—Szőlő-hegy area, the foraminiferal argillaceous marl beds of the Garáb Schilier Formation are found intertongued with the Chlamys-bearing sandstone. From here, I. Korecz-Laky determined, in company of sponge spicules, ostracods sea urchin spines and fish teeth, the following foraminiferal assemblage:

*Spiroplectammina carinata* (D'ORB.), *Bolivina dilatata* RSS., *B. scalprata* var, *miocaenica* MACFADYEN, *B. plicatella* CUSHM., *Dentalina pauperata* D'ORB., *D. acuta* D'ORB., *Elphidium fichtelianum* (D'ORB.), *Robulus inornatus* (D'ORB.), *R. crassus* D'ORB., *Bathysiphon filiformis* M. SARS., *Sigmoilina asperula* (KARRER), *Pullenia bulloides* D'ORB., *Ammodiscus miocenicus* KARRER, *Cibicides ungerianus* D'ORB., *Eponides haidingeri* D'ORB., *Cyclammina karpatica* CICHA — ZAPLETALOVÁ.

The formation is the product of near-shore, opensea, shallow-water deposition. Its total thickness is estimated at 50 to 80 m. Its terminal member is constituted by tuffaceous marls and freshwater limestones of regression facies (with representatives of Limnaea) on Nagy-Kopasz-domb the west of Litke.

**Badenian Stage**

The "Lower Leithakalk", the Heterostegina-bearing argillaceous marl of Nógrádszakál and the blocky basal gravels and conglomerates of Páris-völgy, rocks representing the Badenian stage, are now found only as remnants that have escaped erosion in the study area. Their original thickness may have been 100 to 150 m. No record of Sarmatian to Pannonian sedimentation is available in the study area.

**Pleistocene**

On the western margin of the Ipolytarnóc—Litke hill range, 70 to 95 m above the flood-plain of the Ipoly river (260 m a.sl.) there are topographic surfaces disintegrated into minor units that are considered to represent Early Pleistocene terrace remnants.

J. PRISTAŠ (1979), on a schematic profile, represents five terraces of east—west trend from the vicinity of Balassagyarmat.

GY. PEJA and S. LÁNG (1967) ascribe the denudation of the terraces in the particular subbasins to Late Pleistocene to Early Holocene movements. In their opinion, the NE-SW trending Ipolytarnóc—Szécsény stretch of the river substantially deviates in stratigraphic and tectonic architecture from the Balassagyarmat and Vinica areas. Hence the absence of terraces there.

In 1971, 16 boreholes were put down into the alluvium of the Ipoly between Litke and Ipolytarnóc, in three sections running parallel to the river, progressively farther away from it. They exposed respectively 3, 2 and 1 m of muddy sand and 6, 7 and 5.5 m of early-alluvial sandy gravels.

South of Litke, in Dobroda-völgy, in four boreholes the sandy gravels under 6 to 10 m of sandy clay were observed to grow gradually thicker to the east, the maximum measured having been about 1 m.

## TECTONIC DEVELOPMENT, EVOLUTION HISTORY AND PALAEOGEOGRAPHY

The palaeogeographical—geohistorical events of the Ipolytarnóc area are reconstructed here on the basis of the Neogene palaeogeographic maps of N Hungary by G. HÁMOR (1978, manuscript) and by using the comprehensive palaeogeographic description and map-schemes of the Hungarian Neogene published by G. HÁMOR and K. SZENTGYÖRGYI (1981).

During the Egerian the Ipolytarnóc area was a part of a NE—SW oriented Paleogene sedimentary basin (S Slovakia—Salgótarján—Ipoly valley—Cserhát Mts—Budapest region). The maximum of the transgression is indicated by the shallow-water opensea deposits of the Szécsény Schlier Formation.

The first compressive phases of the Savian orogenic cycle stopped the subsidence of the basement regionally and speeded up the uplift of the background. It was then that the embryon of the so-called Etesi-árok, a structural element controlling the palaeogeography of Nógrád County including Ipolytarnóc, made its appearance. Running in northwest—southeast direction, the graben structure has a length of about 60 to 70 km and a width of about 5 and 15 km. In the graben — along with continuous sedimentation — the schlier facies is replaced by shallow-water, sublittoral to littoral and locally beach-facies, molasse-like, sandstone deposition (Pétervására Sandstone Formation). The formation is composed of cross-bedded glauconitic sand sandstone beds frequently prinching out. Washed together into isolated lenses or nests (pockets), teeth of sharks represent typical faunal elements.

With further intensification of the Savian orogeny, the argillaceous-sandy deposits of opensea development of the Etesi-árok are found intertongued in space with the afore-mentioned basal beds, bearing witness to the cyclicity of the process. Nannozone $NN_3$ and the Mollusca fauna identified in the pelitic facies and the biostratigraphic record of the overlying beds prove that this new transgression took place in Eggenburgian time and that its products are assignable for sure already to the Miocene (Budafok Sand Formation). The first one of the tension phases which replaced the compression phases of the Savian orogeny and which culminated in the formation of depressions resulted in a rapid uplifting of the land area surrounding the Etesi-árok. Produced in masses, the clastic material was transported from northwest direction into the graben and this was filled with fluviatile sediments (Zagyvapálfalva Mottled-Clay Formation). In the streamline of the river, coarse-grained clastics of varying grain size were laid down. The alluvial flood-plain sedimentation is characterized by variegated clays, sandstone bars and pinching-out lenses intertonguing with the former. Southeast of Ipolytarnóc, at a distance of about 25 to 30 km, near the boundary between the continental and marine sedimentary areas, even deltaic deposits dating from the same period (Kazár, Tordas) are known.

It is from this time that the palaeogeographic pattern of Ipolytarnóc is best known. The hilly landscape with an alluvial fill offerred a habitat for forests with a lush undergrowth.

The paleoclimatic conditions are characterized by a mean annual temperature of 20 to 25 °C, a high humidity of the atmosphere and an annual amount of 1.016 to 3.810 mm of rainfall (K. Rásky 1959).

The excavated "footprint-dotted" area may have been the edge of a flood-plain, or possibly a rivulet that flowed from a nearby spring into the flood-plain. What is sure is that it must have been a watering spot, as evidenced quite convincingly by the great number of vertebrate species and their differring habitats. Offering an access "on dry feet" via the sand ridge or sand bar that was made use of for a comparatively long time, the watering place may have been repeatedly invaded by new and new floods which laid down another muddy sand bar (the footprints are found in two horizons). This (These) bedding surface(s) represent(s) that member of the Zagyvapálfalva Mottled-Clay Formation called "Ipolytarnóc Beds".

The idyllic situation was put an end by the tension phase of the Savian orogenic cycle. Along fissures that opened on that occasion rhyolite tuffs were ejected onto the surface regionally in huge masses (Gyulakeszi Rhyolite Tuff Formation). The centre of eruption seems to have lain southeast of Ipolytarnóc, along the southwestern marginal fault of the Etesi-árok.

The tuff flows progressed north- to northeastwards. They did so downslope owing to the very nature of the material and they filled in only the morphologically deeper Etesi-árok. Ipolytarnóc was probably rather far away from the eruption centre, so that the thermal energy of the tuff flow reaching this area may have been already low, as evidenced by the preservation state of plant remains. Its flow velocity could not be high either. The front face of the flood-tuff was probably several metres high. In the Etesi-árok area the maximum thickness of the tuff attained nearly 100 m which had probably resulted from two to three phases of activity that followed one another quite rapidly. It is to these tuff ejecta that the "snapshot" of the "living scenery" of Ipolytarnóc, its burial and preservation are owed. That the volcanic activity was short-lived is proved by the fact that the environmental setting changed almost nothing.

The morphological differences were levelled off and clays and sands were deposited in the course of fluvial—alluvial sedimentation (Salgótarján Lignite Formation, Nógrádmegyer Member). During this new tension phase the Etesi-árok slowly subsided deeper and deeper and contiguous water surfaces developing into peat swamps came into being. This process was repeated several times, several workable lignite seams were formed and finally, in a slowly transgressing brackish-water sea, sediments with Cardium and Congeria shells were deposited. The volcanic eruption occurred at the turn of Eggenburgian and Ottnangian times, so that the age of the Salgótarján Lignite Formation is taken to correspond to the Ottnangian. Two additional circumstances are noteworthy:

— It is in variegated clays formed after the volcanic activity quite close to Ipolytarnóc, at a distance of about 20 to 25 km from it, that the first remains of Mastodon, Prodinotherium (bones and teeth) appear.

— In the Ipolytarnóc area, after the deposition of the rock material of the Nógrádmegyer Member, sedimentation came to an end. The area in question now represents the northeastern, relatively elevated limb of the Etesi-árok.

The subsequent geohistory of the Etesi-árok was controlled by the Styrian orogenic phases. It was in the axial line of the narrowing graben structure that the Karpatian and Early to Late Badenian transgressions took place, filling the invaded zone with marine and, finally, with volcano-sedimentary deposits. In Sarmation time, the Etesi-árok zone also emerged and the sedimentary basin shifted to the southwest of it. The Leithaian and Rhodanian orogenies produced additional sets of longitudinal and transversal faults that have transformed the Etesi-árok and the Ipolytarnóc area into a block-faulted graben-and-horst structure.

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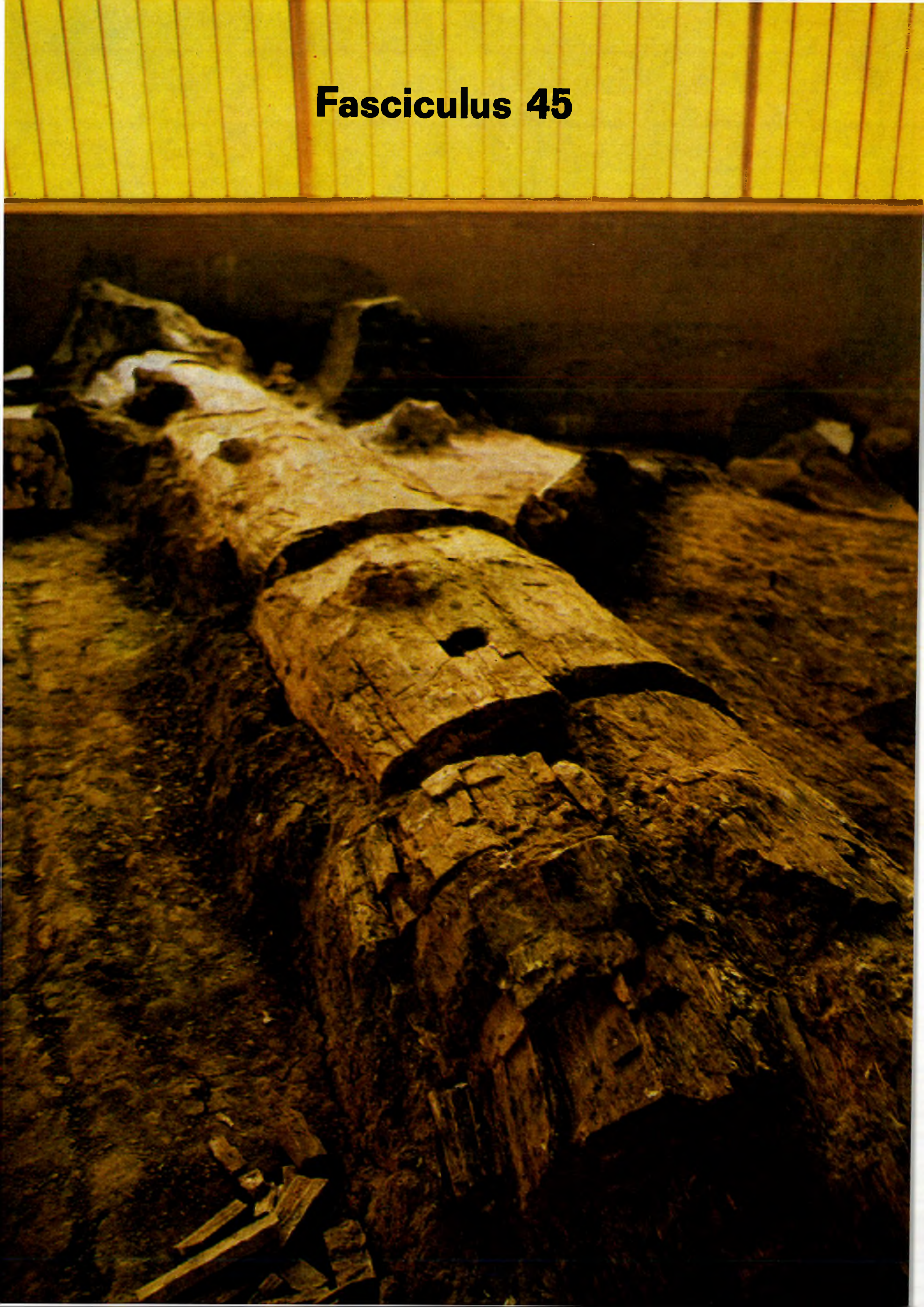
# Fasciculus 45



**Az alapozási munkálatok során előkerült 8 m hosszú kovásodott fenyőtörzs**
Fotó: NÉMETH ERNŐ, 1983

**Silicified pine trunk, 8 m long, recorvered during foundation work**
Photo: E. NÉMETH, 1983