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SECTIO GEOLOGICA

TOMUS XXVI.

BUDAPEST
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REDIGUNT
B. GÉCZY
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GENETIC INTERPRETATION OF THE RESULTS OF MICROTHERMOMETRIC STUDIES ON THE LIQUID/GAS INCLUSIONS OF FLUORITES FROM RAVNAJA (YUGOSLAVIA)*

by

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ABSTRACT

The fluorite, which is the object of our studies here, derives from the hydrotermal fluorite deposits Ravnaja in West Serbia. Besides the essential fluorite mineralization, the sulphide mineralization of Pb. Fe, and Zn is to be found in these deposits. Several generations of fluorites of various colour can be distinguished in most of these occurences. The paper gives an account of the fluid inclusion study carried out on the Ravnaja fluorites. The formation of fluorites took place in two distinctly separate phases at 270 to 245 °C and at 205 to 160 °C (modified with pressure correction) under conditions of gradually decreasing temperatures. Cryoscopic data (eutectic points) suggest that the fluid component of the inclusions is of the alkali-chloride type composition with some bicarbonate-sulphate contaminants added. Freezing tests proved the presence of small amounts of CO_2 in the inclusions. The concentration of the solutions involved is about 3 to 11 NaCl equivalents wt.% – characteristic of the volcanic/subvolcanic environment. The density of the fluids was calculated as 0.98 to 0.80 g/cm^3 with a vapor pressure of $<5-50<$ bars at the time of entrapping. There is no strict correlation between the colour of the specimens and the phase transition temperatures observed during the homogenization and cryoscopic tests.

1. Introduction

Fluorite occurs as main or accessory constituent in various types of metallic and non-metallic mineral deposits. The range of temperatures of formation of fluorite is consequently fairly wide, fluorites are known from pegmatites as well as from various sedimentary facies. Its indifferent optical characteristics (= optical isotropy) together with the usually abundant fluid inclusions it contains, make fluorite one of the best subjects to fluid inclusion studies.

The fluorite in these deposits (Fig. 1) is the essential ore mineral, followed by the sulphide mineralization, mainly with galena. This ore mineralization of fluorite in Ravnaja (West Serbia, Yugoslavia) is connected to Paleogene volcanic/subvolcanic processes. Several generations of fluorite, sometimes intergrown with sulphide minerals such as galena, are known from the Ravnaja deposit; each of which have characteristically different colour.

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* The paper is a revised and shortened version of I. GATTER's preliminary report on homogenization-cryometric tests carried out on fluorite samples from Yugoslavia (1980) and a of lecture "Termometrijsko proucavanje fluidnih inkluzija u fluorita Ravnaje, metodama homogenizacije, kriometrije i dekrepitacije" (15 p) presented by NIKOLIĆ, D. – GATTER, I. – TOMIĆ, D. to the Yugoslav Geological Congress (Jugoslavenski Geološki Kongres) in Budva 13.9.1982.

Fluid inclusion study of the various fluorite types facilitated the establishment of physico-chemical parameters of formation of the ore minerals and provided useful information about the conditions of formation of fluorites of various colour. In the followings detailed description of the investigation of seven different fluorite samples will be given.

Fig 1. Map of localities where the investigated samples were collected from

2. Methods of investigation and description of samples

2.1. Optical microscopy

Slabs of 0.1 to 0.3 mm thickness, polished on both sides were investigated. The colour of the specimens varied widely from the colourless to the almost opaque, deep-purple (anthosite type) varieties. In thin section most fluorite varieties have a characteristic "cloudy" appearance. Purple tint (light or deep) occurs usually in the form of indefinite streakes. Less frequently purple coloured samples may be more or less homogeneous with faint white streaks only. Zoned colouring parallel to (111) was observed in one singular case only. There is no correlation between the distribution of fluid inclusions and the colour of the fluorite crystals investigated.

Sometimes fluorite grains may contain small (50 to 200 μm) crystals of corroded quartz and epidote or may be penetrated by secondary clacite veins in which the size of the calcite crystals is about 500 to 2000 μm. At places quartz grains are concentrated along the boundaries of the different fluorite generations.

Two-phase fluid inclusions are abundant in the fluorite crystals. The size of the inclusions varies from a few micrometers up to 50 to 60 μm. They are of rounded or pipe-like shape. Condensed gases or daughter minerals were not observed.

Based on the distribution of the inclusions and their relationship to the morphology and the texture of the parent mineral the following genetic types can be distinguished (Roedder. E. 1967):

Type "A": (-primary to pseudosecondary) usually round-shaped inclusions within fluorite aggregates or single fluorite crystals, arranged parallel to the (100) growth lines of the parent mineral (Fig. 2)

Type "B": (-pseudosecondary to secondary) usually elongated rod-like inclusions arranged parallel to the (111) cleavage planes of the parent mineral (Fig. 3) In some cases the material filling the corrosion cavities consists of only one (liquid) phase.

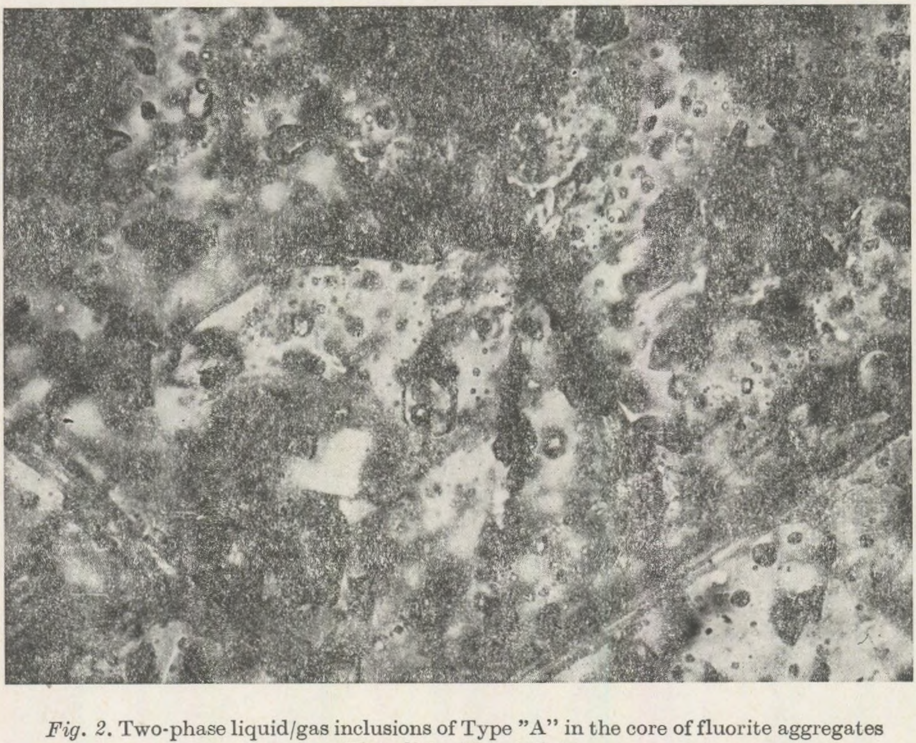

Fig. 2. Two-phase liquid/gas inclusions of Type "A" in the core of fluorite aggregates
Plain light M = 166.4x

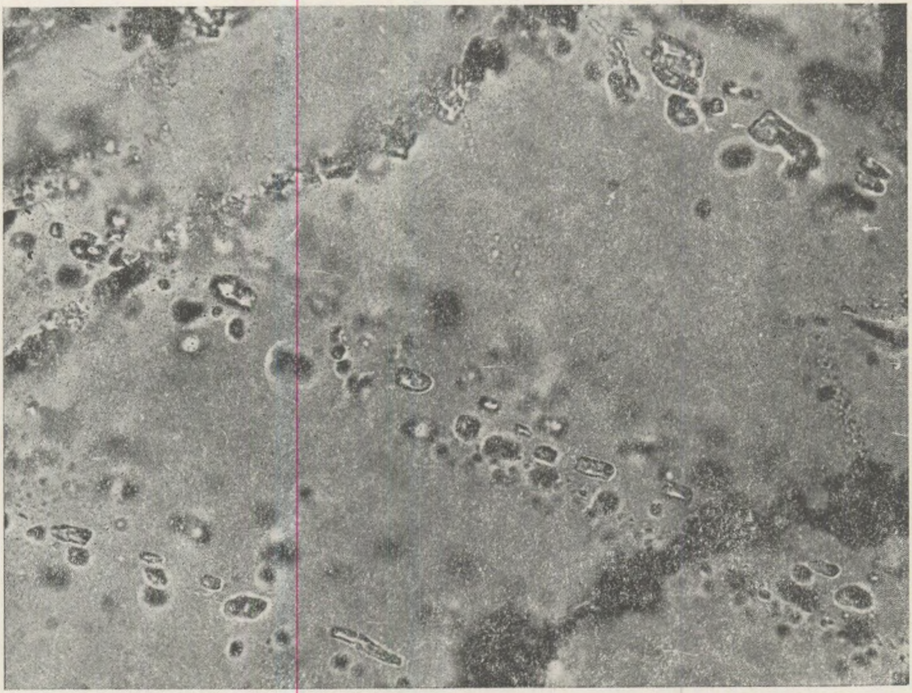

Fig. 3. Two-phase inclusions of Type "B" arranged in a line.
Plain light, M = 340x

2.2 *Microthermometric measurements*

The measurements were carried out with a CHAIXMECA cooling-heating stage mounted on a ZEISS AMPLIVAL – POL photomicroscope. Calibration of the instrument was undertaken with 17 different components of analytical purity, with a total optical magnification of 400× (GATTER, I. 1980). All measurements were carried out at the Mineralogical Department of Etvös L. University, Budapest.

2.2.1. Homogenization tests

The samples were heated at a rate of 3 to 5 °C pro min. Rate of heating was decreased to 0.5 to 0.8 °C pro min right before the expected homogenization to facilitate more precize record of the homogenization temperature (T_h). Homogenization phenomena were observed in the liquid phase only.

As proved by numerous model experiments and crystal-growth tests, in the case of an "open" system (i.e. characterized by hydrostatic pressure) T_h satisfactorily represents the minimum temperature of formation of the mineral phase regarded (SAPOSNIKOV, A. A. – ERMAKOV, N. P. 1968; ROEDDER, E. – SKINNER, B. J. 1968; etc). In the case of a geologically “closed” system the possible minimum temperature of formation can be calculated by using the method of “pressure correction” described by Potter, R. W. II. 1977. The reliability of the results of these calculations, however, depends largely on the reliability of general geological information concerning the type of the deposit, the thickness of the strata involved, etc.

The results of our homogenization tests are summarized by Fig.4 where also the colour of the individual samples is indicated. The diagram exhibits two definite maxima:

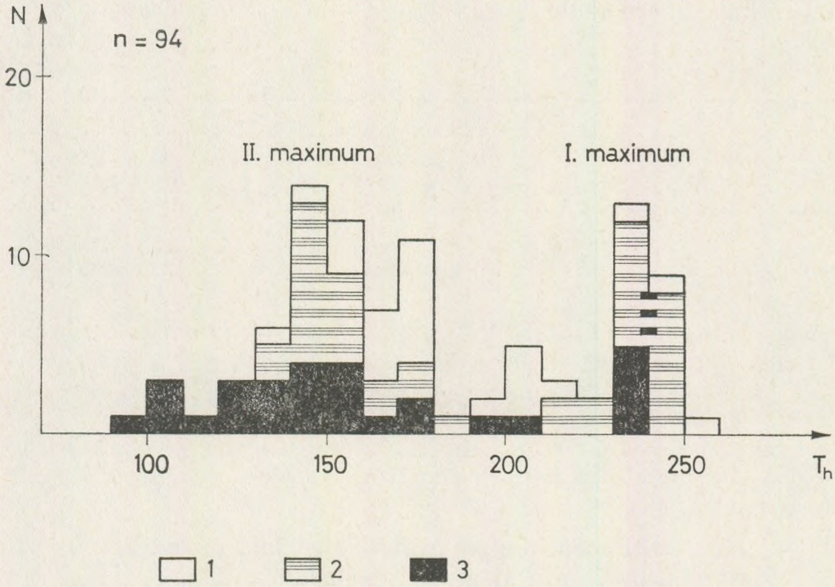

Fig 4. Results of the homogenization tests
Key: (1) transparent (with a slight purple tint); (2) purple (light to deep); (3) blackish purple

Maximum № 1: between 230 and 250 °C stands for inclusions of the primary to pseudosecondary type. The observed temperatures represent also the temperature of formation of the tiny galena crystals intergrown with the fluorite grains.

Maximum № 2: between 140 and 180 °C, representing the temperature of formation of the pseudosecondary-secondary inclusions provides information about the processes which took place after the main stage of ore mineralization.

As to the relationship between colour and temperature of formation of the fluorite crystals the correlation is loose. In the deep-purple specimen only inclusions of the pseudosecondary-secondary type could be investigated and their T_h falls within the area of maximum N° 2. Inclusions observed within the light to deep purple coloured variety gave temperatures characteristic partly of maximum N° 1 partly of maximum N° 2. Homogenization temperatures measured on inclusions of the transparent variety fall in between the two characteristic maxima. Based on general geological considerations, in addition to the vapour pressure of the hydrothermal fluid system, a lithostatic pressure of about 1000 to 500 meters of cover beds of 2.7 g/cm^3 specific density should be calculated with during the formation of the minerals concerned. Accordingly the actual temperatures of formation modified with the above mentioned "pressure correction" (for 5% NaCl solution) are as follows:

Table 1.

$T_{homog.}$ [°C]	$T_{formation}$ [°C]	
	in case of 500 m of cover	in case of 1000 m of cover
230 – 250	245 – 260	255 – 270
140 – 180	160 – 195	170 – 205

The relatively low (+ 20 to 25 H°C) figures of pressure correction confirm the mesothermal temperature of formation.

2.2.2. Cryoscopic measurements

Investigation below room-temperature reveal the phase-transitions taking place in the closed frozen salt-solution. Cryoscopy provides information about

T_0 – the solidification temperature of the fluid phase, and – when warmed up slowly at room temperatures:

T_1 – the so called "first" melting point or eutectic temperature, depending on the chemical composition of the fluid (it is independent from the concentration of the solution) (Roedder, E. 1971; Borisenko, A. S. 1977)

T_2 – the so called "second" melting point, which facilitates the calculation of the concentration (c) of the solution in NaCl equivalents (Roedder, E. 1962; Potter, R. W. II. et al 1978).

When homogenization and cryoscopic tests are carried out on one and the same inclusion also additional parameters can be calculated indirectly: p:ϱ-T_h and c allow the graphical determination of density and vapor pressure of the fluids involved (in: Almad, S. N. – Rose, A. W. 1980; Akinici, Ö. 1976). According to the method of Bodnar, R. J. 1983 the density can be calculated numerically, too.

Solidification temperatures (T_0) of the denser (fluid) constituent of the inclusions varied between – 60 and – 36.5 °C. The frozen phase was always a fine-grained, frequently opaque aggregate. Sometimes – mostly in the case of primary inclusions – the formation of a few vol. percents of

CO_2 condensate could be observed, the outlines of which, however, gradually faded as it reacted with the frozen phase. The melting point of the hydrate crystal could be detected only once (−0.8 °C). The refraction index of the crystal was low ($n_{hydrate} < n_{solution}$) and it had a mamillated structure.

The eutectic point of the system falls between −5 and −22 °C (Fig. 5A). This calls for an alkali-chloridic composition with some bicarbonate or sulphate contaminants. The colour of the samples seems to be in correlation with the eutectic points: the transparent variety gave eutectic points close to the $NaCl-H_2O$ system, the figures of the light-coloured crystals provided rather scattered results whereas the eutectic points of the deep-purple, blackish variety represented and intensely mixed system of solutions.

Concentrations calculated on the basis of the "second" melting point (T_2) are shown by Fig. 5B. They call for a system consisting of a concentration of 3 to 11 NaCl equivalents (max. 7 to 8 wt. %). The correlation

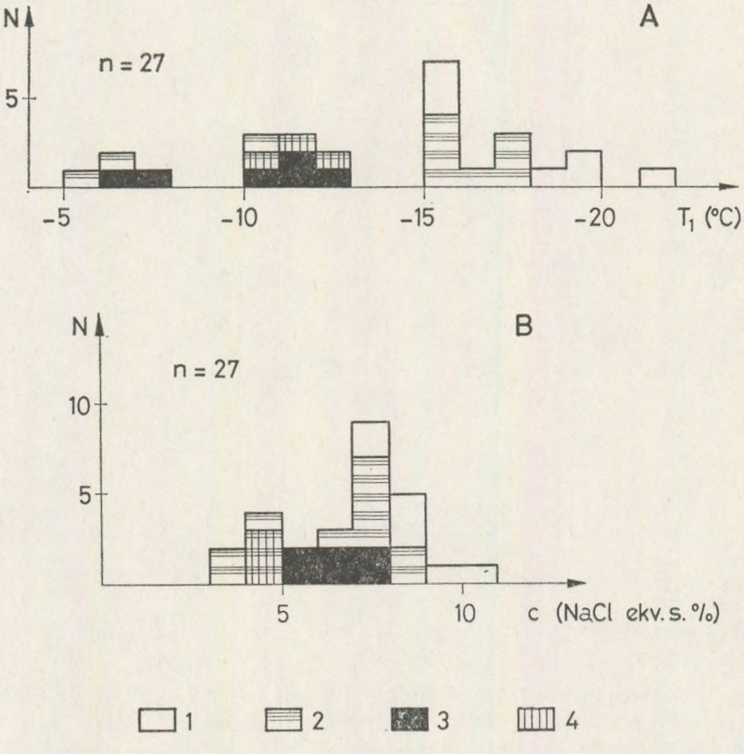

Fig. 5. Results of the cryoscopic tests
(A) Eutectic points; (B) Concentrations
Key: (1) transparent (with a light purple tint); (2) purple (light to deep); (3) blackish purple; (4) CO_2-condensate at the moment of solidification

between the concentration figures and the colour of the samples is similar to that observed in the case of T_1. The concentration of the light-coloured samples is higher (7 to 11%) than that of the purple ones (3 to 9%) whereas the figures of black fluorite are the lowest with 5 to 8%. Condensation of CO_2 was observed in specimens of low concentrations only.

Demonstrating the relationship between T_1 and c, Fig. 6 clearly shows that variations of the chemical composition of the fluid are – as a rule – accompanied also by continuous changes of the concentration.

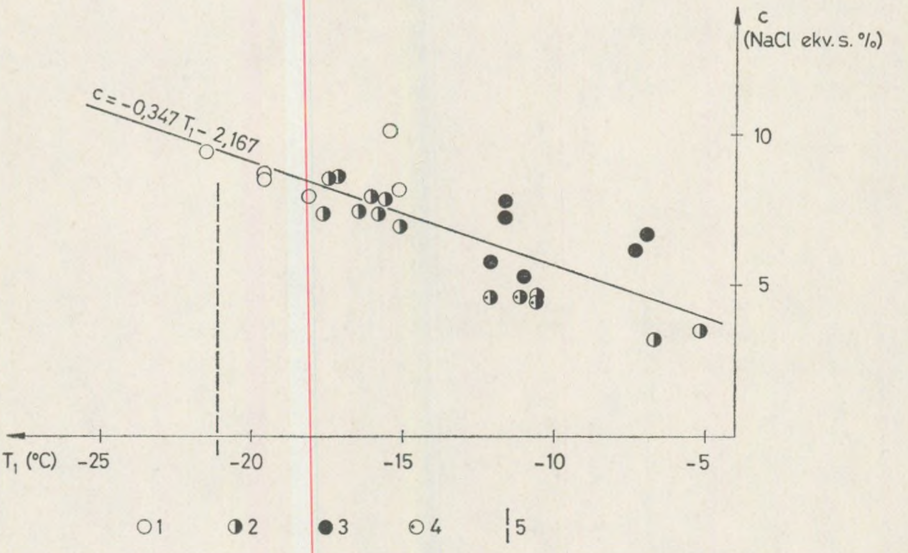

Fig. 6. Interrelation of the eutectic points and the concentration figures of the investigated samples

Key: (1) transparent (with a light purple tint); (2) purple (light to deep); (3) blackish purple; (4) CO_2-condensate on freezing; (5) eutectic point of the $NaCl-H_2O$ system

Using the diagrams of the above cited authors the density of the fluid system could be calculated as follows (Fig. 5). In the moment of homogenization, density is 1.00 to 0.83 g/cm^3. When taking also the pressure correction into consideration, these figures become slightly modified (0.98 to 0.80 g/cm^3). The density of inclusions – the CO_2 content of which was disclosed by cryoscopic measurements – proved to be invariably lower than that of the other inclusions investigated. The vapour pressure of the system was 5 – 50 bar as shown by the diagram of Fig. 7.

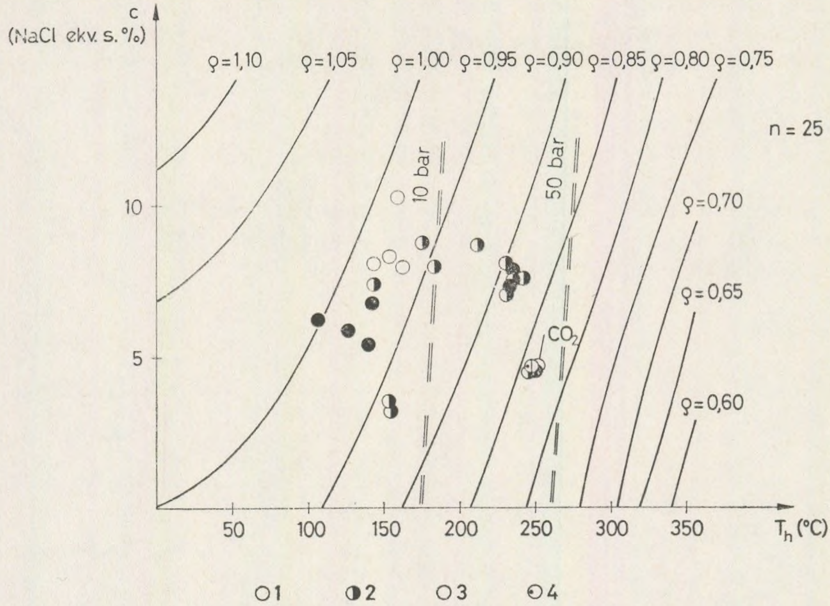

Fig. 7. Density – pressure diagram
Key. (1) transparent (with a light purple tint); (2) purple (light to deep); (3) blackish purple; (4) CO_2 condensate on freezing

3. Summary

The formation of fluorite crystals at Ravnaja took place in two separate phases, under mesothermal conditions, most probably as a result of gradually but not continuously decreasing temperature. Temperatures of formation (after pressure correction) gave two intervals (275 – 245 °C and 205 – 160 °C). The multistaged nature of the formation was inferred on the basis of corrosion phenomena. There is no strict correlation between the colour and the temperature of formation of the various types of fluorites. which is in contrast to the observations of Chojecka, E. 1978; Polikovski, V. S. et al 1976; Dominique, J. et al. 1973 and others who on the basis of fluid inclusion study of several occurrences suggested that a correlation existed between paragenetic sequence – colour – temperature of formation (and salinity).

Cryometric data suggest an alkali-chloridic composition of the fluid inclusions with minor bicarbonate-sulphate contaminants. Along with the fluid components the inclusions contain also a few percentages (>10 mol %) of CO_2 the distribution of which is inhomogeneous. The concentration of the solutions is low which by analogy proves the subvolcanic/volcanic character of the deposit (Roedder, E. – Bodnar, R. J. 1980). The change of the chemical character of the solutions during the cryometry tests was continuous and was accompanied by a characteristic change of the concentration. The original density of the fluid at the time of entrapment had been 0.98 to 0.80 g/cm^3 with a vapour-pressure of about < 5 to > 50 bars.

Acknowledgements

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GEOCHEMISCHE UNTERSUCHUNGEN ÜBER EINE EOZÄN–OLIGOZÄN KALKSTEIN–SERIE AUS DEM NORDEN DES SIEBENBÜRGISCHEN BECKENS (RUMÄNIEN)

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ABSTRACT

The paper reports the geochemical investigation of a superior eocene and inferior oligocene aged limestone complex situated a quarry near Letca (county Sălaj). The sample were collected in a vertical direction, 1 Lt being the notation for the superior horizon.

Tables 1 and 2 present the results of chemical analyses for major elements, resp. these of spectral analyses for minor elements. Diagrams (fig. 5, 6, 7, 8) presenting the content of different elements (on the ordinate) plotted vs. the horizons, were used to establish the correlation between the elements.

The values of the empirical linear correlation coefficients are presented in table 4. On the basis of this table were established groups of elements and their distribution in these two main phases: carbonated phase and residue insoluble in HCl. Using the values of this table a dendrogram was depicted represented in fig. 9. The dendrogram shows approximately the same elementgroups as the analyse of the proceeding correlation.

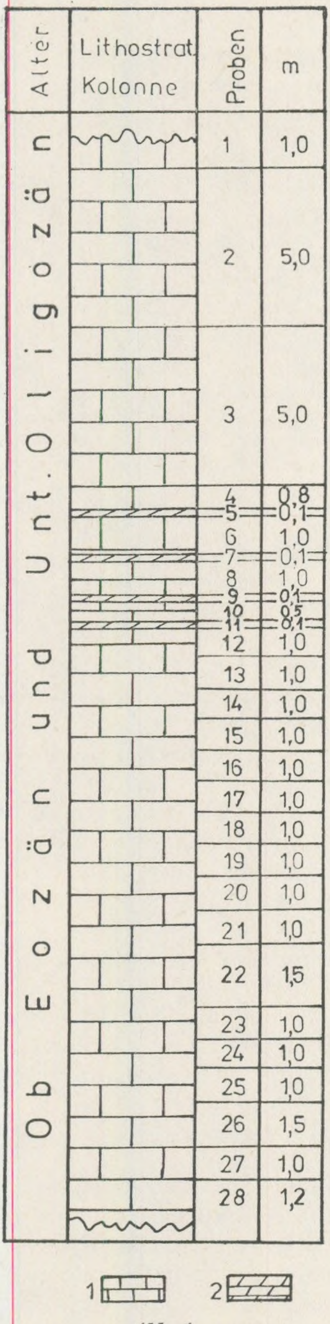
Im Norden des Dorfes Letca (Kreis Sălaj) hat man einen Kalksteinbruch von 50 m geöffnet. Aus diesem Steinbruch haben wir 28 Proben senkrecht, aus ebensovielen Horizonten, gesammelt.

In der lithostratigraphischen Kolonne aus Abb. 1. haben wir mit Ziffern die Stelle der gesammelten Proben notiert, mit 1 symbolisierten wir den obersten Horizont und mit 28 den untersten Horizont. Die Kalksteine aus dem Steinbruch sind von den sogenannten ,,Kalkstein von Culmea Cozlei" vertreten. benannt von Gr. RĂILEANU und E. SAULEA (1956). Sie umfasst eine komprehensive Serie aus dem höheren Eozän und dem unteren Oligozän.

Das geochemisches Studium der Kalksteine aus dem Gebiet wurde von J. IMREH, N. MÉSZÁROS und Mitarbeiter (1978, 1980, 1981) unternommen, es wurden die Kalksteine, die sich ostlich von Letca (Glod, Piatra, Poiana Blenchii, Rohia) befinden, studiert. Das gesammelte Material wurde einem chemischen und spektralen Analyse unterzogen.

I. Chemisches Studium

Die chemische Analyse der Proben ist in Tabelle 1 dargestellt, wo die Ergebnisse in Gewichtsprozenten wiedergegeben sind. Die letzten zwei Kolonnen des Tabelles enthalten das freie Kalzyt und Dolomyt die berechnet wurden. Aus den Daten des Tabelles haben wir Hystogramme zusammengestellt, die die Frequenz von SiO_2, Al_2O_3, Fe_2O_3, $CaCO_3$ und $CaMg(CO_3)_2$ enthält.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2 5,0
3 5,0
4 0,8
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23 1,0
24 1,0
25 1,0
26 1,5
27 1,0
28 1,2
1
2

Abb. 1.

Tabelle 1.

Nr	Proba	K_2O%	Na_2O%	SiO_2%	Al_2O_3%	Fe_2O_3%	P_2O_5%	Kalzit%	Dolomit %
1	1 Lt	0,06	0,34	0,33	0,13	0,07	0,005	98,99	0,17
2	2 Lt	0,06	0,40	0,58	0,16	0,17	0,0087	98,86	0,20
3	3 Lt	0,05	0,42	0,41	0,23	0,10	0,0059	98,88	0,24
4	4 Lt	0,06	0,40	0,55	0,20	0,15	0,0064	98,99	0,13
5	5 Lt	0,17	0,39	4,91	1,45	0,61	0,0064	87,89	4,06
6	6 Lt	0,15	0,45	1,61	0,38	0,22	0,0119	96,59	0,45
7	7 Lt	0,52	0,44	12,48	3,51	1,66	0,0101	74,16	5,44
8	8 Lt	0,05	0,44	0,81	0,12	0,18	0,0041	96,99	1,09
9	9 Lt	0,65	0,48	15,76	4,43	2,38	0,0260	71,51	4,57
10	10 Lt	0,04	0,43	0,46	0,19	0,15	0,0036	98,54	0,63
11	11 Lt	0,12	0,44	2,70	1,05	0,63	0,0045	94,14	0,21
12	12 Lt	0,08	0,44	1,85	0,60	0,48	0,0130	95,83	0,21
13	13 Lt	0,05	0,46	1,55	0,32	0,30	0,0064	96,39	0,91
14	14 Lt	0,06	0,45	1,49	0,28	0,17	0,0064	96,36	1,09
15	15 Lt	0,13	0,46	1,60	0,99	0,29	0,0090	95,66	1,35
16	16 Lt	0,11	0,45	2,60	1,40	0,46	0,0050	81,82	13,71
17	17 Lt	0,10	0,40	2,21	1,14	0,45	0,0050	94,29	0,91
18	18 Lt	0,08	0,42	2,01	1,03	0,36	0,0010	93,43	3,19
19	19 Lt	0,16	0,40	3,28	1,72	0,44	0,0010	90,37	3,19
20	20 Lt	0,16	0,42	2,64	1,30	0,39	0,0090	90,50	4,11
21	21 Lt	0,14	0,44	2,58	1,23	0,33	–	90,21	5,48
22	22 Lt	0,17	0,42	1,66	0,98	0,41	–	94,72	1,37
23	23 Lt	0,20	0,42	1,91	1,21	0,37	0,0090	94,38	0,92
24	24 Lt	0,09	0,44	3,11	1,07	0,48	0,0160	91,48	3,67
25	25 Lt	0,10	0,42	3,13	1,11	0,48	0,0090	92,97	1,83
26	26 Lt	0,12	0,44	3,95	1,28	0,71	0,0090	87,99	5,48
27	27 Lt	0,11	0,46	2,38	1,52	0,46	0,0070	93,32	1,13
28	28 Lt	0,13	0,46	3,93	1,14	0,56	0,0020	85,25	8,68

Der SiO_2 Gehalt. Aus der Tabelle 1 kann man heraussehen, daß der Gehalt in SiO_2 sich zwischen ziemlich großen Grenzen wechselt, von 0,33% bis 15,76%. Man bemerkt, daß sowohl die niedrigen (0,33 – 0,55%) als auch die höheren Gehalte (12,48 – 15,76%) in den oberen Horizonten vorkommen. Die konstruirte Hystogramme auf Klassen je 1,25% zeigt eine rechte unimodale, asymetrische Allüre, mit einer maximen Frequenz (N = 10) in der Klasse 1,25 – 2,5%. (Abb. 2a).

Der Al_2O_3 Gehalt. So wie im Fall des SiO_2, auch im Falle des Al_2O_3, kann man bemerken, daß die niedrigen Werte (0,13 – 0,20%) und die hoheren Werte (3,51 – 4,43%), sich in den Proben aus den höchsten Horizonten befinden. Die Hystogramme, hergestellt auf Klassen von 0,35%, zeigt zwei große Frequenzen (N = 8 und N = 9), welche der Frequenzkurve eine klare bimodale Allüre verleiht, das heißt, daß das Aluminium bei der Bildung einiger Mineralien aus zwei verschiedenen Phasen teilnimmt. (Abb. 2b).

Der Fe_2O_3 Gehalt. Auch im Falle des Eisens ist gültig die Feststellung von Silizium und dem Aluminium. Die Hystogramme hergestellt auf Klassen von je 0,2%, zeigt ein Frequenzmaximum (N = 9) bei der Klasse 0,4 – 0,6%. Die Kurve ist unimodal mit einer rechten Asymetrie. (Abb. 2c).

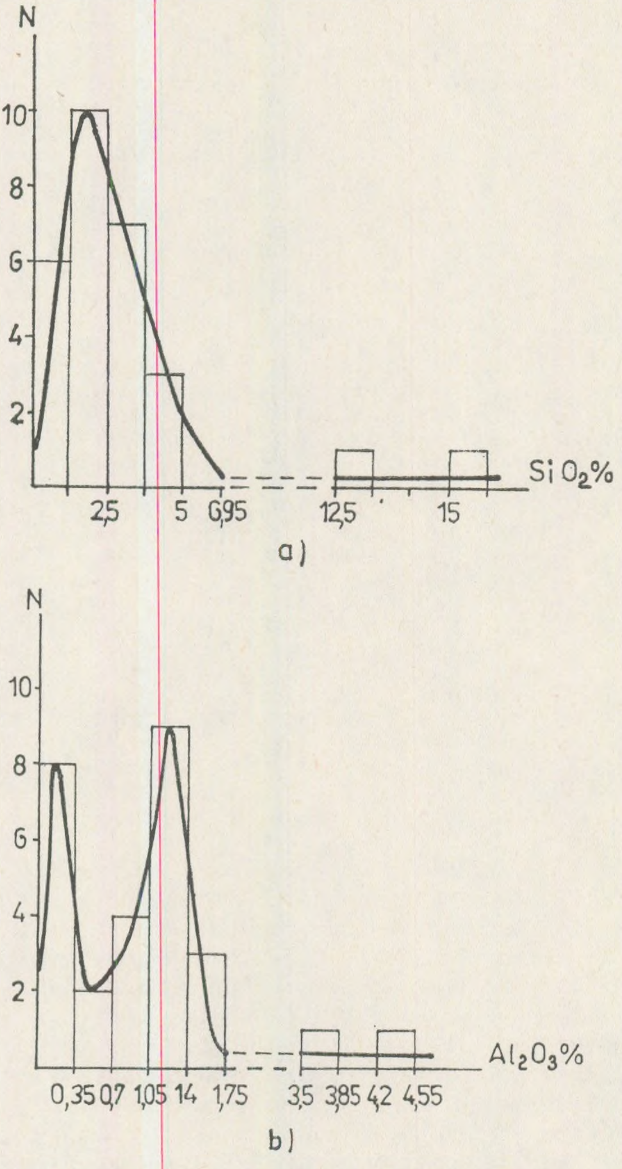


Abb. 2.

Der $CaCO_3$ Gehalt. Die Inhalte in $CaCO_3$ schwanken zwischen 71,51% und 98,99%. Sowie es zeigt auf der Hystogramme, die auf Klassen je 2% hergestellt ist, die meisten Werte befinden sich in den Klassen 94 – 96% (N = 6) und 98 – 100% (N = 5). Die Kurve hat eine bimodale Allüre. (Abb. 3a).

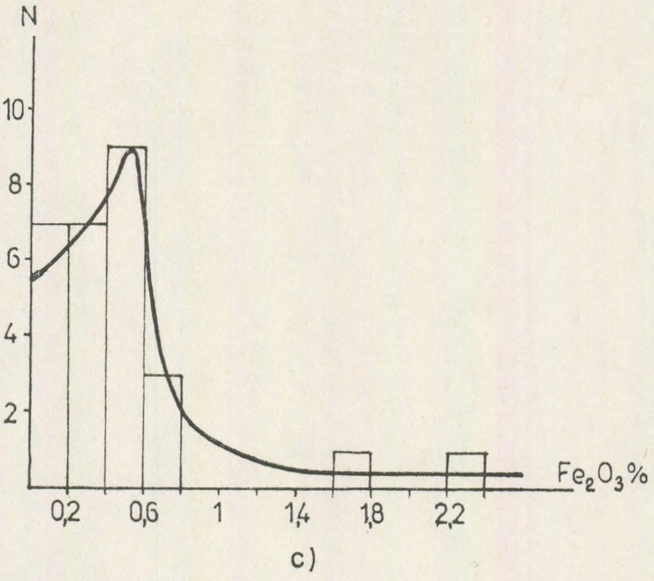


Abb. 2.

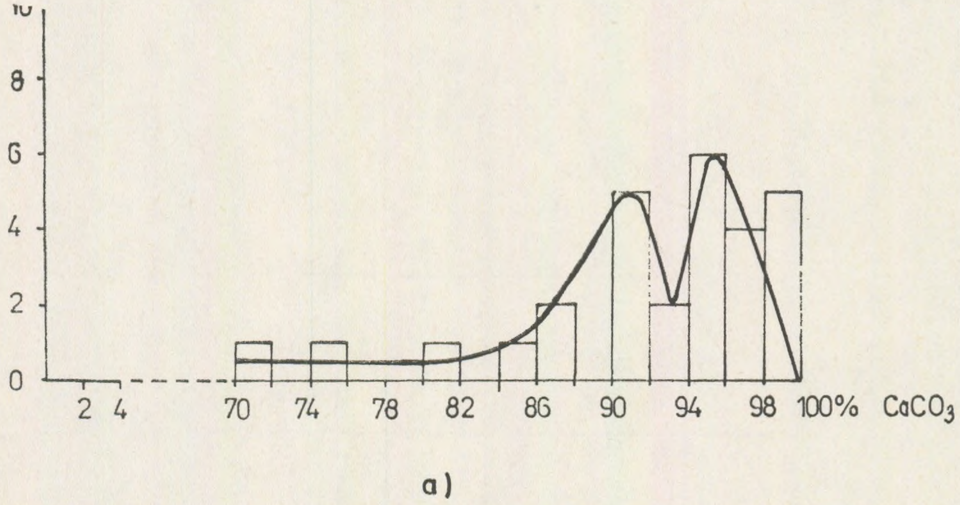
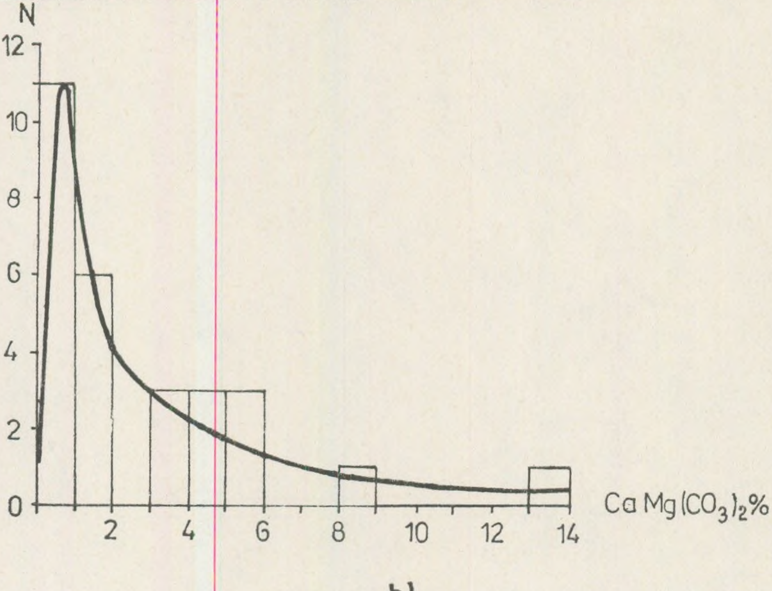


Abb. 3.

Der $CaMg(CO_3)_2$ Gehalt. Der Gehalt in Dolomit wechselt zwischen 0,13% und 13,71%. Die größte Frequenz kommt in der Klasse 0 – 1% vor, so wie es zeigt auf der Hystogramme die hergestellt ist auf Klassen von 1%. Die Kurve hat eine unimodale Allüre mit einer rechter Asymetrie. (Abb. 3b).


N
12
10
8
6
4
2
0
2
4
6
8
10
12
14
Ca Mg (CO3)2%

b)

Abb. 3.

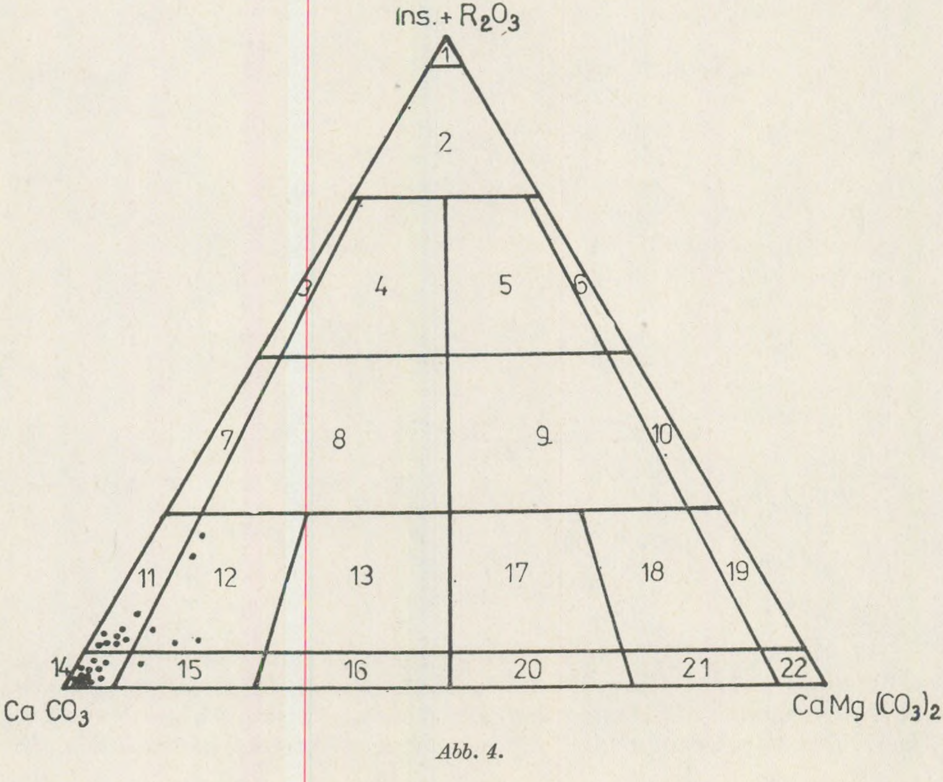

Ins. + R2O3
1
2
3
4
5
6
7
8
9
10
11
12
13
17
18
19
14
15
16
20
21
22
Ca CO3
Ca Mg (CO3)2

Abb. 4.

Vergleicht man die Hystograme von $CaCO_3$ und $CaMg(CO_3)_2$, stellt man fest, daß die Inhalte umgekehrt verteilt sind. Wenn beim $CaCO_3$ die häufigsten Werte bei den größten Inhalten vorkommen, beim $CaMg(CO_3)_2$ kommen sie bei den kleinsten Gehalten vor, dieses beweist, daß diese zwei Mineralien sich antagonistisch benehmen.

Die chemische Klassifikation der Proben

Bei der chemischen Klassifikation der Proben haben wir das Dreieck Wischneakow verwendet (zitiert nach Ruhin 1963), auf wessen Ecken wir folgendes dargestellt haben: $Ins + R_2O_3$, $CaCO_3$ und $CaMg(CO_3)_2$.

Aus dem Dreieck (Abb. 4), geht hervor, daß die meisten Proben sich in der 14-ten Zelle befinden, diese entspricht einem puren Kalkstein. Die übrigen Proben befinden sich in Zelle 11 (tonerdiger Kalkstein), 12 (tonerdiger schwach dolomitischer Kalkstein und 15 (Kalkstein schwach dolomitisch).

Die Verteilung in Horizonten der Hauptelemente

Um zuschauen die Verteilung in Horizonten der Elemente, bestimmt durch die chemischen Analysen, haben wir graphische Darstellungen gemacht, auf der Ordinate sind die Inhalte dargestellt, auf der Abszisse die Horizonte. In Abb. 5 in welchen wir die Verteilung von $CaCO_3$ und $CaMg(CO_3)_2$ dargestellt haben, kann man feststellen daß die kleinsten Inhalte von $CaCO_3$ in den obersten Horizonten vorkommen. Was die Art der Verteilung anbelangt, aus dem Abbildung geht eine antagonistische Verteilung hervor, daß heißt in den Horizonten in denen der Inhalt in $CaCO_3$ sinkt (Spitzen nach unten gerichtet), der Inhalt in $CaMg(CO_3)_2$ erhöht (Spitzen nach oben gerichtet). Diese antagonistische Verteilung zwischen Kalzit und Dolomit zeigt klar, daß diese zwei Mineralien sich in zwei verschiedene Etappen gebildet haben, obwohl sie derselben Phase angehören, daß heißt der karbonatischen Phase.

So wie wir auch anderen tertiären Kalksteinen aus dem Siebenbürgischen Becken beobachten haben, das Dolomit hat sich im dolomitischen Prozess gebildet als ein Erzeugnis der Metasomatose zwischen dem organischen Kalkstein und dem Meereswasser.

Es ist interesant, daß im Kalkstein aus Mokkatam (Egypten) ein oberster eozäner Kalkstein Essam El Hinawi und S.M. Loukina (1871) hat dasselbe dolomitisations Phenomän beobachtet.

Wenn man in derselben Art SiO_2, Al_2O_3 und Fe_2O_3 (Abb. 6) darstellt. kann man eine parallele. klare Verteilung zwischen SiO_2 und Al_2O_3 in allen Horizonten feststellen, und eine parallele Verteilung zwischen SiO_2 und Fe_2O_3, außer einem einziegen Horizont. Die parallele Verteilung zwischen Si, Al und Fe zeigt, daß sie im unlöslichen Residium in HCl enthalten sind, als Silikate, Oxyde oder Sulfide, und bilden die zweite wichtigste Phase des Kalksteines, daß heißt die sandige Phase. Das verschiedene Verhalten der karbonatischen und sandigen Phase erkennt man leicht, wenn die

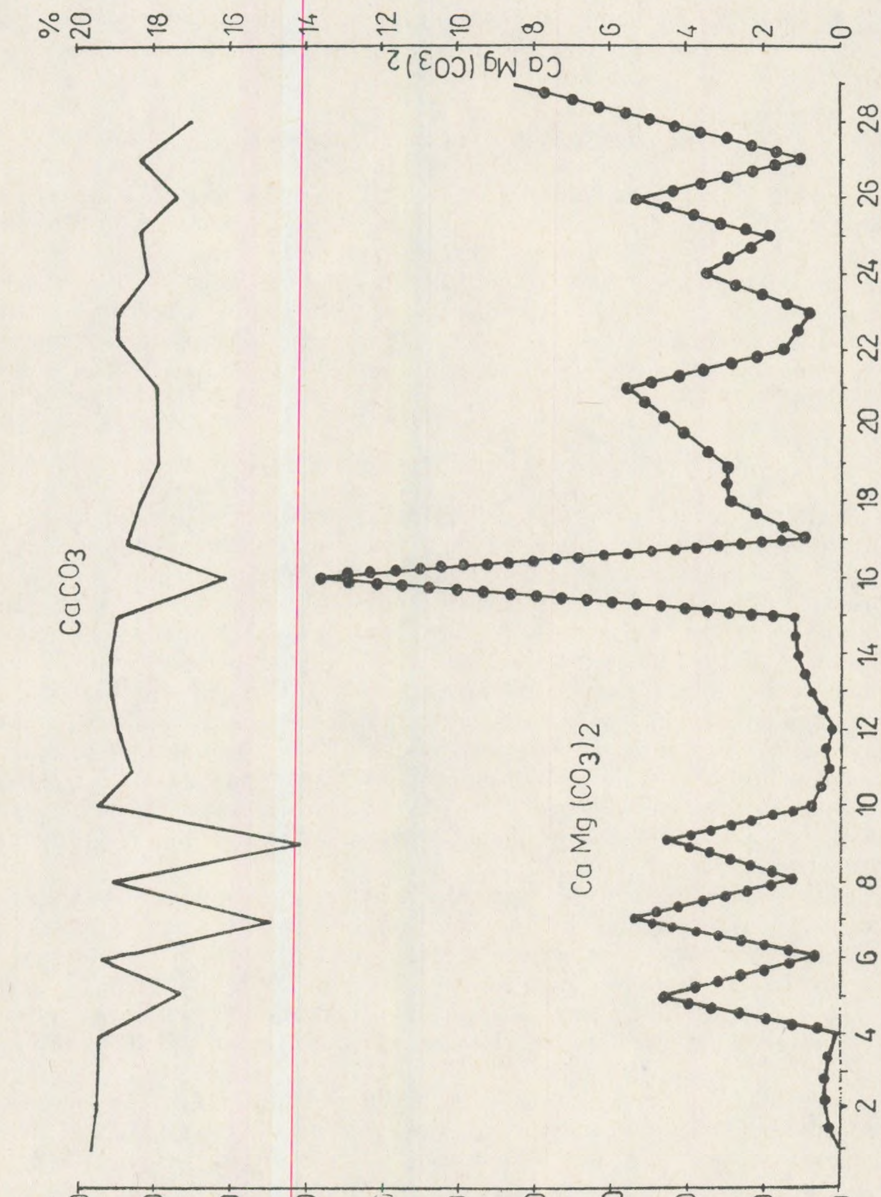

%
100
90
80
70
60
50
40
30
20
10
0
Ca CO3
CaCO3
Ca Mg (CO3)2
%
20
18
16
14
12
10
8
6
4
2
0
Ca Mg (CO3)2
2
4
6
8
10
12
14
16
18
20
22
24
26
28

Abb. 5.

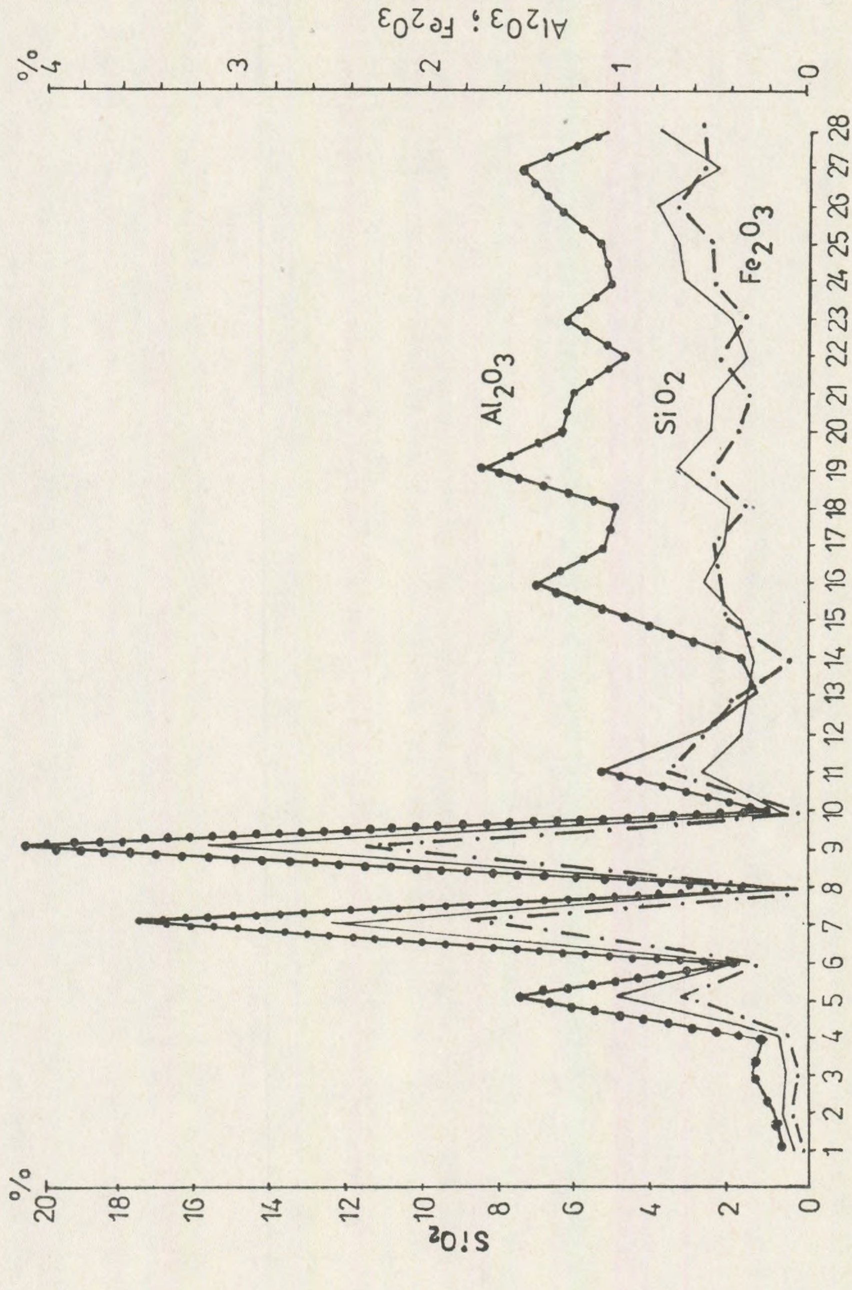

Al_2O_3; Fe_2O_3
%
0
1
2
3
4
SiO_2
%
0
2
4
6
8
10
12
14
16
18
20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
Al_2O_3
SiO_2
Fe_2O_3

Abb. 6.

Tabelle 2.

ppm

Nr.	Probe	Ba	Sr	W	Mn	Ga	Cr	Sn	Ni	Mo	V	Ti	Co	Be
1	1 Lt	4900	1600	—	70	—	—	—	—	10	35	120	—	3
2	2 Lt	5600	1000	—	120	—	—	—	—	10	32	50	3	3
3	3 Lt	5600	1500	—	80	—	—	—	—	10	30	40	3	3
4	4 Lt	5600	1400	—	70	—	—	—	—	—	26	30	—	—
5	5 Lt	5200	1000	—	150	10	—	—	28	10	32	310	—	—
6	6 Lt	5700	1200	—	100	10	30	—	25	10	29	40	—	3
7	7 Lt	5400	1000	—	30	—	30	—	28	5	45	940	—	3
8	8 Lt	5200	1700	100	50	—	—	—	20	5	29	30	—	—
9	9 Lt	4700	1000	—	180	26	700	30	66	10	56	1000	3	3
10	10 Lt	5200	1500	—	80	10	—	—	25	—	20	60	—	—
11	11 Lt	5700	1400	—	240	30	100	—	56	5	37	70	3	—
12	12 Lt	5600	1600	—	200	18	—	—	25	—	27	90	—	—
13	13 Lt	5600	1000	—	—	—	—	—	—	—	—	10	—	—
14	14 Lt	5900	1500	—	310	10	—	—	—	—	10	10	—	—
15	15 Lt	5500	4000	—	200	—	—	—	—	—	10	10	—	—
16	16 Lt	5000	1000	—	160	30	—	—	28	—	43	30	3	—
17	17 Lt	5600	900	—	600	15	—	—	25	—	27	20	—	—
18	18 Lt	5200	900	—	220	12	—	—	—	—	22	10	—	—
19	19 Lt	5600	900	—	310	10	—	—	—	—	24	10	—	—
20	20 Lt	5600	900	—	290	10	—	—	—	—	26	40	—	—
21	21 Lt	5400	900	—	230	23	—	—	20	—	27	50	—	—
22	22 Lt	5900	1000	—	360	18	—	—	25	—	23	30	—	—
23	23 Lt	5400	1000	—	380	17	—	—	10		27	20	—	—
24	24 Lt	5200	1500	—	70	32	100	—	30	—	29	70	3	—
25	25 Lt	5700	1600	—	60	15	—	—	10	—	22	40	—	—
26	26 Lt	5700	1200	—	130	18	—	—	—	—	22	40	—	—
27	27 Lt	5400	1400	—	—	10	—	—	—	—	—	10	—	—
28	28 Lt	5600	1300	—	130	24	—	—	10	—	26	50	—	—

Verteilungskurve des $CaCO_3$, welches das führende Mineral bzw das Element (Ca) der karbonatischen Phase ist, mit der Verteilungskurve des SiO_2, welches das führende Mineral, bzw das Element (Si) der sandigen Phase ist vergleichen.

II. Das spektrale Studium

In der Tabelle 2 stellen wir eine spektrale Analyse der Proben dar, gesammelt aus den Kalksteine von Letca. Die Gehalte sind in g/t ausgedrückt. Es wurden 13 Elemente bestimmt, unter welchen sich das Sr und Ba in größten Mengen befinden, zwei typische spuren Elemente und sehr wichtige im geochemischen Studium der Kalksteine. Die besondere Wichtigkeit dieser zwei Elemente, folgt nicht nur aus unserem Studium der tertiären Kalksteinen aus dem Siebenbürgischen Becken (1965, 1967, 1970, 1971, 1972), sondern auch aus denen M. FORNASERI und L. GRANDI (1963, 1968) die, die Kalksteine aus Italien studierten, welche karbonatische Formationen aus dem Trias bis Tertiär enthalten, dieses beweisst, daß das Sr und Ba zwei charakteristische Spurenelemente in allgemeinen und nicht nur für die tertiären Kalksteine sind.

Bei den anderen Kalksteinen, die wir von uns studiert haben in den meisten Proben die Gehalt des Sr überholt die des Ba. Der Kalkstein von Letca ist in dieser Beziehung eine Ausnahm, weil die Gehalt des Ba die des Sr überholt. In der Tabelle 3 stellen wir die Beziehung Sr/Ba dar, für die Proben von Letca und zum Vergleich für die aus Glod und Piatra, die sich nur 20 – 30 Km östlich befinden, und die wir vorher studiert haben (1980, 1981). Aus der Tabelle 3 folgt, daß bei Glod und Piatra nur in einigen Horizonten das Verhältnis Sr/Ba kleiner ist als 1, am übrigen ist er größer als 1,

Tabelle 3.

$\left(\text{Verhältnis } \frac{\text{Sr\%)}}{\text{Ba\%)}}\right)$

Proben	Letca	Glod	Piatra	Proben	Letca	Glod	Piatra
1	0,32	0,33	0,07	15	0,72	8,00	2,93
2	0,17	7,80	0,12	16	0,20	1,25	5,40
3	0,26	0,50	0,77	17	0,16	3,68	1,76
4	0,25	5,00	0,18	18	0,17	2,40	5,53
5	0,19	0,53	0,7	19	0,16	4,11	28,00
6	0,21	5,00	1,58	20	0,16	20,58	14,00
7	0,18	9,20	2,10	21	0,16	3,33	14,00
8	0,32	12,5	1,30	22	0,17	4,00	24,00
9	0,21	7,50	1,03	23	0,18	–	7,40
10	0,28	3,22	0,84	24	0,28	–	22,00
11	0,24	5,83	0,72	25	0,28	–	–
12	0,28	3,22	1,50	26	0,21	–	–
13	0,17	3,22	1,42	27	0,25	–	–
14	0,25	2,85	1,25	28	0,23	–	–

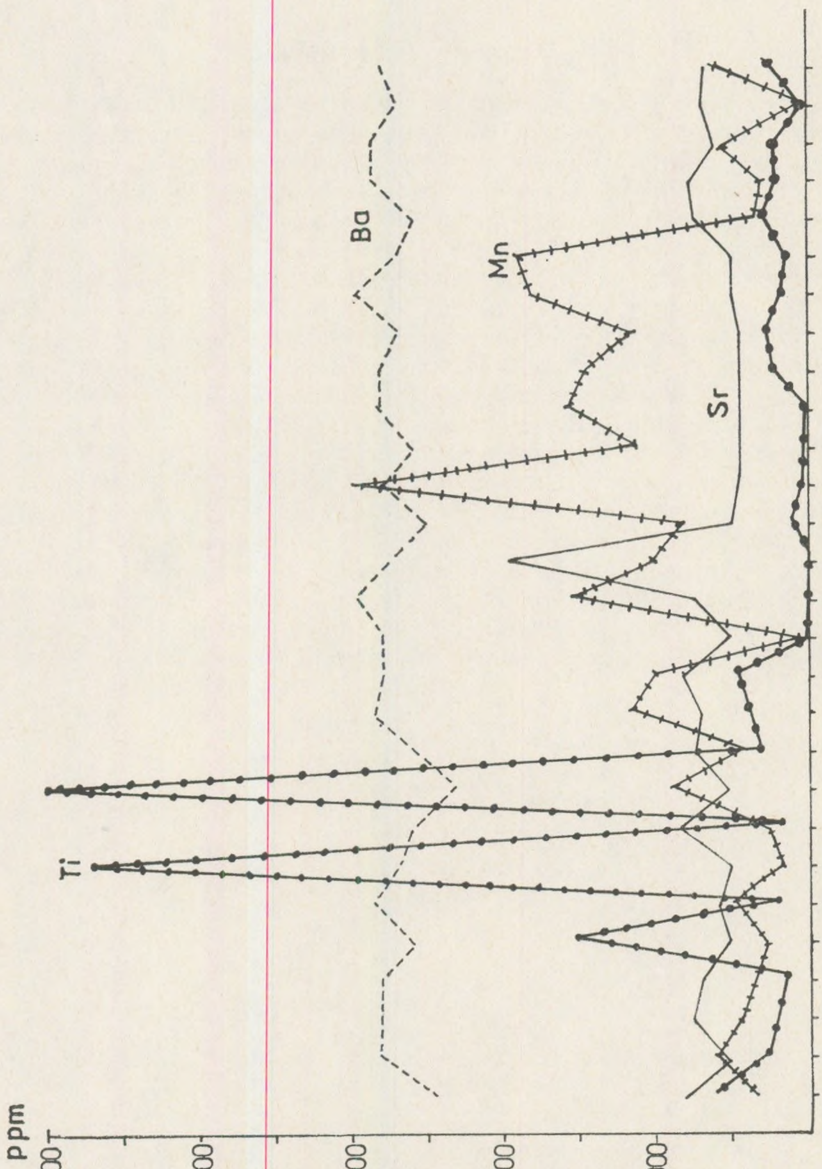

ppm
10.000
8000
6000
4000
2000
Sr — Ba — Mn×10 — Ti×10
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
Ti
Ba
Mn
Sr

Abb. 7.

manchmal sind es große Werte (24 – 28). Bei Letca alle Werte sind kleiner als 1. Die großen Werte in Ba ist eine Karakteristik für den Kalkstein von Letca und es ist der erste aus dem Siebenbürgischen Becken bei dem wir dieses Phenomän beobachtet haben.

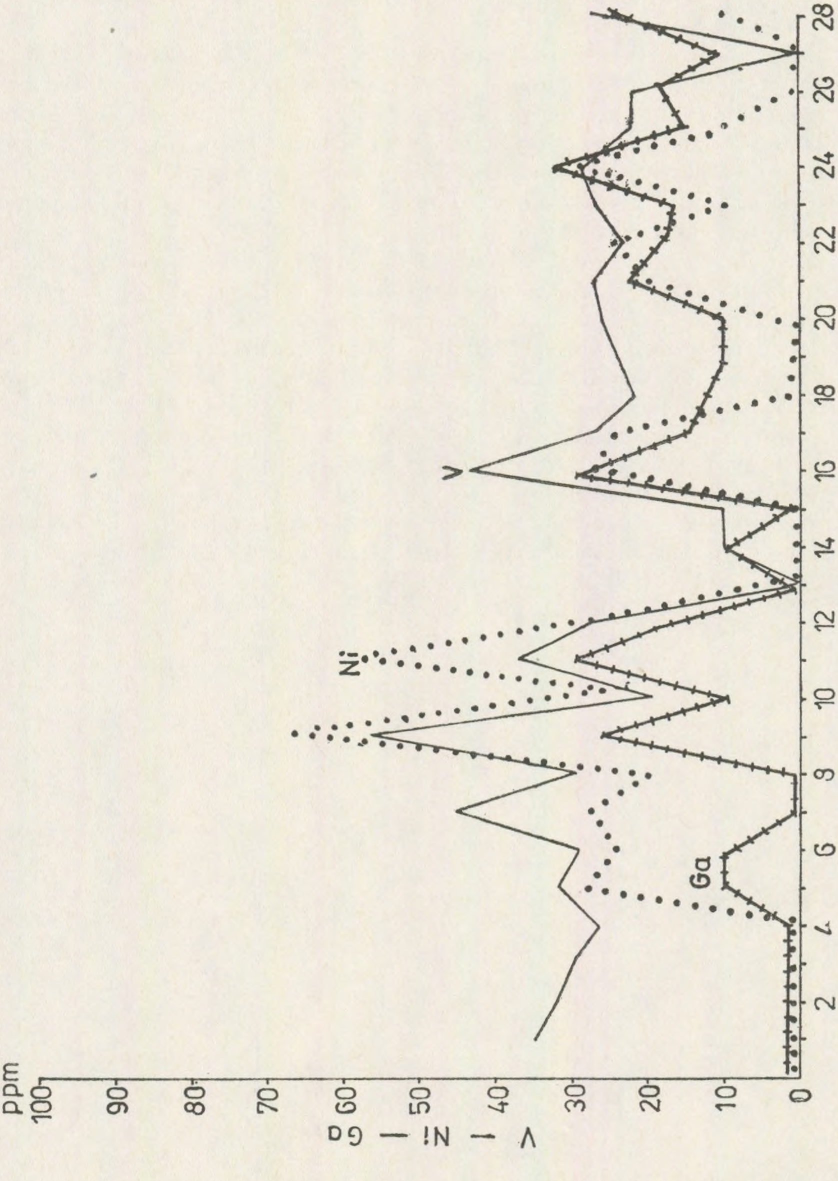


Abb. 8.

Die Verteilung in Horizonte der Spurenelemente

So wie im Falle der Hauptelemente haben wir graphische Darstellungen konstruirt, in denen wir die senkrechte Verteilung der Elemente, die wir mit spektralen Analysen bestimmt haben, dargestellt haben.

Nachdem wir die Tabelle 2 studiert haben, sind wir zu Schlußfolgerung gekommen, daß man in den Darstellungen nicht die Elemente darstellt die nur in den einigen Horizonten vorkommen. Solche Elemente sind: Co, Be, Sn, Mo, W. Um die Abbildungen nicht zu bedringen haben wir zwei Darstellungen gemacht, eine für Sr, Ba, Mn und Ti und eine für V, Ni und Ga.

Diese Darstellungen haben den Vorteil, daß sie uns sowohl die senkrechte quantitative Verteilung der Elemente zeigen als auch die Verteilung (parallele oder antagonistische) in Horizonten und daraus können Korrelationsschlußfolgerungen abziehen.

Aus Abb. 7 kann man feststellen, daß der Gehalt in Ba und Sr wenig sich wechselt, außer dem 15-ten Horizont, in welchem das Sr einen Maximum zeigt. Die Verteilung in Horizonten des Sr und Ba ist parallel in den obersten Horizonten (unterer Oligozän) und wechselt parallel und antagonistisch von einem Horizont zum anderen in den untersten Horizonten (oberer Eozän). Diese Verteilung zeigt eine positive Ba – Sr Korrelation in den obersten Horizonten und eine positive und negative Korrelation von Horizont zu Horizont in den untersten Horizonten.

Man kann eine parallele Verteilung, daß heißt eine positive Korrelation, zwischen Mn – Ba in fast allen Horizonten feststellen, das beweist, daß das Ba sich an der Oberfläche der MnO_2 – Gel fixierte, die sich aus den kolloidalen Lösungen gebildet haben (F. W. TSCHUKHROW 1955).

	Si	Fe	Al	Ca	Mg	K	Na	P
Si	1,00	0,98	0,95	–0,97	0,39	0,85	0,36	0,62
Fe	0,98	1,00	0,94	–0,95	0,35	0,84	0,39	0,65
Al	0,95	0,94	1,00	–0,97	0,47	0,80	0,35	0,51
Ca	–0,97	–0,95	–0,97	1,00	–0,56	–0,80	–0,37	–0,53
Mg	0,39	0,35	0,47	–0,56	1,00	0,23	0,24	0,05
K	0,85	0,84	0,80	–0,80	0,23	1,00	0,22	0,58
Na	0,36	0,39	0,35	–0,37	0,24	0,22	1,00	0,41
P	0,62	0,65	0,51	–0,53	0,05	0,58	0,41	1,00
Ba	–0,40	–0,39	–0,40	0,41	–0,39	–0,30	0,03	–0,32
Sr	–0,22	–0,21	–0,22	0,27	–0,26	–0,23	0,19	0,10
Mn	–0,07	–0,03	0,08	0,03	–0,03	0,00	–0,12	–0,19
Ga	0,25	0,31	0,34	–0,33	0,47	0,07	0,32	0,23
Cr	0,76	0,81	0,70	–0,68	0,14	0,69	0,39	0,74
Ni	0,59	0,64	0,53	–0,57	0,19	0,45	0,33	0,55
Mo	0,26	0,22	0,10	–0,16	–0,16	0,43	–0,24	–0,31
V	0,57	0,57	0,51	–0,58	0,39	0,60	–0,14	0,38
Ti	0,95	0,92	0,84	–0,89	0,26	0,85	0,22	0,59
Co	0,20	0,25	0,18	–0,20	0,25	0,32	0,19	0,38

Das Titanium hat eine antagonistische Verteilung im Vergleich zum Ba, aber vor allem im Vergleich zum Ca, dieses beweist daß das Ti nicht an der karbonatischen Phase gehört. Die parallele Verteilung mit Si und Fe zeigt eine positive Korrelation des Ti mit diesen Elementen und seine Angehörigkeit der unlöslichen Phase.

Aus Abb. 8 folgt eine perfekte parallele Verteilung zwischen Ni, V und Ga, was eine positive Korrelation zwischen diesen Elementen zeigt. Wenn wir diese drei Elemente (Ni, V, Ga) mit den führenden Elementen der karbonatischen Phase(Ca) oder der sandigen Phase (Si) korrelieren, kann man feststellen, daß zwischen Ca, Ni und V eine antagonistische Verteilung existiert, dieses zeigt eine negative Korrelation, was ausschließ die Angehörigkeit an die karbonatischen Phase. Die positive Korrelation, die die aus einer parallelen Verteilung folgt zwischen Ni, V, Ga und Si, Fe, Al, zeigt daß diese drei Elemente (Ni, V, Ga) sich in dem Residium das unlöslich in HCl ist befindet.

III. Das Studium der Korrelation der Elemente

Zur Korrelation der Elemente die durch die chemischen und spektralen Analysen bestimmt wurden, haben wir den empyrischen Koeffizienten der linearen Korrelation ,,r" verwendet. Die ,,r" Werte sind in der Matrix enthalten und dargestellt in der Tabelle 4. Aus den Daten des Matrix haben wir eine Dendrogramme zusammengestellt und in Abb. 9 dargestellt. Zur Herstellung der Dendrogramme haben wir die bekannte Methode, die in der Bibliographie als ,,Single Lineage" bekannt ist (J. C. DAVIS 1973), verwendet.

Tabelle 4.

Ba	Sr	Mn	Ga	Cr	Ni	Mo	V	Ti	Co
−0,40	−0,22	−0,07	0,25	0,70	0,59	0,26	0,57	0,95	0,20
−0,39	−0,21	−0,03	0,31	0,81	0,64	0,22	0,57	0,92	0,25
−0,40	−0,22	0,08	0,34	0,70	0,53	0,10	0,51	0,84	0,18
0,41	0,27	0,03	−0,33	−0,68	−0,57	−0,16	−0,58	−0,89	−0,20
−0,39	−0,26	−0,03	0,47	0,14	0,19	−0,16	0,39	0,26	0,25
−0,30	−0,23	0,00	0,07	0,69	0,47	0,43	0,60	0,85	0,32
0,03	0,19	−0,12	0,32	0,39	0,33	−0,24	−0,14	0,22	0,19
−0,32	0,10	−0,19	0,23	0,74	0,55	0,31	0,38	0,59	0,38
1,00	0,04	0,29	−0,16	−0,50	−0,42	−0,31	−0,49	−0,46	−0,28
0,04	1,00	−0,16	−0,27	−0,10	−0,11	−0,08	−0,31	−0,17	−0,08
0,29	−0,16	1,00	0,32	0,00	0,00	−0,34	0,05	−0,19	−0,11
−0,16	−0,27	0,32	1,00	0,37	0,54	−0,26	0,33	0,05	0,41
−0,50	−0,10	0,00	0,37	1,00	0,67	0,35	0,53	0,71	0,46
−0,42	−0,11	0,00	0,54	0,67	1,00	0,33	0,65	0,59	0,48
−0,31	−0,08	−0,34	−0,26	0,35	0,33	1,00	0,54	0,43	0,39
−0,49	−0,31	0,05	0,33	0,53	0,65	0,54	1,00	0,63	0,52
−0,40	−0,17	−0,19	0,05	0,71	0,59	0,43	0,63	1,00	0,20
−0,28	−0,08	−0,11	0,41	0,46	0,48	0,39	0,52	0,20	1,00

Aus der Dendrogramme geht hervor, daß man drei Hauptgruppen der Elemente festsetzen kann. In der ersten Gruppe sind folgende Elemente: Si, Fe, Al, Ti, K, P, Cr, Ni, V und Mo. In der zweiten Gruppe: Mg, Ga, Na und in der dritten: Ca, Ba, Mn, Sr.

Die erste Hauptgruppe kann man in Untergruppen auf Grund der „r“ Werte in Betracht zum Si einteilen. Man kann feststellen, daß die großen positiven Werte der Korrelation sind zwischen: Si – Fe (0,98), Si – Ti

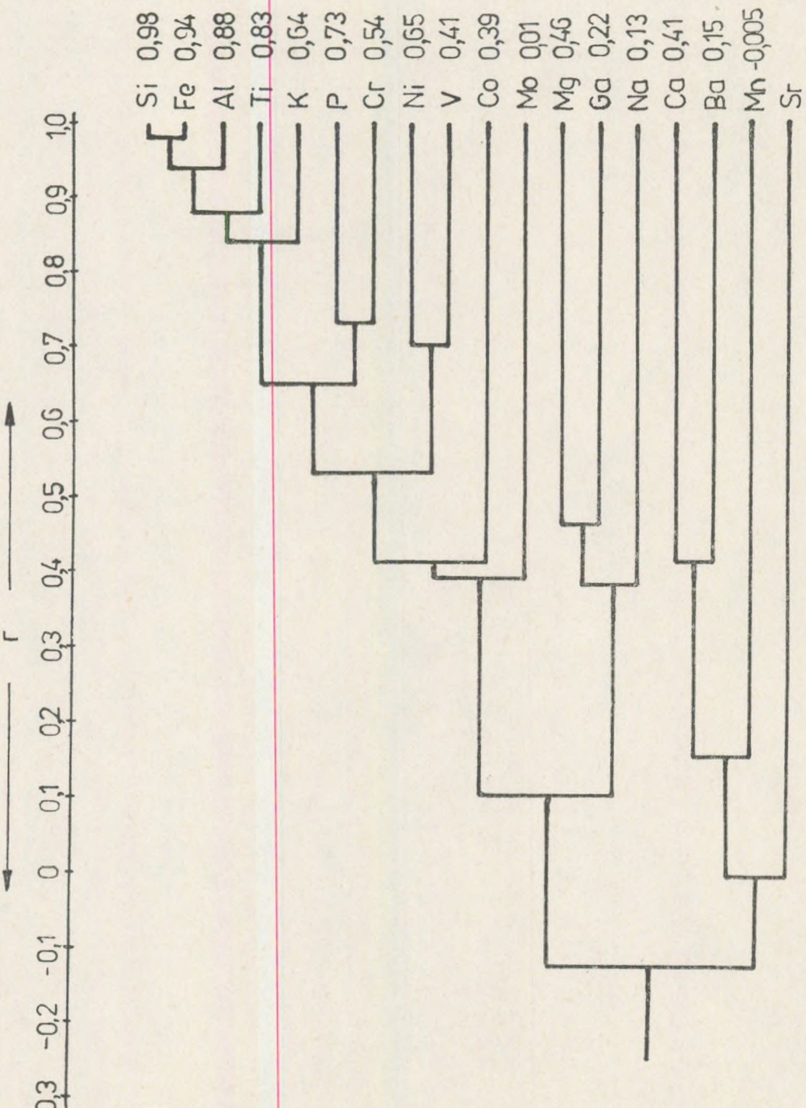


Abb. 9.

(0,95), Si – Al (0,95), das heiß daß diese Elemente sich zusammen in der sandigen Phase der Kalksteine befinden. Dieselbe Schlußfolgerung zieht man auch aus Abb. 6 und 7, wo man stellt fest eine parallele Verteilung in Horizonten der Elemente.

In der folgenden Untergruppe befinden sich zwei Elemente, Cr und K, deren „r" Werte etwas kleiner sind: Si – Cr (0,70), Fe – Cr (0,81), Al – Cr (0,70), bzw Si – K (0,85), Fe – K (0,84), Al – K (0,80). Dieses zeigt, daß sowohl das Cr als auch die K sich in der sandigen Phase befinden. Die feste Verbindung zwischen K und Si, Fe, Al zeigt die Anwesenheit der K in den Alumosilikaten. Die großen negativen Werte der Korrelation Ca – K (– 0,80), sowie auch Ca – Cr (– 0,68) zeigt, daß diese zwei Elemente (K, Cr) nicht der karbonatischen Phase angehören, deren Leitelement Ca ist.

In der letzten Untergruppe befinden sich die Elemente deren Verbindungen mit dem Si schwächer sind. Die "r" Werte schwanken zwischen 0,62 (Si – P) und 0,20 (Si – Co).

Auch im Falle dieser Elemente (P, Ga, Ni, Mo, V, Co) die Korrelation mit dem Ca ist negativ.

Auf Grund der Dendrogramme kann man die erste Hauptgruppe wie folgt einteilen: a) Si, Fe, Al, Ti, K; b) P, Cr; c) Ni, V; d) Mo, Co. Diese vier Untergruppen der Elemente reflektieren eine Korrelation der Elemente aus dem magmatischen Zyklus, dieses zeigt eine magmatische Genesis des terigenen Materiales, welche die sandige Phase des Kalksteines aus Letca bildet.

Die zweite Hauptgruppe hat drei Elemente deren „r" Werte zwischen 0,23 (Mg – NA) und 0,47 (Mg – Ga) sich befinden. Was die Anwesenheit dieser Elemente betrifft, kann man eine positive Korrelation des Mg, Ga und Na mit den leitenden Elemente der sandigen Phase feststellen: Si, Al, Fe – Na (0,35 – 0,39); Si, Al, Fe – Ga (0,24 – 0,34) und Si, Al, Fe – Mg (0,35 – 0,47). Die Korrelation mit dem Ca ist negativ bei allen drei Elementen (– 0,56, – 0,35, – 0,33), Von da folgt, daß die Elemente aus der zweiten Hauptgruppe der sandigen Phase angehören.

Die dritte Hauptgruppe enthält die Elemente die an der karbonatischen Phase gebunden sind: Ca, Ba, Mn und Sr. Die positiven Werte der Korrelation mit Beziehung zum Ca, 0,41 (Ba), 0,27 (Sr), bzw negativ zum Si, – 0.40 (Ba), – 0.22 (Sr) zeigt, daß diese zwei Elemente der karbonatischen Phase angehören. Das Mn hat eine unbestimmte Stellung, weil sowohl die negative als auch die positive Korrelationswerte nahe an Null haben. Dieses zeigt die Possibilität, daß das Mn sowohl der karbonatischen als auch der sandigen Phase angehört.

Das Studium der Korrelation der Elemente hat bezeugt was wir auch an anderen tertiären Kalksteinen festgestellt haben, nämlich daß die Leitelemente des unlöslichen Residiums Si, Al, Fe sind und der karbonatischen Phase Ca als Hauptelement und Sr und Ba als Spurelemente sind.

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MINERALOGY, PETROLOGY AND GEOCHEMISTRY OF ULTRAMAFIC NODULES IN LAMPROPHYR DIKES OF ALCSÚTDOBOZ – 2 BOREHOLE (BAKONYICUM, HUNGARY): THEIR ORIGIN AND GENETIC IMPLICATIONS

by

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(Abstract of doctoral thesis accepted by Eötvös University, Budapest)

Twelve magmatic bodies in Alcsútdoboz – 2 borehole (SW Budapest) are dikes and belong to the Middle(?) to Upper Cretaceous lamprophyr-carbonatite association known in NE Transdanubia. These dikes are monchiquite ones according to their mineralogical and chemical composition and texture. The main components (olivine, augite – Ti-augite, Ti-phlogopite) have been crystallized in greater depths, thus a partially crystallized melt has been injected into a Seisian – Lower Campilian sedimentary sequence.

The monchiquite contains nodules of extremely variable mineralogical composition. These are most frequent in two dikes and can be classified into five groups petrographically:

- Megacrysts (clinopyroxene, olivine, plagioclase, opaque minerals, apatite, quartz)
- Ultramafic xenoliths (containing olivine, clinopyroxene, orthopyroxene, spinel)
- Alkaline magmatite nodules (containing potash feldspar, plagioclase, clinopyroxene, quartz, apatite, mica, opaque minerals)
- quartzite xenoliths (from the sedimentary host rock)
- calcitic anhydrite (from the sedimentary host rock)

The ultramafic xenoliths were ranged into the following three genetic groups after the geochemistry of their components:

1. High temperature (1265 – 1370 °C), high pressure (50 – 60 kbar) lherzolite xenoliths originated from very great depths (150 – 180 km), containing primary phlogopite of mantle origin. Their texture indicates a complex metamorphic history.
2. Somewhat lower temperature (ca. 1000 °C) and lower pressure (50 kbar) xenoliths originated from 50 – 80 km depth. These are mostly of porphyroclastic texture and possibly originated from alkaline basaltic magma. Simultaneous occurrence of these two kinds of xenoliths indicate magma mixing. This is also supported by a partial metasomatism (phlogopitisation) of xenoliths of the alkaline basaltic melt.

3. MARID-type xenoliths displaying magmatic texture. These have been originated from hybride magma after mixing. This is the probable origin of the high pressure olivine and clinopyroxene megacrysts, too.

The alkaline magmatite nodules, plagioclase, apatite, green clinopyroxene and Ti-magnetite megacrysts and the green clinopyroxenite came to the ascending melt from an alkaline granite – alkaline syenite body situated in the crust. The alkaline magmatite probably has genetic connections with the lamprophyre.

Discrimination factors determined from the composition of the lamprophyre and its clinopyroxene, and chemical composition of lherzolite nodule components (Al_2O_3-depleted clino- and orthopyroxene, chromitic spinel) indicate that the magmatism has been connected to intraplate deep faults. Further geological studies are needed to interpret the relations of this Middle(?) to Upper Cretaceous magmatism and the Late Mesozoic history of the Bakonyicum (Transdanubian Midmountains). Similar dikes are known in the Western Carpathians (Banská Bystrica and Malé Karpaty) and in the Alps; their age are Middle Cretaceous, Upper Cretaceous and Upper Oligocene.

Further studies of the lamprophyres in the NE sector of Bakonyicum are justified by the well-known REE, Th and Nb anomalies probably connected to this magmatic association.

MINERALOGY AND PETROGRAPHY OF PYROCLASTICS IN EOCENE/OLIGOCENE BOUNDARY PROFILES (HUNGARY)

by

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ABSTRACT

Micromineralogical examinations of pyroclastic layers in Eocene/Oligocene boundary profiles in and around Budapest proved the presence of volcanogenic components (feldspar, euhedral quartz, fragments of volcanic rocks, unweathered biotite, hornblende, ilmenite), terrigenous components (garnet, apatite, zircon, rutile, partly rounded quartz or quartzite, weathered biotite) and diagenetic pyrite, epigenetic limonite, calcite and gypsum. Most samples were crystalloclastic andesite and/or dacite tuff. Tuffitic layers of the borehole profiles are not suitable for stratigraphical correlation, however, significant relationships were shown among mineral compositions of pyroclastic layers within each borehole. Consequently, the volcanogenic components most probably were derived from small volcanic centres with weak, repeated eruptions. This volcanism might belong to the last effects of the tonalite magmatism.

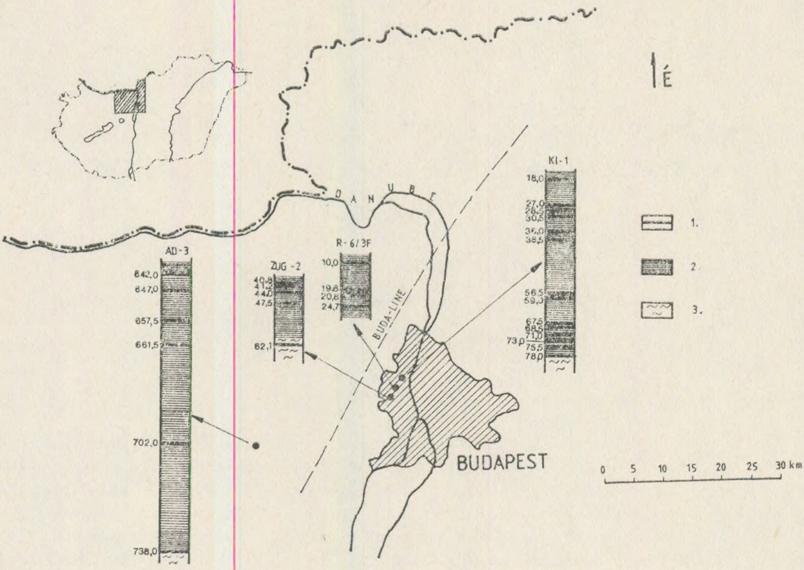
Introduction

Our pyroclastics investigations in Eocene/Oligocene boundary profiles were suggested by Prof. T. Báldi and were carried out with generous support from Prof. I. Kubovics. This paper contains results of the investigation of volcanogenic layers from Kiscell – 1 (Kl – 1), Alcsútdoboz – 3 (AD – 3), Zugliget – 2 (Zug – 2) and Rózsadomb – 6/3F (R6/3F) boreholes (Fig. 1), presented at the meeting of IGCP project 174: Terminal Eocene Events at Visegrád in 1983.

Similar layers has been inadequately indicated up to now, consequently our data could serve as a basis for further research. Stratigraphical, palaeontological and palaeogeographical conclusions derived from these profiles have been summarized by Báldi (1984). The reader is referred to his paper.

Methods

The volcanogenic material is strongly weathered. 100 to 200 gram samples were soaked in water. The grain size fraction between 0.125 – 0.250 mm was yielded by wet sieving. Heavy liquids were used to obtain the heavy minerals from this fraction (0.6 – 27.5%). which were examined by binocular and polarizing microscopes.



The samples

The volcanogenic layers were 2 to 12 cm thick. Columnar, white, argillitized, calcitized or fresh, lustrous feldspars, biotite flakes, columnar, black amphiboles, quartz grains of greasy lustre and angular, limonitic, or gray, weathered rock fragments could be observed in some layers by the naked eye. The groundmass consists of dark grey clay minerals, associated by limonitic and/or carbonate material in near-surface layers. The tuff layers are not bedded, except in some biotite-rich samples (e.g. Kl – 1 borehole: 78.0 m; AD – 3 borehole: 738.0 m). All layers are friable and can be crumbled by the fingers.

Mineralogy and petrography of the tuffite layers

Results of the micromineralogical investigations are shown in tables 1, 2 3, and 4. Characteristics of more frequent and genetically important components are summarized below.

Pyrite. Euhedral (hexahedral or "pyritohedral"). fragmented or agglomerated. Appears in foraminifer (Globigerina) tests in boreholes Zug – 2 and R6/3F.

Ilmenite (+magnetite). Euhedral or fragmented, fresh angular grains, frequently cut by calcite-filled veins. Euhedral magnetite could be identified in sample 38.5 m of borehole Kiscell – 1 only.

Biotite. Two varieties have been found. Frequent is a thin, reddish-brown, translucent type forming fragmented plates, found in all samples except borehole Kl – 1, 78.0 m sample. Rare is a black, lustrous, fresh type forming slightly fragmented flakes or short pseudo-hexagonal columns. Carbonate apophyses may be observed along cleavages of the latter. It forms a considerable part of 78.0 m sample of borehole Kl – 1. Also this type is characteristic for all volcanogenic layers of AD – 3 borehole and plays a dominant role in 738.0 m layer of AD – 3 and 24.7 m layer of R6/3F boreholes. Chloritisation of both types were proven by X-ray diffraction method by L. Bognár.

Amphibole. Mostly columnar, black or dark greyish green angular grains surrounded by cleavage planes; rarely fragmented. Optical properties indicate hornblende. Most of the grains are calcitized in the margins and along cleavage planes in AD – 3 borehole. R6/3F and Zug – 2 boreholes contained no fresh amphiboles. Kl – 1 borehole contained this mineral in 18.0 m and 36.0 m layers. However. it can be easily recognized in larger grain size fractions. mostly as pyritized grains.

Garnet. Reddish brown to pink, lustrous, fragmented, angular grains. Dominate in 73.0 m layer of KL – 1 borehole. Larger grains in Zug – 2 borehole often contain opaque (ilmenite) inclusions.

Feldspar. Columnar or elongated grains mostly surrounded by cleavage planes. Fresh sections display nacreous lustre. Most are plagioclases of basic oligoclase – labradorite composition. showing twin lamellae and zoning. AD – 3 borehole contains only such grains. In three layers of Kl – 3 borehole contains only such grains. In three layers of Kl – 1 borehole (30.5 m; 38.5 m; 68.5 m) a small part of feldspars is different: these are potassium feldspars (sanidines) in accordance with X-ray diffraction results of L. Bognár. Feldspars in other volcanogenic layers of Kl – 1, R6/3F and Zug – 2 boreholes couldn't be determined by the applied method, due to their strong argillitization.

Quartz. Uncoloured, fragmented, angular grains. In 67.5 m layer of Kl – 1 borehole euhedral, hexagonal, bipyramidal quartz grains are present. All pyroclastic layers contain a small quantity of grey, slightly rounded quartzite grains coated by limonite.

Rock fragments. Irregular, angular, wholly altered, grey or limonite-coated, red grains. White, wholly argillitized feldspar grains were recognized in larger grain size fractions. Amphiboles altered mostly to calcite in AD – 3 borehole and mostly to pyrite in the other three boreholes have been observed. These grains are considered as andesite (dacite) fragments.

Conclusions and discussion

Felspars, volcanic rock fragments, fresh pseudo-hexagonal biotites, biotites, amphiboles, ilmenites, part of the quartz grains and all euhedral quartz grains in the 67.5 m sample of Kl – 1 borehole are considered as volcanogenic components.

All samples – except 73.0 m in Kl – 1 borehole and 44.0 m and 47.5 m in Zug – 2 borehole – are considered as crystalloclastic pyroclastics. Their mineral composition indicate andesite and/or dacite tuff, except the

Volume percentage of heavy and light minerals of the
(Kl – 1

Component / Depth (m)	Heavy minerals							
	Pyrite	Ilmenite + magnetite	Biotite	Garnet	Apatite	Zircon	Limonite	Rutile
18.0	95	2	–	1	–	–	–	–
27,0	90	6	2	1	–	–	–	–
28,5	87	7	3	1	1	–	–	1
30,5	88	9	2	1	1	–	–	–
36,0	73	16	4	2	2	1	1	–
38,5	88	5	4	1	–	–	2	–
56.5	47	51	–	–	–	1	–	1
59.0	20	64	13	–	3	–	–	–
67.5	9	89	–	–	1	1	–	–
68.5	13	22	61	2	1	1	–	–
71.0	47	51	–	–	2	–	–	–
73.0	3	6	3	87	1	–	–	–
75.5	59	4	34	2	1	–	–	–
78.0	–	–	97	1	–	–	2	–

Volume percentage of heavy and light minerals of the
(AD – 3

Component / Depth (m)	Heavy minerals						
	Pyrite	Biotite	Ilmenite + magnetite	Hornblende	Apatite	Limonite	Garnet
642.0	16	13	32	35	1	2	1
647.0	38	7	35	1	5	10	3
657.5	8	27	14	45	2	2	1
661.5	22	33	30	18	2	2	1
702.0	30	31	35	–	1	2	–
738.0	4	87	–	–	1	3	2

67.5 m sample of Kl – 1 borehole, which can be considered as rhyolite tuff of acidic magmatic origin (high percentage of euhedral, high-temperature quartz). Pyroclastic rocks of similar composition in Hungary are mentioned by Juhász (1971), Jámbor et al. (1972, 1981), Kubovics (1977), Szepesházy (1977), Báldi (1982, 1983) and Balázs et al (1980).

Redeposition of volcanogenic components is not probable in most samples, proven by grain shapes (angular volcanic fragments, euhedral quartz, tabular feldspars, columnar amphiboles) and especially by pseudo-

Table 1

volcanogenic beds (0.125 – 0.25 mm fraction)
borehole)

			Light minerals				0.125 – 0.25 mm fraction (wt%)	Heavy minerals in the 0.125 – 0.25 mm fractions (wt%)
Hornblende	Tourmaline	Epidote	Feldspar	Quartz	Calcite	Lithoclast		
1	1	–	37	6	–	57	1.55	14,83
–	–	1	39	9	–	52	4.48	9.02
–	–	–	43	16	24	17	4.51	4.18
–	–	–	48	5	41	6	3.61	15.66
1	–	–	33	5	–	62	2.29	5.00
–	–	–	54	3	11	32	4.27	7.85
–	–	–	34	8	–	58	5.91	12.05
–	–	–	31	17	–	52	2.26	26.68
–	–	–	13	87	–	–	2.12	26.45
–	–	–	21	9	57	13	4.56	15.99
–	–	–	57	15	–	28	8.35	2.74
–	–	–	–	71	–	29	4.90	6.05
–	–	–	51	13	–	36	6.36	3.52
–	–	–	–	26	74	–	14.90	15.11

Table 2.

volcanogenic beds (0.125 – 0.25 mm fraction)
borehole)

			Light minerals				0.125 – 0.25 mm fraction (wt%)	Heavy minerals in the 0.125 – 0.25 mm fractions (wt%)
Rutile	Zircon	Tourmaline	Plagioclase	Quartz (Quartzite)	Calcite	Lithoclast		
–	–	–	77	5	11	7	30.51	0.72
1	–	–	85	9	3	3	16.20	1.21
1	–	–	78	6	10	6	35.28	0.68
1	1	–	32	59	7	2	5.50	0.60
–	1	–	21	61	3	14	26.40	1.00
1	1	1	7	81	12	–	16.20	1.24

hexagonal. short columns of biotite, which would disaggregate to small flakes even by insignificant reworking. In some layers, where feldspars are wholly altered and garnets and/or apatites are significantly concentrated (Zug – 2 borehole: 40.8 m; 48.2 m; 62.1 m; R6/3F borehole: 10.0 m; 13.6 m; 20.8 m) slight redeposition of volcanogenic material may be supposed within the basin. Usually it is not followed by relative concentration of biotite; the observation of Dubay (1962) on Oligocene tuffs in the North Zala basin, concerning relative concentration of biotite as indicator of tuff

Table 3.

Volume percentage of heavy and light minerals of the volcanogenic beds (0.125 – 0.25 mm fraction)
(Zug – 2 borehole)

Component / Depth (m)	Heavy minerals								Light minerals				0.125 – 0.25 mm fraction (wt%)	Heavy minerals in the 0.125 – 0.25 mm fraction (wt%)
	Pyrite	Biotite	Ilmenite	Garnet	Apatite	Limonite	Zircon	Tourmaline	Feldspar	Quartz, Quartzit	Calcite	Lithoclast		
40.8	54	2	25	–	7	10	1	1	3	12	19	31	3.14	2.44
41.2	31	43	14	2	6	3	1	–	16	13	28	43	3.43	4.20
44.0	3	31	16	39	10	–	1	–	–	29	27	44	7.46	15.80
47.5	7	55	8	16	10	3	1	–	–	26	41	33	5.08	7.20
62.1	20	66	11	–	2	1	–	–	8	13	51	28	4.40	12.10

Table 4.

Volume percentage of heavy and light minerals of the volcanogenic beds (0.125 – 0.25 mm fraction)
(R6/3F borehole)

Component / Depth (m)	Heavy minerals									Light minerals				0.125 – 0.25 mm fraction (wt%)	Heavy minerals in the 0.125 – 0.25 mm fraction (wt%)
	Pyrite	Biotite	Ilmenite	Limonite	Apatite	Garnet	Zircon	Rutile	Tourmaline	Feldspar	Quartz	Gypsum	Lithoclast		
10.0	16	4	47	33	–	–	–	–	–	8	7	14	71	3.1	14.10
19.6	72	2	17	–	4	4	–	1	–	39	9	–	52	3.6	22.46
20.8	36	44	14	–	4	1	1	–	–	14	18	–	68	3.6	27.50
24.7	47	31	18	2	–	–	1	–	1	38	13	–	59	7.7	8.00

redeposition cannot be applied to our samples. Garnets, apatites, rutiles, tourmalines and fragmented or rounded quartz (quartzite) – being resistant minerals – are considered as terrigenous components.

Consequently, those samples (Kl – 1 borehole: 73.0 m; Zug – 2 borehole: 44.0 m and 47.5 m) enriched in garnets but lacking feldspars were not considered as pyroclastics. However, garnets, apatites and zircons may be volcanogenic components, see for example the not so rare garnets in magmatites of the Alpine tonalite belt. This is mentioned by Gatto et al. (1975) in the Alps and by Kiss (1954), Harrach (1980) and Dunkl (1983) in Hungary. We may put the question if it is a right method to derive all garnets as terrigenous components from metamorphic source rocks. This problem may be approached by micromineralogical investigations of Tard Clay and by detailed mineralogical and geochemical examination of garnets.

All of our samples contain pyrite. Báldi (1983) indicated that the laminitic pelite of Tard Clay containing tuffite intercalations contains 2 to 7% pyrite due to the anoxic depositional environment. So we consider the pyrite in the tuffs and the pyrite in Tard Clay both as of diagenetic origin. We could observe that pyrite is the dominant component among heavy minerals of tuff layers in the upper member of Tard Clay (Kl – 1 borehole: 18.0 m; 27.0 m; 28.5 m; 30.5 m; 36.0 m; 38.5 m), while it is dominant in only one layer (73.5 m) of the lower member. This sharp contrast may be due to physico-chemical causes affecting the sediments during deposition and diagenesis.

Limonite, calcite and gypsum are epigenetic components of the pyroclastics. Limonite is an oxydation product of pyrite, while calcite originates partly from feldspars and amphiboles.

Grain size of tuffs does not exceed 2 cm. Báldi (1983) concluded that the volcanic material originated from a "not very near" eruption centre. We complete this statement: the pyroclastics were derived from repeated explosive eruptions of low intensity volcanic centres. No correlation is possible among the borehole profiles based on pyroclastic layers due to considerable differences in composition and quantity of volcanogenic components. However, some pyroclastic layers within each borehole display close relationships by mineralogical composition. Several papers indicate that the Lower Oligocene tuffs are products of the tonalite belt volcanism in Hungary (Szepesházy, 1977; Báldi, 1982, 1983; Balázs et al., 1980). Only Jámbor et al. (1982) consider Recsk as a separate volcanic centre of this belt.

Their statement is correct in the present tectonic situation, as proven Early Oligocene (Late Kiscellian) magmatites have been found in the Balatonfenyves borehole (Balogh et al., 1983) only in the Hungarian part of the tonalite belt. The latter was considered as tonalite (quartz-diorite) by Buda (1975).

We can raise the question that what tectonic process caused the pyroclastic volcanism of the tonalite belt in Hungary. Báldi (1982) says, that the southward subduction of the Penninic zone lasted until Early Kiscellian. Termination of this process as indicated by the decreasing then missing tuff intercalations in the Upper Beds of Tard Clay. According to his concept these pyroclastics are the last products of an attenuating magmatism. The volcanogenic material is derived from several small centres by repeated explosions and rarely suffered insignificant redeposition within the basin.

The Bakony unit reached its present position by 450 – 500 km transcurrent faulting during the Middle Eocene – Late Oligocene interval, according to the palaeogeographic reconstruction of Kázmér (1984). This process might be associated with significant magmatism. The decreasing, then missing tuff intercalations in the Kiscell Clay indeicate the termination of the transcurrent faulting. This opinion also considers the pyroclastics of the Tard Clay as products of an attenuating magmatism.

The problematic questions might be answered by geochemical investigations of the magmatites of the tonalite belt in Hungary and by comparisons with Alpine analogues.

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GEOHISTORY AND MINERAL RESOURCES OF HUNGARY

by

Á. JUHÁSZ

(Abstract of doctoral thesis accepted by Eötvös University, Budapest)

This book* summarizes the geohistory and mineral resources of Hungary mainly on the basis of geological explorations executed in the 70s and partly at the beginning of the 80s. In the first main chapter I intended to give an equally exhaustive survey both of metamorphic and magmatic and of sedimentary formations. At the time of publication of the book of Elemér Vadász: "Geology of Hungary" (1960) the deep of the plains was not yet explored by means of deep drillings to such an extent, that the genetics and structural relations of the crystalline base of basin could have been properly assessed. The chapters dealing with the metamorphic and igneous rocks of the Great Hungarian Plain, the Danube – Tisza interfluve included are based mainly on my own ten years of researches. The assessment of the base of basin of the Great Hungarian Plain was possible mainly on the basis of comparison with the Transylvanian central range of mountains. The majority of the crystalline base of basin of the *Tiszántúl* (Hungarian territory east of the river Tisza) is reminding us of the especially metamorphic types of rocks of the Bihar-autochtonous and of the Kodru-overlying systems. In the base of basin of South-Tiszántúl such rock masses are occuring, which can be identified with the more slightly metamorphosed slate series of the Transylvanian central range of mountains and with the Kodru granite also. On the other hand the crystalline rocks of the deeps of the Danube-Tisza interfluve are related first of all to the larger crystalline slate milieu of the Mecsek-mountains' granite. In spite of the uncertainties of the absolute dating it may be stated, that the primary age of the sedimentary and igneous rocks to be found in the base of basin of the Great Hungarian Plain is mostly Proterozoic and the metamorphosis of the most intensively metamorphic series can be related to the Assyntian orogenesis and that of the more slightly metamorphosed rock to the Variscan one. The Variscan orogenesis led in the old metamorphic series to retrograde metamorphosis.

The granite masses of the Mecsek-mountain (and as analogy the Danube – Tisza interfluve) are the results of the Variscan orogenesis also.

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* Published by Gondolat Kiadó, Budapest, 1983 (in Hungarian).

Also the assessment of the West-Transdanubian crystalline mountains has been partly changed; the Sopron Mountains can be regarded henceforward as part of the Lower Eastern Alpine overlying system, however, according to the recent researches, the Kőszeg Mountains is built from metamorphic series of mezozoic sedimentary and igneous rocks and belongs to the Pennine overlying system. The base of basin of the plain in Northwestern Hungary (Kisalföld) originated predominantly from the slightly Variscan metamorphism of Paleozoic sedimentary rocks. The anchi- and epimetamorphic rocks of the Kisalföld (and of the environs of the Lake Balaton) are along the structural line of Zagreb – Kaposvár – Dunaújváros – Miskolc contiguous with the more considerably metamorphosed and generally older crystalline rocks of the Mecsek Mountains – Great Hungarian Plain. In the context of the structural connections of the younger formations in Hungary, it should be noted, that owing to the fact, that since the publication of Elemér Vadász's book, the "Geology of Hungary" the theory of plate tectonics spread all over the world. I tried to systematize the geohistory of Hungary on the basis of the new global theory. This main chapter is resting first of all on the critical treatment of the Hungarian publications following the plate-tectonical way of looking; in this chapter my own researches are limited to the submarine basaltic volcanites, and of flyschlike sediments of the base of basin of the Great Hungarian Plian.

Concerning the submarine basaltic volcanism of the base of basin of the Great Hungarian Plain, the deep drillings effected up to the present did not permit the demonstration of a possible tholeiitic character. This is due to the fact, that the drillings serving the search for hydrocarbons penetrated only in the upper, disintegrated zone of volcanites and therefore it was not possible to examine the possibly deeper dyke- or peridotite-series. The occasional relation of volcanites to radiolarites and in some places the development of mélange-character are indicating to deeper marine conditions of formation.

The flysch-sediments covering the base of basin of the Great Hungarian Plain are similarly postulating a deeper aquatic accumulation, or at least an accumulation on the continental slope.

In the third main chapter dealing with the mineral resources I intended to give for the related sciences (geophysics, geography) a genetical systematization of the mineral resources of Hungary and at the same time to give a realistic information for the public about the knowledges of national economical relevance. In this chapter specially are stressed the actual problems, e.g. the Eocene-, or the Lias-programmes.

The fourth main chapter of my book is a regional geological survey of the regions of Hungary; on the basis of concrete explorations this survey is making possible the identification of the main geohistorical events. Therefore my book can be used as geological guide by geography teachers, or by students also, who are feeling a vocation for geology.

TECTONIC UNITS OF HUNGARY: THEIR BOUNDARIES AND STRATIGRAPHY (A BIBLIOGRAPHIC GUIDE)

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ABSTRACT

This review paper presents a brief description of pre-Neogene tectonic units of Hungary. Their boundaries are defined, stratigraphic columns are described and possible palaeogeographic relationships are outlined. Bibliographic references for descriptive papers (stratigraphy, palaeontology, sedimentology, petrology, geochemistry, metamorphic grade, radiometric ages, etc) are included. Data for igneous activity, metamorphism, deformation, tectonic position and economic geology are supplied. Neogene and Quaternary basin evolution and volcanism are discussed. Appendices list books on the geology of Hungary, review papers of each periods, available maps and periodicals publishing geological information.

Introduction

This paper presents a brief review of fundamental geological information on Hungary. The style is concise, similar to that used by PALFREYMAN (1984) in his treatise on Australia.

First, boundaries of tectonic units are defined. Then each unit is shortly characterized, followed by a more detailed treatment (rocks, fossil content, depositional environment, magmatism, metamorphic grade, radiometric age. etc) with references to the latest relevant publications, written or having summaries in English, French or German. Our aim is that the interested reader would find the last paper on his problem to start with.

The review of pre-Neogene units is followed by the outlines of Neogene and Quaternary sedimentation, volcanism and tectonics. Up to now no distinct tectonic units have been recognized, so a general picture is given only.

The four Appendices (on books, review papers, maps and periodicals) serve to define the available sources of information on Hungarian geology.

All publications were used to make this compilation received prior to 31 March, 1985.

The author knows it for certain that several omissions and mistakes occur in this paper; therefore readers are asked to tell or write him on missing, unnecessary, outdated or otherwise imperfect information contained in this paper to the following address: M. KÁZMÉR. Eötvös University. Department of Palaeontology, H – 1083 Budapest, Kun Béla tér 2, Hungary. Maybe an updated version will follow some years later. Thank you.

Boundaries of tectonic units (Fig. 1)

All boundaries discussed below are subsurface in Hungary.

1. Overthrust plane of Lower Austroalpine (Sopron) nappes on Penninic (Rechnitz – Kőszeg) units. Age of overthrust: Campanian. Transport of chromite from Penninic ultramafics into Gosau and flysch basins of the Alps ceased before Late Campanian, when the northwards moving Austroalpine nappes covered the Penninic units (OBERHAUSER. 1973).

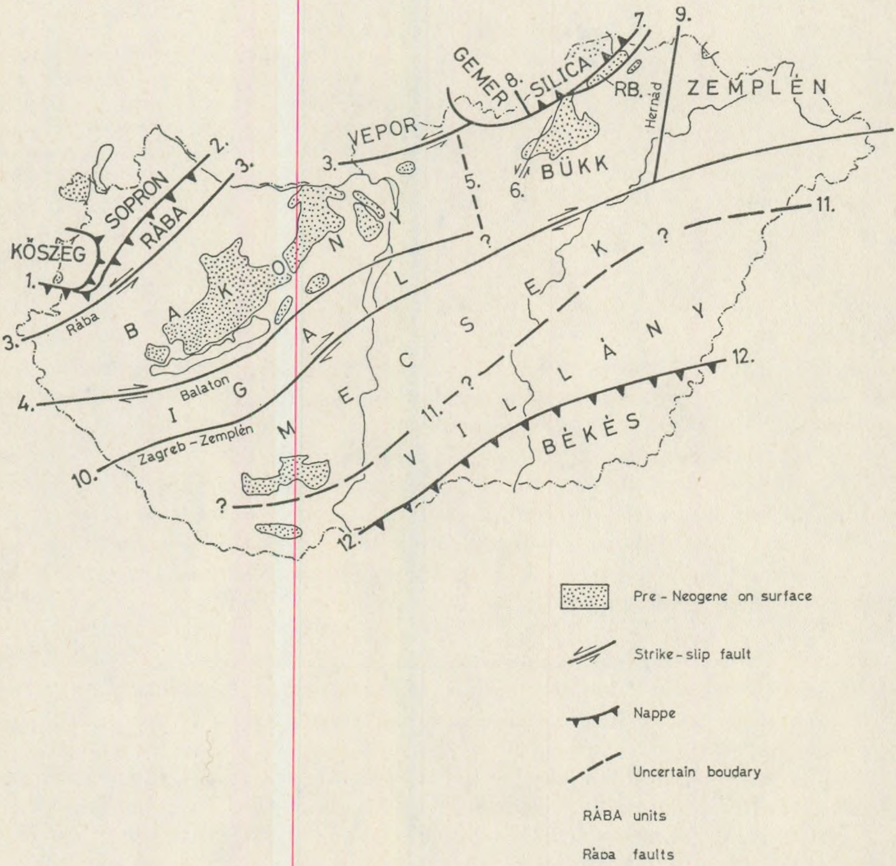

Fig. 1.: Tectonic units in Hungary and their boundaries (after CSÁSZÁR and HAAS, 1984, modified). Numbers refer to descriptions of boundaries in the text. Stippled: pre-Neogene formations on surface. Note, that nearly all tectonic boundaries are below thick Neogene-Quaternary sedimentary cover. RB = Rudabánya unit.

2. Overthrust plane of Upper Austroalpine (Rába) nappe on Lower Austroalpine (e.g. Sopron) units. Age: certainly pre-Gosau, i.e. before Senonian. Gosau sediments in Austria are deposited on folded Austroalpine rocks; possibly pre-Cenomanian: chromite of Penninic ophiolitic origin was directly supplied to Upper Austroalpine "Randcenoman" basin in its immediate southern neighbourhood, i.e. Upper Austroalpine units were thrusted over Lower Austroalpine ones to reach that position before Cenomanian (OHERHAUSER, 1980).

3. Rába fault. Left-lateral strike-slip fault, direct continuation of Periadriatic northern branch DAV lineament (KOVÁCS S., 1983). Age: not older than Middle Eocene, not younger than Late Oligocene. Displacement: ca. 450 km. Formed during continental escape of Bakony unit from the Alps (KÁZMÉR, 1984a).

4. Balaton fault. Right-lateral strike-slip fault, direct continuation of Pusteria – Gailtal – Karavanka lineament (Periadriatic southern branch) (KOVÁCS, 1983). Displacement: ca. 450 km. Formed during continental escape of Bakony unit from the Alps (KÁZMÉR, 1984a). Age: not older than Middle Eocene, not younger than Late Oligocene. Most probably Middle Oligocene, as shown by contemporaneous tonalite plutonism and andesite volcanism along the leaky transform Balaton fault (KÁZMÉR, 1984b).

5. Unnamed left-lateral strike-slip fault. Age: unknown, probably Cenozoic.

6. Darnó fault. Left-lateral strike-slip fault of Late Miocene age (BALLA and HAVAS, 1982). It is not a main palaeogeographic boundary as considered before, since it falls within Bükk unit (ZELENKA and BAKSA et al., 1983).

7. Overthrust plane of Silica nappe over Rudabánya unit. Age: certainly younger than Medial Triassic (age of ophiolites mixed in the basal evaporitic melange) and certainly older than Senonian (age of post-tectonic sediments in Czechoslovakia).

8. Probable overthrust plane of Silica nappe over subsurface Gemeride units. Age: pre-Senonian (see No. 8).

9. Hernád (?) fault (confusions with name). Probable strike-slip fault of unknown displacement. Age: unknown; possibly Miocene (significant calc-alkaline volcanism along its strike).

10. Zagreb – Zemplin fault. Right-lateral strike-slip fault. Age: unknown. Possibly Middle Cretaceous (palaeogeographic causes: WEIN, 1978), or latest: Miocene (significant calc-alkaline volcanism along its strike). Explanations for positioning its eastern end between Zemplén and Mecsek units: it is localized here (instead of between Bükk and Zemplén units) to fulfil its definition: the Zagreb – Zemplén fault forms the northern tectonic margin of Mecsek unit.

11. Unnamed strike-slip fault. Definition: separates Mecsek and Villány units. Age: unknown.

12. Overthrust plane of Békés (Codru) nappes over Villány unit ("Bihor autochthonous"). Age: pre-Coniacian (BLEAHU and LUPU et al., 1981).

Pre-Neogene tectonic units

Neogene and Quaternary is characterized by a diffuse extensional regime (HORVÁTH, 1984) (see later), where distinct tectonic units haven't been recognized. Pre-Neogene formations are grouped into tectonic units (bounded by strike-slip faults and thrust planes) after their common lithologic, metamorphic and/or deformation character.

Layout of this chapter follows PALFREYMAN (1984). References: the most comprehensive one and/or the latest one are included. Formations younger than Oligocene are not discussed in this chapter.

KŐSZEG – RECHNITZ UNIT (FIG. 2)

Age – Jurassic to Early Cretaceous.

Margins – Lower Austroalpine units W, N and E; Upper Austroalpine: S. Extends to Austria.

Physiography – Low to medium hills. Mostly covered by lowland of Neogene sediments.

Elements – Marine metasediments, some ultramafic intrusions.

Stratigraphy – Lower unit: Jurassic(?) quartz phyllite and calcareous phyllite (with conglomerate lenses) and greenschist. Upper unit: Cretaceous(?) calcareous and graphitic phyllite, greenschist, serpentinite.

Igneous activity – Mesozoic tholeiitic ultramafics and mafics.

Metamorphism: – Alpine greenschist facies. Small HP/LT metamorphism. Cooling age: 12 m.y.

Deformation: – strongly folded; tectonic (thrust?) contact between lower and upper units.

Tectonic position – Probably autochthonous. Lies below Lower and Upper Austroalpine units.

Connections – It is the easternmost Penninic window of the Alps. Nearest small windows: Bernstein and Möltern in Austria.

Economic geology – Antimonite in the lower unit, at the calcareous phyllite-greenschist boundary (Schlaining, Austria). Talcum: Felsőcsatár (Hungary). Precious serpentinite.

References – PAHR (1980a), KOLLER and PAHR (1980).

Stratigraphic details

Coloured map: BANDAT (1932).

Stratigraphic continuity of the formations is not proven; tectonic (thrust) contacts are possible. Total thickness of all formations (Rechnitzer Serie of PAHR, 1980a): 2000 m. The whole unit is metamorphosed in greenschist facies (PAHR, 1980a).

1. *Kőszeg Quartzphyllite Formation*. Quartz phyllite, metasandstone, quartzite (PAHR, 1980a).

2. *Velem Calcareous Phyllite Formation*. Calcareous phyllite (with limestone beds in Austria) and greenschist. Age: Lower to Middle Cretaceous based on sponge spicules (SCHÖNLAUB, 1973). The Upper Jurassic – Lower Cretaceous biostratigraphic data of KŐVÁRI from Ikervár – 2 bore-

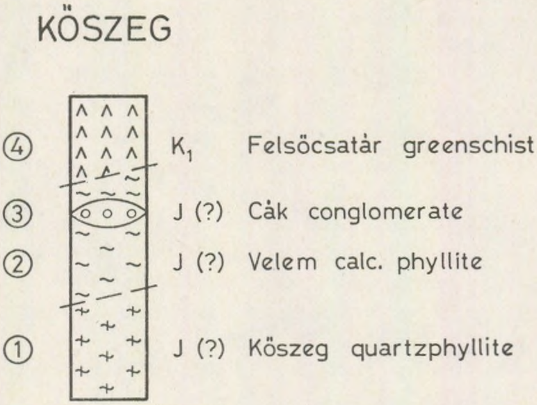

Fig. 2.: Hypothetical stratigraphic column of Kőszeg unit in Hungary (after CSÁSZÁR and HAAS, 1983, modified). Numbers refer to the text.

hole (in JUHÁSZ and KŐHÁTI, 1966) based on tintinnids and *Lombardia* must be revised (these possibly belong to a tectonic scale of Bakony unit). Mineralogy: FELVÁRI and VICZIÁN (1973).

3. *Cák Conglomerate Formation.* Intercalations in the upper part of Velem Calcareous Phyllite. Mostly dolomite pebbles with rare limestone and gneiss ones (JUHÁSZ, 1965; ORAVECZ, 1979). Age of pebbles: Middle Triassic after MOSTLER and PAHR (1981), based on holothurian sclerites and conodonts. Deposited in fluviatile-delta (ORAVECZ, 1979) or seashore (MOSTLER and PAHR, 1981) environment. As it is intercalated in pelagic marine metasediments of the oceanic Penninic zone, we consider the Cák Conglomerate as olisthostrome, originated from compressive tectonic movements, uplift and erosion at the end of Jurassic or later.

4. *Felsőcsatár Greenschist formation.* Mostly pyroclastics and less lava rocks of mafic, tholeiitic composition, metamorphosed to greenschist, talc schists and ultramafics altered to serpentinite. Ophiolitic suite (KOLLER and PAHR, 1980). K–Ar cooling age of crossite (blue amphibole): 12 m.y. (KUBOVICS, 1983), associated with the Miocene uplift of the Alps (HP/LT metamorphism).

SOPRON UNIT

Age – Palaeozoic.

Margins – Upper Austroalpine towards W, N and E; Penninic Kőszeg unit toward S. Extends to Austria.

Physiography – Low to medium hills. Mostly covered by lowlands of Neogene and Quaternary sediments.

Stratigraphy – Fertőrákos group: amphibolite, gneiss and quartz phyllite. Sopron Group: metapelites injected by granitoids; amphibolite, quartzite, leucophyllite intercalations.

Igneous activity – Palaeozoic mafic volcanism (amphibolite); Variscan granitoid intrusions.

Metamorphism – Possible Caledonian metamorphism. Felsőrákos: Variscan greenschist facies. Sopron: Variscan amphibolite facies, Variscan greenschist facies and Alpine retrograde overprint.

Deformation – Both groups are strongly folded and imbricated. Tectonic position – Allochthonous. Footwall: Penninic units at Kőszeg–Rechnitz; hangingwall: Upper Austroalpine to the N and SE.

Connections – Fertőrákos group belongs to the Lower Austroalpine Wechsel unit and Sopron Group to Lower (or Middle) Austroalpine Grobgneis group of Semmering unit. Economic geology – REE mineralization in metapelites and quartzites.

References – PAHR (1980b), LELKES–FELVÁRI, SASSI and VISONÁ (1984).

Stratigraphic details

True stratigraphical details are not available as yet, due to the lack of more reliable radiometric data.

Sopron Crystalline Complex (= Grobgneis group). Three main rock types have been distinguished by LELKES–FELVÁRI et al. (1984): 1) acidic gneisses and metavolcanics; 2) metapelites; 3) amphibolites. Originally granites have been injected into mostly pelitic sediments containing volcanic intercalations. Special rocks are: Mg-Al rich quartzites (LELKES–FELVÁRI et al., 1984) and Mg-rich metapelites (leuchtenbergite-containing leucophyllite: LELKES–FELVÁRI et al., 1983). Petrology: LELKES–FELVÁRI et al., (1983, 1984). Radiometric age of granites: 340 ± 10 m.y. (SCHARBERT in PAHR, 1980b). In Austria a Central–Alpine Permo–Triassic sedimentary cover overlies the crystalline basement. The crystalline rocks are products of a Caledonian(?) and a Variscan amphibolite-facies metamorphic event (LELKES–FELVÁRI et al., 1984). The crystalline basement and the sedimentary cover suffered Alpine (retrograde) greenschist-facies metamorphism (PAHR, 1980b). Petrographic map: KISHÁZI (1975). REE and thorium mineralization in micaschists: FAZEKAS et al., (1975).

Fertőrákos Crystalline Complex (Wechsel unit: KÓSA and FAZEKAS, 1981*).* Petrographical and stratigraphical description and interpretation: KÓSA and FAZEKAS (1981). Total known thickness: 2000 m. Lower part: amphibolite (originally basic lava and pyroclastics, pelites). Middle part: micaschist with some amphibolite (originally pelitic-psammitic sequence without limestones, with less volcanic substance). Upper part: micaschist, gneiss, rare marble (originally: upwards fining psammitic-pelitic sequence with rare limestone intercalations). Graphitic micaschist is located rarely at tectonic contacts. Interpretation: Palaeozoic sedimentary-volcanic complex which suffered Variscan epidote-amphibolite-facies metamorphism. Alpine retrograde greenschist-facies metamorphism occurs. The metamorphism was slightly different than in the Austrian part of the Wechsel unit.

RÁBA UNIT

Age – Silurian to Devonian.

Margins – Penninic (Kőszeg) and Lower Austroalpine (Sopron) units to NW; Bakony unit to SW, separated by the Palaeogene transcurrent Rába fault. Extends to Austria to the SW (Graz Palaeozoic). NE extension to Czechoslovakia unknown.

Physiography – Subsurface unit covered by Neogene and Quaternary lowland.

Stratigraphy – Silurian(?) phyllite with volcanite intercalations. Devonian dolomite.

Igneous activity – Silurian(?) mafic, intermediate and some acidic volcanism.

Metamorphism – Very low to low grade.

Deformation – Strongly folded.

Tectonic position – Allochthonous. Probably overlies Penninic and Lower Austroalpine units.

Connections – South-westwards extends into the Upper Austroalpine Graz Palaeozoic of Austria.

Economic geology – Devonian dolomite contains thermal mineral water.

Reference – BALÁZS (1971).

Stratigraphic details

As no recognizable fossils have been found, the age determinations are mostly hypothetical (BALÁZS, 1971, 1975; SZEDERKÉNYI, 1980). A Silurian (?) phyllite and metamorphic sandstone complex containing some metadiabase is overlain by a thick Devonian(?) crystalline dolomite.

Geological map of the Neogene basement is given by BALÁZS (1971).

BAKONY UNIT (Figs. 3–6)

Age – Ordovician to Oligocene.

Margins – Austroalpine units (Kőszeg and Rába units) to NW, separated by Palaeogene Rába wrench fault; Igal unit to SE, separated by Palaeogene Balaton wrench fault. NE end cut by a Cenozoic wrench fault; westwards extends to Austria (to Drauzug unit).

Physiography – Low to medium hills, partly covered by Neogene and Quaternary sediments.

Stratigraphy – Lower Palaeozoic palegic shales; Upper Palaeozoic neritic shales, limestones and terrestrial clastics, Variscan granitoids; unconformably overlain by Permian sandstones, Triassic neritic and pelagic carbonates and marls, Jurassic pelagic limestones and radiolarites, Cretaceous pelagic and neritic carbonates and shales; these are unconformably overlain by Upper Cretaceous marls and reef limestones; these are unconformably overlain by neritic and pelagic Eocene marls and limestones; these are mostly unconformably overlain by Oligocene fluviatile to marine clastic sediments. Igneous activity – Lower Palaeozoic ignimbrites; Palaeozoic basalts; Permian rhyolite and granitoids; Middle Triassic intermediate volcanism; Middle Cretaceous lamprophyres; Eocene andesitic volcanism; Oligocene andesites and tonalites. Metamorphism – Hercynian very low to low grade metamorphism. The southeastern wrench fault zone contains small units with Hercynian greenshcist facies metamorphism (Balatonfőkajár) and Lower Carboniferous non-metamorphosed rocks (Szabadbattyán) side by side.

Deformation – Variscan folding; later minor folds and extensive – partly synsedimentary – faulting.

Tectonic position – Probably autochthonous.

Connections – Palaeozoic to Eocene sediments and volcanism display apparent Southern Alpine and Upper Austroalpine connections.

Economic geology – Jurassic sedimentary Mn-ores; Lower Cretaceous Zementmergel; Middle and Upper Cretaceous and Eocene bauxites; Upper Cretaceous and Eocene lignite; Miocene brown coal. Thermal waters from Triassic carbonate rocks. Oligocene sedimentary kaolinite. Oligocene and Pliocene white sands. Permian or Palaeogene hydrothermal lead mineralization. Oil and gas in Cretaceous to Pliocene reservoirs.

References – FÜLÖP (1968), WEIN (1969).

Stratigraphic details

1. *Balatonfőkajár Quartzphyllite Formation*. Cambrian(?). Quartzphyllite, chloritephyllite, chloritegneiss. Thickness: more than 200 m. Metamorphism: Variscan greenschist facies. Petrography: BUBICS (1977), LELKES–FELVÁRI (1978). Inferred Cambrian age is based on its highest metamorphic degree in the Bakony unit (DUDKO et al., 1985), LELKES–FELVÁRI et al., (1981) and LELKES–FELVÁRI and SASSI (*t*1983) consider it as Ordovician based on rare acidic pyroclastics, which have analogues in the Eastern Alps.

2. *Pelitic-psammitic shales (Révfülöp Shale and Lovas Shale Formations)*. Ordovician to Lower Devonian. Probably pelagic shales of considerable thickness, containing limestone, black chert, acidic (rarely neutral) pyroclastics and mafic rocks (the latter is of unknown stratigraphic position an Litér). Petrography: BUBICS (1977). Very low to low grade metamorphism. Rare fossiliferous beds indicate Ordovician (ALBANI et al.. 1984: acritarchs), Silurian (ORAVECZ. 1964, 1965: acritarchs, graptolites; GÓCZÁN, 1971a: acritarchs; KOZUR, 1984a: conodonts) and Devonian (LELKES–FELVÁRI et al., 1984: conodonts) ages. The latter conodonts were exsolved from griotte, a Devonian pelagic limestone. Radiometric age of a diabase intercalation: 170 m.y. (DUDKO et al., 1985).

3. *White limestone (Polgárdi Limestone Formation)* Silurian or Devonian. Pure, white, partly recrystallized platform limestone. Lithology: LELKES–FELVÁRI (1978). Deposited in a lagoon: Lofer cyclothems and

recrystallized stromatoporoids: Dudko et al., (1985). Age: Devonian: Lelkes–Felvári (1978) or Silurian (Dudko et al., 1985). Metasomatic recrystallization and occurrences of skarn (Dudko et al., 1985).

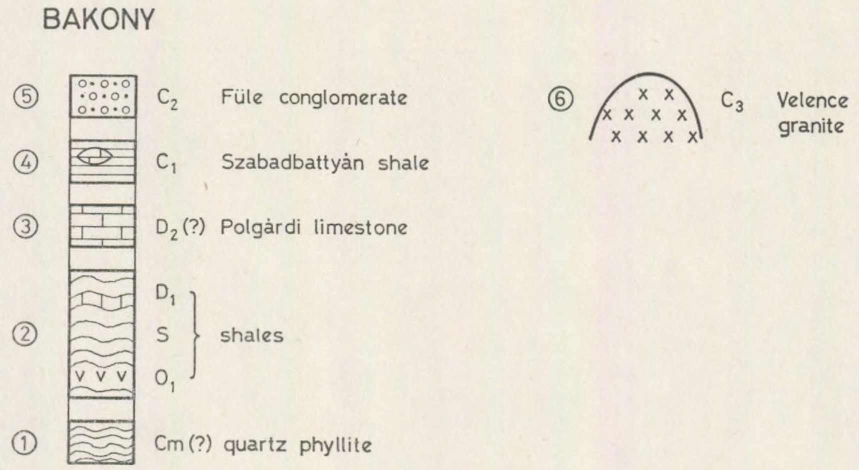

Fig. 3.: Pre-Permian formations of Bakony unit (after Dudko et al., 1985, modified). This stratigraphic column is highly hypothetic since all formations have thrust and/or strike-slip tectonic boundaries. Numbers refer to the text.

4. *Fossiliferous shale (Szabadbattyán Shale Formation)* with limestone lenses. Lower Carboniferous. Viséan. Bituminous. No metamorphism. Lithology: Lelkes–Felvári (1978). Age: Upper Viséan (Monostori (1978). Fossils: calcareous algae: Földvári (1952); foraminifers: Monostori (1974, 1976, 1978); Sidó (1978); corals: Mihály (1973); brachiopods (Földvári (1952), Detre (1971). Permian or Palaeogene lead mineralization: Földvári (1952).

5. *Terrigenous conglomerate (Füle Conglomerate Formation)*. Upper Carboniferous. Grey and red conglomerate, sandstone and siltstone. Pebbles: local quartzite, sandstone, lydite, sericite shale, quartz porphyry: Lelkes–Felvári (1978). No metamorphism. Thickness: more than 300 m. Alluvial fan (Majoros in Dudko et al., 1985). Age: Late Carboniferous, Westphalian–Lower Stephanian. Fossils: spores and pollen: Barabás–Stuhl (1971, 1975); plants: Andreánszky (1962), Lelkes–Felvári (1978), Mihály (1980).

6. *Velence granite (Velence Granite Formation, Dinnyés Quartzdiorite Formation. Ságvár monzogranite)*. Upper Carboniferous or Lower Permian. K–Ar ages: Velence: 280–290 m.y., Ságvár: 259 m.y. (Balogh, Árva–Soós and Buda, 1983), Dinnyés: 272 m.y. (Dudko et al., 1985). Petrology and geochemistry: Buda (1981), Nagy B. (1967), Gokhale (1966), REE geochemistry: Pantó (1977). Regional geology: Jantsky (1957).

Permian (Fig. 4)

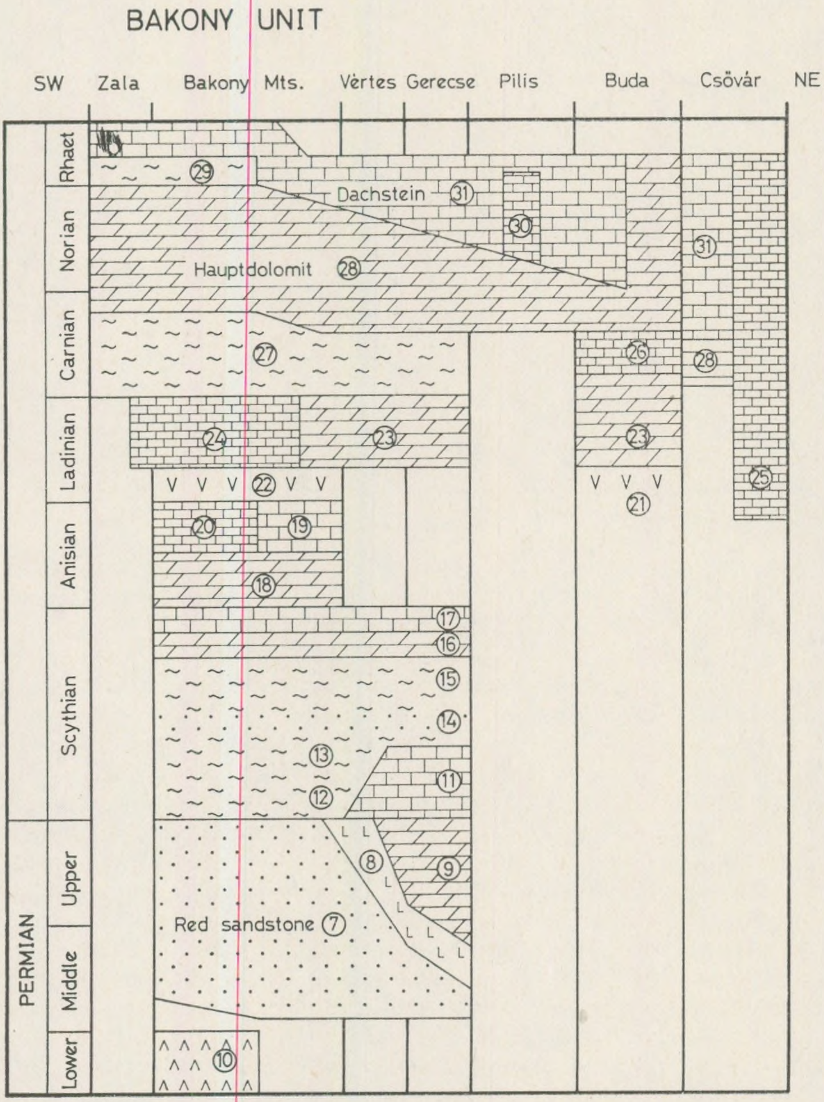

Fig. 4.: Permian and Triassic formations of Bakony unit (after MAJOROS, 1983; CSÁSZÁR and HAAS, 1983, modified). Numbers refer to the text.

Middle to Upper Permian to fluviatile, lagoonal and marine environments: a molasse basin open to the eastern sea. Facies belts are perpendicular to the length of Bakony unit (MAJOROS, 1980). Apparent similarities to the Late Permian facies pattern of the eastern Southern Alps were recognized by MAJOROS (1980).

7. *Red sandstone (Balatonfelvidék Sandstone Formation).* Middle to Upper Permian. Fluviatile red sandstone and conglomerate, 200 to 1000 m thick. Lithology: MAJOROS (1980, 1983). Biostratigraphy: BARABÁS–STUHL (1975); spores: STUHL (1961); reptile footprints: MAJOROS (1964), KASZAP (1968); fossil woods: GREGUSS (1967).

8. *Evaporite (Tabajd Evaporite Formation).* Middle to Upper Permian. Alternating dolomite, gypsum, anhydrite, marl and siltstone deposited in a hypersaline lagoon and sabkha. Lithology: MAJOROS (1983); palynostratigraphy: BARABÁS–STUHL (1975).

9. *Dolomite (Dinnyés Dolomite Formation).* Upper Permian. Dark dolomite with limestone, marl and siltstone intercalations. Lithology: MAJOROS (1983); biostratigraphy: based on foraminifers. calcareous algae and sporomorphs: BALOGH and DOBOSI et al. (1983).

10. *Dacite porphyry (Kékkút Dacite Porphyry Formation).* Subsurface unit (150 km^2). Subvolcanic complex or stratovolcano consisting mainly lava rocks. Product of Late Palaeozoic subsequent volcanism in the marginal part of a molasse basin. Rb–Sr age: 277 ± 70 m.y. (KOVÁCH and SVINGOR in MAJOROS, 1983). Petrology and geochemistry: FAZEKAS et al. (1981).

Triassic

Early Triassic: shallow marine carbonate sedimentation with decreasing terrigenous influx; Middle Triassic: carbonate platforms and deep basins with cherty limestones and calc-alkaline volcanism. Late Triassic: carbonate platform, marginal reef and deep sea to the east. Facies relationships indicate an original position between Southern Alps and Upper Austroalpine units (KOVÁCS, 1982).

11. *Limestone (Alcsútdoboz Limestone Formation).* Lower Scythian. Subsurface unit. Calcerous marl and limestone. Lithology and biostratigraphy (foraminifers and sporomorphs): BALOGH and DOBOSI et al. (1983).

12. *Dolomite (Nádaskút Dolomite Member of Werfen Formation).* Lower Scythian. Bedded, silty-sandy dolomite with evaporite intercalations. Unfossiliferous. Lithology: LÓCZY (1913), BALOGH (1981).

13. *Marl (Arács Marl Member of Werfen Formation).* Scythian. Laminated marl with dolomite intercalations. Stratigraphy: LÓCZY (1913). BALOGH and DOBOSI et al. (1983). Bivalves: FRECH (1912), BITTNER (1912a).

14. *Sandstone (Hidegkút Sandstone Member of Werfen Formation).* Scythian. Laminated sandstone and siltstone with thin gastropod-ooid-limestone intercalations. Lithology: LÓCZY (1913). Bivalves: BITTNER (1912a)

15. *Tirolites marl (Csopak Marl Member of Werfen Formation).* Scythian. Gray, bedded marl with rare ammonites and abundant bivalves and thin limestone intercalations. Neritic. Stratigraphy: BALOGH (1981). Lithology: BÉRCZI–MAKK (1970). Facies: BALOGH and DOBOSI et al. (1983). Fossils: bivalves and gastropods: FRECH (1911a); foraminifers: BÉRCZI–MAKK (1970). Microfacies: VÉGH–NEUBRANDT (1972).

16. *Cellular dolomite (rauhwacke) (Aszófő Dolomite Formation).* Upper Scythian. Bedded dolomite with voids of exsolved anhydrite. Lithology: Bérczi–Makk (1970). Rare foraminifers and sporomorphs: Balogh and Dobosi et al. (1983).

17. *Bituminous, laminated limestone (Iszkahegy Limestone Formation).* Upper Scythian. Deposited in a restricted, shallow marine environment. Lithology: Bérczi–Makk (1970). Bivalves: Frech (1911a). Microfacies: Végh –Neubrandt (1972).

18. *Dolomite with dasyclads. (Megyehegy Dolomite Formation).* Lower Anisian. Deposited in a reef lagoon. Stratigraphy and lithology: Lóczy (1913).

19. *Limestone with dasyclads (Tagyon Limestone Formation).* Upper Anisian. White limestone with dasyclads deposited in a reef lagoon. Stratigraphy: Balogh and Dobosi et al. (1913). Foraminifers: Oravecz–Scheffer (1980).

20. *Silty, tuffitic and cherty limestones (Felsőörs Limestone Formation).* Upper Anisian. (Reifling and Recoaro limestones, Alpine Muschelkalk). Neritic to bathyal limestones. Stratigraphy: Szabó and Kovács et al. (1980), Balogh and Dobosi et al. (1983). Fossils: ammonites: Arthaber (1911), Frech (1912); bivalves: Kittl (1912a); brachiopods: Bittner (1912b); ostracods: Kozur (1970); conodonts: Szabó and Kovács et al. (1980)

21. Tectonic scale of *pyroxenic andesite* in Budaörs–1 borehole and *andesite and rhyolite pebbles* in Eocene conglomerates of Buda Mts. and easternmost Bakony unit. Petrographic description is given by Nagy E., Nagy G. and Széky F. (1967), they considered it as Eocene; Kubovics (1984) assigned them to the Mesozoic (Triassic), in the caption of his Fig. 1. Probably these are the easternmost relics of a more extensive Ladinian calc-alkaline volcanism in Bakony unit.

22. *Tuffitic, cherty limestone (Buchenstein beds, pietra verde) (Buchenstein Formation).* Lower Ladinian. Bathyal limestone and bedded chert with green trachytic tuffitic intercalations. Stratigraphy: Szabó I. et al. (1980), Balogh, Dobosi et al. (1983). Fossils: ammonites: Frech (1911b); bivalves: Kittl (1912a); ostracods: Méhes (1911); conodonts: Szabó I. et al. (1980). Stratigraphy, petrology and geochemistry of tuffites: Szabó and Ravasz (1970), Ravasz (1973).

23. *Dolomite with dasyclads (Diplopora dolomite; Budaörs Dolomite Formation).* Ladinian. Shallow marine dolomite with locally abundant dasyclads. Stratigraphy: Kutassy (1927).

24. *Cherty red limestone (Tridentinus –Kalk; Wengener Schichten) (Nemesvámos Limestone Formation).* Ladinian, Bathyal cherty, nodular limestone with rare tuffitic intercalations. Lithology and ammonites: Detre et al. (1979). Holothurian sclerites: Kozur and Mostler (1971).

25. *Cherty limestone and marl (Csővár Limestone Formation).* Ladinian to Rhaetian. With pelagic fauna, containing reworked material from a Dachstein reef (Kozur and Mostler, 1973). Lithology: Detre (1970); facies: Kozur and Mostler (1973). Fossils: bivalves: Vadász (1911), Detre (1971b); holothurian sclerites: Kozur and Mostler (1973).

26. *Cherty limestone (Raibl beds; Mátyáshegy Formation).* Carnian. Bituminous marl, limestone and dolomite beds (WEIN, 1977).

27. *Carnian marl (Obere Mergelgruppe, Raibler Schichten) (Veszprém Marl Formation).* Carnian. Contains several members: Sóly Marl, Füred Limestone, Chondrites limestone, Estheria marl, Austriacum limestone, Lima and Nucula marl and Sándorhegy limestone: BALOGH (1981). Hemipelagic(?) marl containing several thick limestone intercalations. Lithology: PEREGI (1979). Microfacies of interfingering carbonates: GÓCZÁN et al. (1983). Biostratigraphy (foraminifers and spore-pollen): KRIVÁN (1965), GÓCZÁN et al. (1983), BALOGH, DOBOSI et al. (1983). Fossils: foraminifers: ORAVECZ–SCHEFFER (1967, 1971); sponges: VINASSA DE REGNY (1911); bivalves: BITTNER (1912), FRECH (1911a, 1912), KITTL (1912a); gastropods: KITTL (1912b); cephalopods: FRECH (1911a, b); brachiopods: BITTNER (1912); crinoids and echinoids: BATHER (1911); ostracods: MÉHES (1911), SZÉLES (1965), KOZUR (1972); reptiles: JAEKEL (1911a. b).

28. *Hauptdolomit (Hauptdolomit Formation).* Upper Carnian to Norian. Light grey, bedded, compact platform dolomite with rare megafossils. Contains less dolomitized beds. Stratigraphy: ORAVECZ (1963), BALOGH (1981). Lithology: BADINSZKY (1973a). Sedimentology: HAAS et al. (1984), HAAS and DOBOSI (1982), GECSE (1984). Geochemistry: GECSE (1984). Fossils: megalodonts: VÉGH–NEUBRANDT (1974, 1982).

29. *Kössen beds (Kössen Formation).* Lower Rhaetian. Dark grey, finely laminated, fossil-rich marl and limestone. Lithology: VÉGH (1964b), HAAS et al. (1984). Fossils: spores and pollen: VENKATACHALA and GÓCZÁN (1964); foraminifers: GELLAI (1974), BÉRCZI–MAKK (1980); bivalves: VÉGH (1964), VÖRÖS (1981), CSÁSZÁR et al. (1982); ostracods: KOZUR and ORAVECZ–SCHEFFER (1972).

30. *Bituminous limestone (couches à Avicula:* ORAVECZ, 1962*) (Feketehegy Limestone Formation).* Norian. Grey, well bedded bituminous dolomites conformably overlain by limestone containing bivalve lumachelles. Age: Carnian (ORAVECZ, 1962) revised by BALOGH (1981) as Norian. Bivalves and ammonites: ORAVECZ (1962).

31. *Dachstein limestone (Dachstein Formation).* Norian to Rhaetian. Cyclic, peritidal, white, compact limestone showing Lofer cyclothems (HAAS, 1982), BALOGH and DOBOSI et al. (1983). Biostratigraphy: VÉGH–NEUBRANDT (1982), CSÁSZÁR, KOVÁCS–BODROGI and VÖRÖS (1982), DETRE (1970). Sedimentology and facies: FÜLÖP (1976), HAAS (1982), HAAS and DOBOSI (1982), CSÁSZÁR et al. (1982), GECSE (1984), HAAS et al. (1984). Microfacies: VÉGH–NEUBRANDT (1960), GELLAI (1972). Fossils: foraminifers: BÉRCZI–MAKK (1978a, 1980); megalodonts: VÉGH–NEUBRANDT (1982); other molluscs: KUTASSY (1936), VÖRÖS (1981); ammonoids: BÉRCZI–MAKK (1969).

Jurassic (Fig. 5.)

32. *Liassic Dachstein limestone (Kardosrét Limestone Formation).* White limestone with small oncoids, without Lofer cyclothems. Hettangian to Lower Sinemurian. Biostratigraphy and lithology: HAAS et al. (1984). Contains brachiopods. 150 m thick.

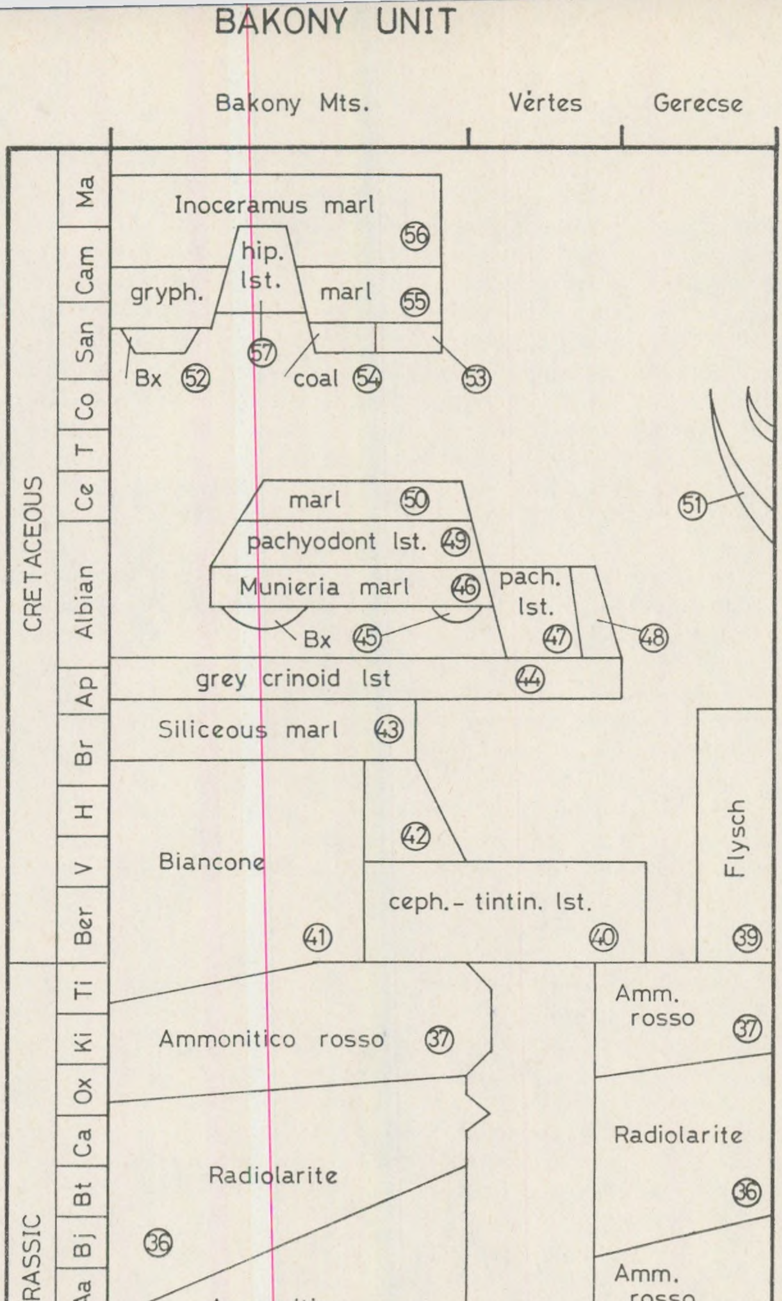

Fig. 5.: Jurassic and Cretaceous formations of Bakony unit (after Császár and Haas, 1983, simplified). Numbers refer to the text.

33. *Ammonitico rosso (lower).* Sinemurian to Bathonian. *(Pisznice Limestone Fm., Isztimér Limestone F., Tűzkövesárok Limestone Fm., Kisgerecse Marl Fm., Eplény Limestone Fm., Tölgyhát Limestone Fm.)* Thin, mostly condensed, red, pelagic limestone and marl sequence. Lower part contains abundant crinoids and brachiopods. Rich, well-known ammonite faunae. Interfingers with Hierlatz limestone, magnanese ores and radiolarites. Lithology: GÉCZY (1961), KONDA (1970), FÜLÖP (1976), HAAS et al. (1984). Facies: GALÁCZ and VÖRÖS (1972). Biostratigraphy: FÜLÖP (1971), GÉCZY (1974), GALÁCZ (1976). Fossils: gastropcds: SZABÓ J. (1982); ammonoids: GÉCZY (1966, 1967a, 1967b, 1971, 1972, 1976), GALÁCZ (1980); brachiopods (VÖRÖS (1983).

34. *Hierlatz limestone (Hierlatz Formation).* Sinemurian to Tithonian, discontinuous. White or red limestone with abundant crinoids and brachiopods deposited at the foot of submarine slopes. Lithology: FÜLÖP (1976), HAAS et al. (1984). Facies: GALÁCZ and VÖRÖS (1972). Brachiopods: VÖRÖS (1983).

35. *Manganese ore (Úrkút Manganese ore Formation).* At the Toarcian base black, manganiferous clay occurs, locally containing payable Mn-carbonate and Mn-oxide ores (Grasselly et al., 1969). Mineralogy: rhodochrosite and pyrolusite: CSEH–NÉMETH and GRASSELLY (1966). Origin: sedimentary: SZABÓ Z. and GRASSELLY (1980) or volcanic: SZABÓ Z., GRASSELLY and CSEH–NÉMETH (1981). Age determinated by the position of Mn-coated beds in almost the whole Bakony unit. Fossils: spores and pollen: KEDVES and SIMONCSICS (1971).

36. *Radiolarite (Lókút Radiolarite Formation).* Brown, red or green chert beds or siliceous limestones. Age: Aalenian to Oxfordian (heterochronous). Lithology: FÜLÖP (1976). Stratigraphy: FÜLÖP (1971).

37. *Ammonitico rosso (upper) (Pálihálás Limestone Formation).* Oxfordian to Tithonian. Red, condensed, nodular or bedded limestone. Stratigraphy and lithology: FÜLÖP (1971), HAAS et al. (1984). Ammonites: VÍGH (1981, 1984); brachiopods: VÍGH (1981).

38. *Biancone (Mogyorósdomb Limestone Formation).* Tithonian to Lower Berriasian. White, bedded, compact, cherty limestone. Lithology: HAAS et al. (1984). Ammonites: VÍGH (1984). Calpionellid stratigraphy: KNAUER (1983).

Cretaceous (Fig. 5)

39. *Flysch (Felsővadács Breccia Member, Bersek Marl Formation, Lábatlan Sandstone Formation, Köszörűkőbánya Conglomerate Formation).* Berriasian to Lower Aptian. Occurs in E Gerecse Mts. only. Limestone breccia, marl with thin sandstone intercalations, sandstone with marl intercalations, conglomerate. Sandstone deposited by turbidity currents. (CSÁSZÁR in CSÁSZÁR and HAAS, 1984a). Lithology, stratigraphy, palaeogeography: FÜLÖP (1958). The sandstone contains chromite, the conglomerate contains "diabase" (FÜLÖP, 1958). Fossils: spores and pollen: RÁKOSI (1971); ammonites: NAGY I. Z. (1967, 1968), VÍGH (1984).

40. *Cephalopod-tintinnid limestone (Szentivánhegy Limestone Formation).* Berriasian to Lower Valanginian. Downwards continuous into

Upper Jurassic Biancone, ammonitico rosso. Bedded, thin (1.5 m) limestone with rich ammonite fauna: VÍGH (1971). Lithology: FÖLDVÁRI et al. (1973), FÜLÖP (1976). Nannoconus (Protista): BÁLDI–BEKE (1965). Tintinnina: FÜLÖP (1964).

41. *Biancone (Mogyorósdomb Limestone Formation)*. Tithonian to Lower Barremian. White to light grey, bedded limestone with chert nodules and layers. Lithology: HAAS et al. (1984). Regional studies: FÜLÖP (1964). Biostratigraphy and fossils: HAAS et al. (1984). Nannoconus (Protista): BÁLDI–BEKE (1965); tintinnina: KNAUER (1983).

42. *Crinoid-cephalopod limestone (Borzavár Limestone Formation)* Valanginian to Lower Barremian. Grey, thick-bedded crinoid limestone, locally with abundant ammonite fauna. Lithology and stratigraphy: FÜLÖP (1964). Fossils: ammonoids: NAGY I. Z. (1981); echinoids: SZÖRÉNYI (1965); crinoids: SIEVERTS–DORECK (1961).

43. *Siliceous marl (Sümeg Marl Formation)*. Barremian to Lower Aptian. Grey, compact, siliceous, silty marl. 250 m thick. Subsurface unit. Lithology and stratigraphy: FÜLÖP (1964), HAAS et al. (1984). Fossils: nannoconus (Protista): BÁLDI–BEKE (1965).

44. *Grey crinoid limestone (Tata Limestone Formation)*. Upper Aptian to Lowermost Albian. Winnowed crinoid and extraclast (limestone, marl) sparite. Cherty. Lithology and biostratigraphy: FÜLÖP (1976), HAAS et al. (1984). Fossils: spores and pollen: JUHÁSZ (1983); foraminifers: SIDÓ (1975); echinoids: SZÖRÉNYI (1965).

45. *Alsópere Bauxite Formation*. Lower Albian pisoidic karst bauxite lying on Triassic Dachstein limestone and overlain by Albian Munieria marl. Stratigraphic position: KÁROLY et al. (1970). Overburden: CSÁSZÁR: (1981).

46. *Munieria marl (Tés Marl Formation)*. Middle Albian. Gray or mottled clayey marl and limestone. Deposited in mostly lacustrine environment. Abundant Munieria (Characeae, Algae). Distribution and facies: CSÁSZÁR (1978). Biostratigraphy and fossils: spores and pollen: DEÁK (1965), JUHÁSZ (1973); plants: RÁKOSI (1982); gastropods: BENKŐ–CZABALAY (1965); ostracods: ZALÁNYI (1959).

47. *Lower pachyodont limestone (Környe Limestone Formation)*. Albian. Grey, fossil-rich reef limestone (pachyodonts, Orbitolina). Subsurface unit.

48. *Grey siltstone (Vértessomló Aleurolite Formation)*. Lower Albian. Subsurface unit. Possibly connected to the flysch in Gerecse. Lithology: FÖLDVÁRI et al. (1973). Probable age: Upper Aptian(?) to Lower Albian: CSÁSZÁR and HAAS (1983). Spores and pollen: JUHÁSZ (1983).

49. *Upper pachyodont limestone (Zirc Limestone Formation)* Upper Albian. White, compact limestone with bivalves, Orbitolina; tabular limestone with silty intercalations. Lithology: CSÁSZÁR (1981). Facies: KNAUER and GELLAI (1983). Stratigraphy: SCHOLZ (1973a, 1974). Microfacies: GELLAI (1973a). Fossils: calcareous algae: PEYBERNÈS (1977); PEYBERNÈS and CONRAD (1979); spore and pollen: JUHÁSZ (1983); planktonic microfossils: KNAUER (1974); foraminifers: GELLAI (1973a); gastropods: BENKŐ–CZABALAY (1965), CZABALAY (1981); holothurian sclerites: GELLAI (1973b).

50. *Glauconite marl (= Turrilites marl, Pénzeskút Marl Formation)*. Cenomanian or Vraconian. Grey, silty, glauconitic marl with abundant pelagic fauna. Stratigraphy: SCHOLZ (1973a, 1974). Fossils: spores and pollen: JUHÁSZ (1983); planktonic microfossils: KNAUER (1974); foraminifers: SIDÓ (1971); gastropods: CZABALAY (1965); ammonites: SCHOLZ (1979); echinoids: SZÖRÉNYI (1955).

51. *Lamprophyre dykes*. Monchiquite, silicocarbonatite (beforsite), polzenite, alkaline picrite porphyry and microgabbro dykes cutting Upper Carboniferous granites, Upper Permian and Upper Triassic carbonates. K–Ar age: 69 and 77 m.y. Petrology and geochemistry: HORVÁTH et al. (1983), HORVÁTH and ÓDOR (1984). Distribution: DUDKO (1984), HORVÁTH and ÓDOR (1984).

52. *Bauxite (Halimba Bauxite Formation)*. Lower Senonian karst bauxite lying on Triassic to Albian limestones, overlain by Senonian lacustrine coal measures. Stratigraphic position: KÁROLY et al. (1970). Palaeogeography: HAAS (1984).

53. *Terrestrial clastics (Csehbánya Formation)*. Lower Campanian. Variegated pelite, sandstone and gravel. Lithology: HAAS et al. (1984). Stratigraphy and palaeogeography: HAAS and JOCHA–EDELÉNYI (1979), HAAS (1980). Palynostratigraphy: SIEGL (1983).

54. *Coal measures (Ajka Coal Formation)*. Upper Santonian to Lower Campanian. Lacustrine marl, silt, sand and limestone with workable coal seams. Rich mollusc fauna. Lithology: HAAS et al. (1984). Stratigraphy and palaeogeography: Haas and JOCHA–EDELÉNYI (1979), HAAS (1980), CZABALAY (1983). Fossils: calcareous algae: GELLAI and TÓTH (1982); spores and pollen: GÓCZÁN (1964), SIEGL (1983). Gastropods: BARTHA (1962).

55. *Gryphaea marl (+coral-mollusc marl) (Jákó Marl Formation)*. Campanian. Shallow marine grey marl and siltstone with lumachelles of Exogyra and Pycnodonta bivalves. Lithology: HAAS et al. (1984). Stratigraphy and palaeogeography: HAAS (1983). Fossils: spores and pollen: GÓCZÁN (1964); foraminifer stratigraphy: SIDÓ (1963, 1983a); corals: GÉCZY (1954); bivalves and gastropods: BENKŐ–CZABALAY (1964).

56. *Inoceramus marl (Polány Marl Formation)*. Upper Campanian to Maastrichtian. Pelagic, grey, thin-bedded calcareous marl and clayey limestone. Lithology: HAAS et al. (1984). Stratigraphy and palaeogeography: HAAS and JOCHA–EDELÉNYI (1979), HAAS (1983). Fossils: spores and pollen: GÓCZÁN (1964), foraminifer stratigraphy: SIDÓ (1963a, 1983); bivalves: BENKŐ–CZABALAY (1964); echinoids: SZÖRÉNYI (1955).

57. *Hippurites limestone (Ugod Limestone Formation)*. Campanian to Lower Maastrichtian. Light-coloured limestone with abundant reef-building bivalves. Lithology: HAAS (1979), HAAS et al. (1984). Stratigraphy: HAAS (1979). Palaeogeography: HAAS and JOCHA–EDELÉNYI (1979). Fossils: spores and pollen: GÓCZÁN (1964); foraminifers: SIDÓ (1974); corals: GÉCZY (1954); rudists: CZABALAY (1982); other bivalves: CZABALAY (1975); gastropods: CZABALAY (1976), CZABALAY and GELLAI (1981); echinoids: SZÖRÉNYI (1955).

Palaeogene (Fig. 6)

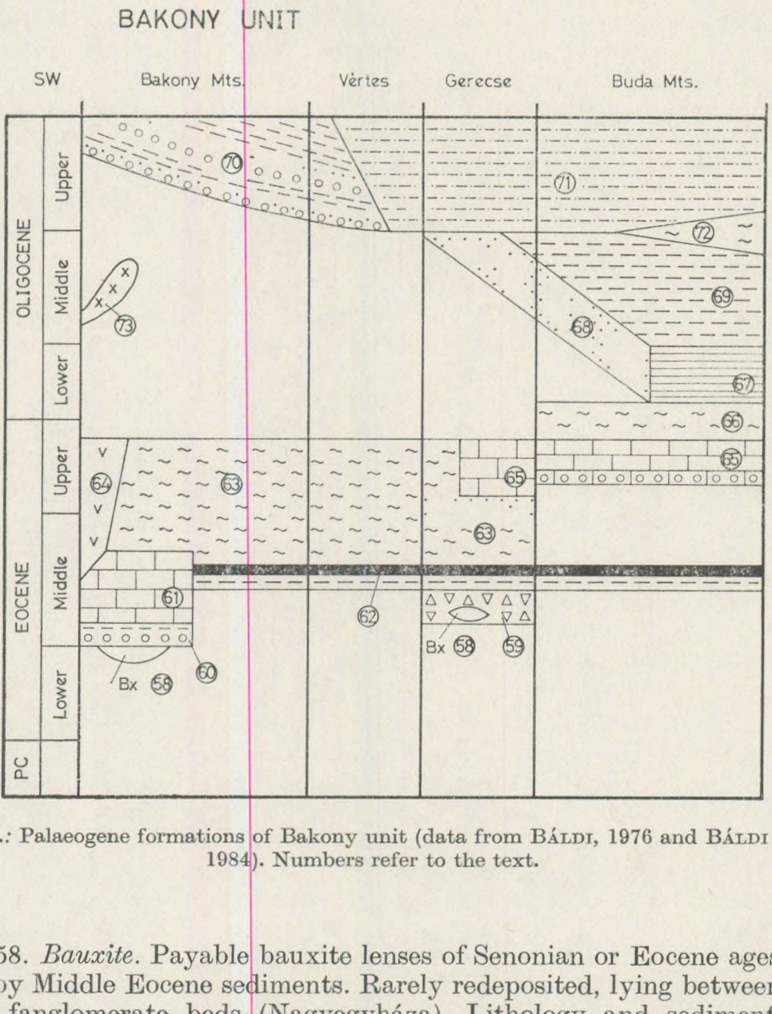

Fig. 6.: Palaeogene formations of Bakony unit (data from Báldi, 1976 and Báldi – Beke, 1984). Numbers refer to the text.

58. *Bauxite.* Payable bauxite lenses of Senonian or Eocene ages overlain by Middle Eocene sediments. Rarely redeposited, lying between dolomite fanglomerate beds (Nagyegyháza). Lithology and sedimentology: Komlóssy (1970), Mindszenty et al. (1984). Micromineralogy: Antal (1973), Vörös and Gecse (1976), Gecse (1982). Texture: Antal (1973), Mindszenty et al. (1984). Palaeogeography: Haas (1984). Fossils: nannoplankton: Báldi – Beke (1974), Brokés (1976); Spore-pollen: Rákosi (1977). Stratigraphy: Károly et al. (1970).

59. *Dolomite fanglomerate.* Upper Middle Eocene redeposited dolomite fragments and pebbles in dolomite siltstone matrix, Payable bauxite and rare coal seam intercalations. Lithology and palaeogeography: Végh (1977), Végh – Neubrandt et al. (1978), Fáy – Tátray (1984).

60. *Conglomerate, clay and limestone (Darvastó Formation).* Lower Middle Eocene. Lacustrine to marine basal beds of the Middle Eocene transgressive sequence. Stratigraphy: BÁLDI–BEKE (1984), KECSKEMÉTI and VÖRÖS (1975). Lithology: KECSKEMÉTI and VÖRÖS (1975), HAAS et al. (1984).

61. *Nummulites limestone (Hauptnummulitenkalk, Szőc Limestone Formation).* Middle Eocene. Shallow marine limestone, clayey marl and marl with abundant larger foraminifers, corallinacean algae, molluscs and corals. Lithology: HAAS et al (1984). Further references see under No. 63.

62. *Coal measures (Tatabánya Formation).* Upper Middle Eocene. The most important payable coal deposits of Hungary. Paralic coal seams with clay, marl and rare limestone intercalations. References see under No. 63.

63. *Fossiliferous marl (Halimba tuffitic formation, Mór Siltstone Formation, Dorog Marl Formation, Tokod Sandstone Formation and Piszke Marl Formation).* Middle to Upper Eocene. Grey marl, clay, siltstone with sandstone, tuffite and limestone intercalations. Deposited in shallow sublittoral to bathyal environments. Extremely rich in mega- and microfossils. Lithology and sedimentology: SÁRKÖZI–FARKAS (1973), DUDICH (1977). Micromineralogy: RADÓCZ–KOMÁROMY (1971). Carbonate microfacies: KECSKEMÉTI and VÖRÖS (1976). Geochemistry: CSÁSZÁR (1967), DUDICH (1981). Stratigraphy: BÁLDI–BEKE and KECSKEMÉTI (1983), BÁLDI–BEKE (1984), KOPEK et al. (1971). Palaeogeography: SZTRÁKOS (1975a), GIDAI (1977), DUDICH and KOPEK (1980), BALÁZS et al. (1981). Fossils: nannoplankton: BÁLDI–BEKE (1984); spore-pollen: KEDVES (1974), RÁKOSI (1973, 1978), RÁKOSI and TÓTH (1980); fossil woods GREGUSS (1967, 1969); larger foraminifers: KECSKEMÉTI and VAŇOVÁ (1972), KECSKEMÉTI (1974), JÁMBOR–KNESS (1973, 1981); smaller benthonic foraminifers: VITÁLIS–ZILAHY (1971); planktonic foraminifers: TOUMARKINE (1971), SAMUEL (1972), HORVÁTH–KOLLÁNYI (1983); molluscs: SZŐTS (1953), STRAUSZ (1966, 1974), KECSKEMÉTI–KÖRMENDY (1980); ostracods: MONOSTORI (1975a); echinoids: SZÖRÉNYI (1973).

64. *Andesite (Zala Andesite Formation, Nadap Andesite Formation).* Mostly pyroclastics, less lava rocks and dykes. Age: uncertain, probably Middle to Upper Eocene, but some dykes in Velence Mts. proved to be Middle Oligocene. Stratigraphy: GIDAI (1971). Mineralogy· SZÉKY–FUX and BARABÁS (1953), SZÉKY–FUX (1957). Petrology: NOSKE–FAZEKAS and EMBEY–ISZTIN (1975), ÓDOR et al. (1983), DARIDA–TICHY et al. (1984). Geochemistry: JUHÁSZ (1971), PANTÓ (1981).

65. *Nummulites limestone (Nagysáp Limestone Formation).* Upper Eocene. Shallow marine limestone with abundant coralline algae, larger foraminifers and echinoderm fragments. Stratigraphy: BÁLDI–BEKE (1984). Lithology and microfacies: MONOSTORI (1965), KÁZMÉR (1985). Further references see under No. 66.

66. *Buda marl (Buda Marl Formation).* Uppermost Eocene to Lowermost Oligocene. Bathyal marl with allodapic limestone beds. Lithology and micromineralogy: SZTRÓKAY (1932). Sedimentology: BODA and

Monostori (1972), Báldi (1983). Stratigraphy: Báldi (1983). Fossils: nannoplankton: Báldi–Beke (1972); plankton foraminifers: Sztrákos (1974). Palaeogeography: Sztrákos (1975a), Balázs et al. (1981), Báldi (1983).

67. *Laminated clay (Tard Clay Formation).* Lower Oligocene, bathyal, grey, clayey silt composed of alternating white, calcareous and dark, silty laminae. Deposited in anoxic environment. Rare sandstone, conglomerate, calcareous turbidite and tuffite intercalations. Lithology and sedimentology: Báldi (1983). Mineralogy of tuffites: Szabó Cs. and Szabó–Balog (1985). Calcareous turbidites: Varga (1982). Fossils: nannoplankton: Báldi–Beke (1977), Nagymarosy (1983); plants: Hably (1979); planktonic foraminifers: Sztrákos (1974), Horváth M. (1985); bivalves: Báldi (1980); ostracods: Monostori (1975b); fishes: Weiler (1933, 1938); mammals: Kretzoi (1940). Palaeogeography: Balázs et al. (1981), Báldi (1983). Stratigraphy: Báldi et al. (1984). 200 m.

68. *Siliceous sandstone (Hárshegy Sandstone Formation).* Middle Oligocene. Shallow marine quartz sandstone with siliceous matrix of hydrothermal origin. Conglomerate, siltstone and rare fireclay intercalations. Lithology: Báldi and Nagymarosy (1976). Stratigraphy and facies: Báldi et al. (1976). Foraminifers: Nagy–Gellai (1973). Molluscs: Báldi et al. (1976), Báldi (1983). 120 m thick.

69. *Foraminifer clay (Kiscell Clay Formation).* Middle Oligocene. Bathyal, grey, clayey silt. Sandy, tuffitic intercalations. Graded sandstone and fluxoturbidite beds. Lithology and stratigraphy: Báldi (1983). Fossils: Nannoplankton: Báldi–Beke (1974, 1977); foraminifers: Sztrákos (1974), Horváth M. and Tóth–Makk (1974); molluscs: Báldi (1983). 200 to 1000 m thick.

70. *Fluviatile beds (Csatka Formation).* Mostly pelite and sand with their conglomerate intercalations. Age: Oligocene to Early Miocene (Korpás, 1981) or Late Oligocene (Báldi, 1976). Lithology and palaeogeography: Korpás (1981). Nannoplankton: Brokés (1978).

71. *Marine sands (Mány Sandstone Formation, Törökbálint Sand Formation, Kováčov Sand Formation).* Upper Oligocene. Brackish to mostly normal marine, shallow to deep sublittoral sands with abundant mollusc fauna. Lithology and stratigraphy: Báldi (1973). Molluscs: Báldi (1973), Janssen (1984), Korpás (1981). Foraminifers: Kenawy (1968), Horváth M. (1981). Nannoplankton: Báldi–Beke (1977, 1980), Brokés (1978). Lithology and mineralogy: Csánk (1969).

72. *Marine pelites (Szécsény Schlier Formation, Eger Formation).* Upper Oligocene. Marine, deep sublittoral to bathyal clay and silts. Lithology and stratigraphy and mollusc fauna: Báldi (1973, 1983). Foraminifers: Kenawy (1968).

A detailed review of Upper Oligocene (Egerian) strata has been published in the "Chronostratigraphie und Neostratotypen" series (Báldi and Seneš, editors, 1975), including descriptions of foraminifers, molluscs, ostracods, vertebrates, nannoplankton, diatoms and palynoflora.

73. *Tonalite (Balatonfenyves Granodiorite Formation).* Middle Oligocene. Lies along the SW margin of Bakony unit. Possibly some of the andesite dykes at Velence Mts. are connected to this magmatism. Petrography and geochemistry: Ravasz–Baranyai and Ravasz (1971). K–Ar age: 30,7 m.y. (Balogh, Árva–Soós and Buda 1983).

VEPOR UNIT (Fig. 7)

Age – Palaeozoic to Oligocene.

Margins – Bakony unit to the south, separated by the Palaeogene Rába wrench fault. Extends to Czechoslovakia, to the Veporide unit of the West Carpathians.

Physiography – Subsurface unit in Hungary. Covered by Miocene sediments and the Middle Miocene Börzsöny volcano.

Stratigraphy – Palaeozoic micaschist and amphibolite schist, unconformably overlain by Oligocene marine clastics.

Igneous activity – Palaeozoic mafic pyroclasts.

Metamorphism – Variscan almandine-amphibolite facies with Alpine retrograde greenschist overprint.

Deformation – Variscan basement strongly folded; Alpine edifice slightly folded (in Czechoslovakia).

Tectonic position – Unknown, probably allochthonous.

Connections – Extends northwards to the Vepor unit of the West Carpathians.

Economic geology – None.

References: Nagy G. and Zsille (1971), Ravasz–Baranyai and Viczián (1976).

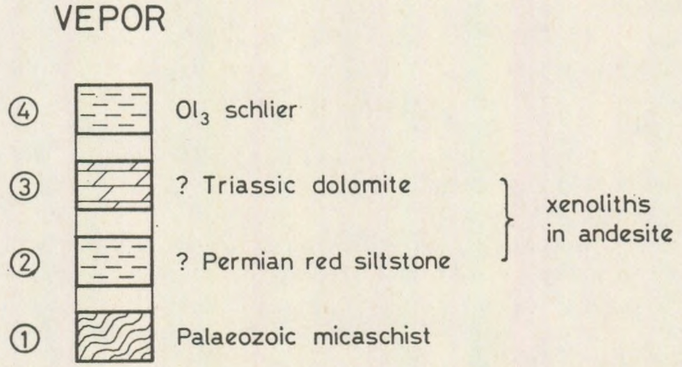

Fig. 7.: Hypothetical stratigraphic column of Vepor unit in Hungary Numbers refer to the text.

Stratigraphic details

1. *Micaschist.* Palaeozoic(?) garnet-micaschist, garnet-amphibolite schist. Variscan almandine-amphibolite facies metamorphism, followed by Alpine greenschist facies retrograde metamorphism. Petrology: RAVASZ–BARANYAI and VICZIÁN (1976).

2. *Red siltstone.* Found as xenoliths in Miocene andesites and pyroclastics in Ipolydamásd and Letkés boreholes. HÁMOR et al. (1973, p. 33) cconsidered them as Cretaceous (?) red marl of Púchov type, while HÁMOR (1976) wrote on Permian red siltstone and fine sandstone of Veporic type.

3. *Triassic dolomite xenoliths* in Miocene andesites. Mentioned by HÁMOR et al. (1973. p. 33).

4. *Upper Oligocene Schlier.* Clayey siltstone and glauconitic sandstone. Stratigraphy: BÁLDI–BEKE et al. (1980). Nannoplankton: BÁLDI–BEKE (1980).

IGAL UNIT (Fig. 8)

Age – Carboniferous to Oligocene.

Margins – Bakony unit to NE, separated by the Palaeogene Balaton wrench fault; Mecsek unit to SW, separated by the Zagreb–Zemplén wrench fault. Westward continuation to the Dinarides (Sava folds); eastern termination towards Bükk unit unknown.

Physiography – covered by Miocene marine to lacustrine sediments.

Stratigraphy – Stratigraphic column is highly speculative. Formations may belong to several tectonic units. Marine Carboniferous and Lower Permian limestone, fluviatile and lagoonar Upper Permian sandstone and dolomite; marine Lower Triassic; Middle to Upper Triassic neritic carbonates; unconformably overlain by neritic Eocene sediments and marine Oligocene clays.

Igneous activity – Triassic(?) ophiolites(?), Palaeogene intermediate volcanism.

Metamorphism – None.

Deformation – Probably folded with overthrusts. Transcurrent faulting might have caused the formation of an extremely complicated tectonic melange.

Tectonic position – Unknown.

Connections – Stratigraphic column similar to Western Dinarides, the Sava folds and Karavanka Mts.

Economic geology – None.

Notes – Several tectonic slivers – Devonian to Permian in age – are located at the northern margin of Igal unit. These are discussed in the section on Bakony unit, together with Oligocene tonalite plutons.

References – SZTRÁKOS (1975b). No up-to-date summary exists on the Palaeozoic and Mesozoic of Igal zone. For details see the hypothetical stratigraphic column.

Stratigraphic details

1. *Upper Carboniferous limestone.* Yellowish white marine limestone pebbles in probably Tertiary conglomerate in Karád – 1 borehole. Foraminifers: MAJZON (1956; 1966, p. 564, p. 569: pl. 50, figs. 3 – 6).

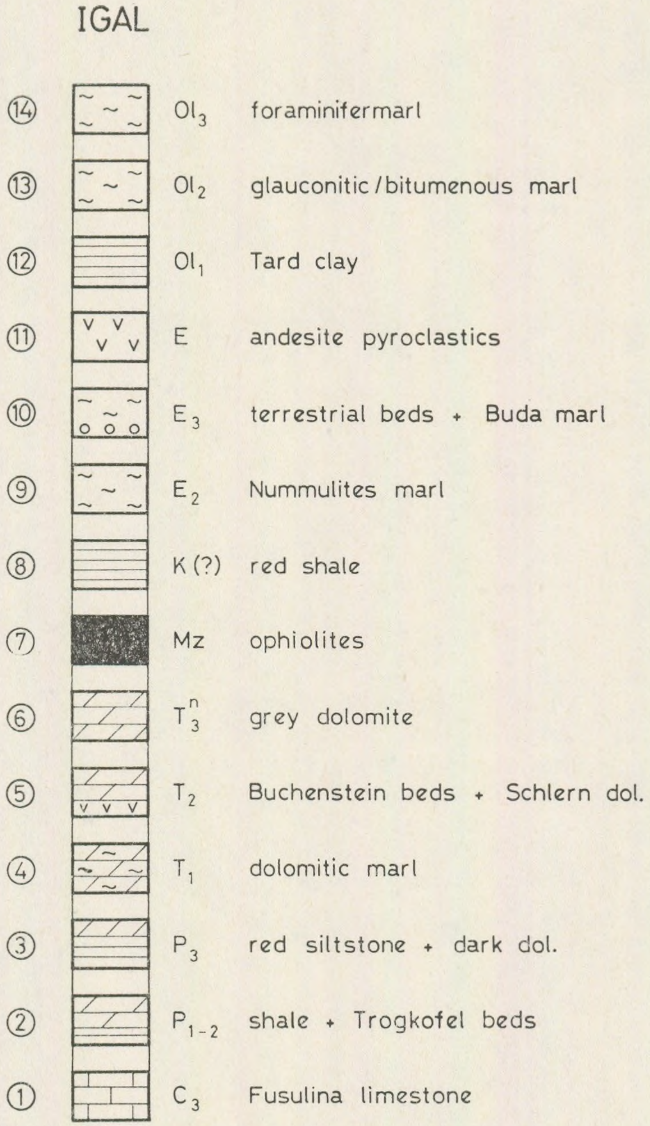

Fig. 8.: Hypothetical stratigraphic column of Igal unit. Note that all formations are known from the subsurface only, forming tectonic scales of unknown position. No stratigraphic contacts are known, except in the Oligocene. Numbers refer to the text.

2. *Lower to Middle Permian sediments (Újfalu Limestone Formation).* Marine fine quartz sandstone and shale with dark dolomite beds and reef detritus (800 m thick), overlain by 350 m dark dolomite and limestone (Újfalu – 1 borehole). Lithology, stratigraphy, calcareous algae and foraminifers: Bérczi – Makk and Kochansky – Devidé (1981). 1150 m total apparent thickness.

3. *Upper Permian sediments.* Three boreholes: Sári – 2 (Bérczi – Makk 1978). Bugyi – 5 (Sidó in Sidó et al., 1974. p. 24, footnote) and Tab – 1 (Szabó I. in Jámbor, 1976, p. 265, p. 270) recovered Upper Permian dark red calcareous siltstone and dark dolomite and limestone. Total apparent thickness in Sári – 1: 270 m. Foraminifers and algae: Bérczi – Makk (1978b).

4. *Lower Triassic foliated (dolomitic) marl.* Localities: boreholes Bugyi – 5 and Pánd – 1. Lithology. stratigraphy and foraminifers: Bérczi – Makk 1976, p. 107).

5. *Middle Triassic tuffitic Buchenstein beds* overlain by thick algal dolomite. Localities: boreholes Seregélyes – 1 and Kápolnásnyék – 1 (dolomite only). Mentioned by Haas (1980a) on p. 63. and Vető-Ákos (1977, p. 295).

6. *Upper Triassic, Norian grey dolomite.* Locality: borehole Igal – 7. Mentioned by Haas and Jámbor (1983, p. 33).

7. *Mesozoic ophiolites* of unknown tectonic and stratigraphic position occur in this belt. Localities: Inke – 9 and Tóalmás – 2 boreholes: basalt, spilite, gabbro and radiolarite. In Lepavina – 1 borehole (in Yugoslavia, at the Hungarian border) harzburgite occurs (Szepesházy, 1977). Geochemical data: Juhász and Vass (1974, Tab. 7).

8. *Cretaceous (?) red claystone, siltstone, conglomerate.* Localities: Nagykáta – 1, Tóalmás – 2 boreholes (mentioned by Sztrákos, 1975a).

9. *Middle Eocene (?) clay, marl and siltstone* with Nummulites. Locality: Tóalmás – 1 and – 3 boreholes (Sztrákos, 1975a).

10. *Upper Eocene terrestrial, variegated clay, silt, conglomerate* (150 m), overlain by freshwater sandstone and clay with coal beds and dacite tuff intercalations (50 m), then by Buda marl, also with tuffs. Localities: boreholes at Bugyi and Sári (Sztrákos, 1975a). In Újhartyán borehole 450 m clay, marl and siltstone with dacite tuff (Juhász, 1971).

11. *Eocene(?) andesite and andesito-dacite pyroclastics* (300 m) in Tab borehole. Mentioned by Jámbor (1976. p. 265).

12. *Lower Oligocene Tard clay* (200 m) with thick sandstone intercalations (Hárshegy sandstone on Fig. 104 of Báldi, 1983), and tuffite beds. Localities: boreholes Tóalmás – 1, – 2, – 3, Nagykáta – 1 (Sztrákos, 1975a).

13. *Middle Oligocene clay and marl* in Bugyi – 2, – 3 and Sári – 1, – 2 boreholes of max. 340 m apparent thickness (Juhász, 1971) with tuffite beds. Glauconitic and bituminous marl, clay with foraminifer fauna, sandstone at Buzsák boreholes in five tectonic scales (Sztrákos, 1975b).

14. *Upper Oligocene sandstone and clayey marl* in Buzsák and Karád boreholes (Sztrákos, 1975b).

BÜKK UNIT (Figs. 9–10)

Age – Ordovician to Oligocene.

Margins – Gemer and Aggtelek–Rudabánya units to N; Zemplén unit to E, separated by Miocene(?) Hernád wrench fault; Mecsek unit to S, separated by Miocene Zagreb–Zemplén wrench fault; Bakony and Igal units to W, separated by wrench fault.

Physiography – uplifted, dissected plateaus and low to middle hills.

Stratigraphy – Ordovician to Lower Carboniferous pelagic shales with olisthostromes; Devonian reef limestones, conformably overlain by Upper Carboniferous neritic shale, limestone and conglomerate; Permian terrestrial to neritic clastics, evaporites and limestones, Triassic neritic limestones; Triassic and Jurassic shales and radiolarites with ophiolites and olisthostromes; unconformably overlain by Upper Cretaceous marine conglomerate; unconformably overlain by Eocene terrestrial conglomerate, neritic limestones and bathyal marls, Oligocene bathyal to neritic shales, clays and sands.

Igneous activity – Upper Devonian, Middle Triassic and Jurassic, mostly tholeiitic basalts; Upper Eocene calc-alkaline andesites.

Metamorphism – Mesozoic Alpine greenschist facies, Mesozoic Alpine zeolite facies. No metamorphism since Late Cretaceous.

Deformation – Palaeozoic and Mesozoic are strongly folded and form several nappes; Upper Cretaceous folded(?); Palaeogene: faulted.

Tectonic position – Probably allochthonous nappe systems.

Connections – Western Dinaride and to Carnic Alps (through Igal unit?).

Economic geology – Large copper, lead and zinc and molybdenum mineralization connected with Eocene andesite intrusions; oil in Palaeogene sandstone reservoirs; cement industry on Triassic limestones and Miocene clays.

References – Palaeozoic: KOVÁCS and PÉRÓ (1983); Mesozoic: BALOGH, KOZUR and PELIKÁN (1984); Palaeogene: BÁLDI (1982).

Stratigraphic details

Palaeozoic (after KOVÁCS and PÉRÓ, 1983) (Fig. 9)
Regional studies on metamorphism: Árkai (1983).

1. *Shale, lydite, sandstone with metabasalts. Mn-rich. (Tapolcsány Formation).* Possibly Silurian. No fossils. KOZUR (1984b) has found a Silurian conodont in a lydite pebble of an Upper Carboniferous(?) conglomerate in borehole Nagybátony 324.

2. *Olisthostrome.* Siegenian to Eifelian, with Llandoverian to Siegenian olistholiths. Limestone olistholiths embedded in calcareous matrix mixed with basic volcaniclastic substance. Composition: tholeiitic metabasalt. Olistholiths: Lower Devonian grey crinoid limestone and Silurian red or green micritic limestone with brachiopods and orthoceratid nautiloids. Similar to the "Schalstein" of the German Devon. Conodonts: KOVÁCS (1981). Petrology and geochemistry: KOVÁCS and VETŐ–ÁKOS (1983). Suffered greenschist metamorphism.

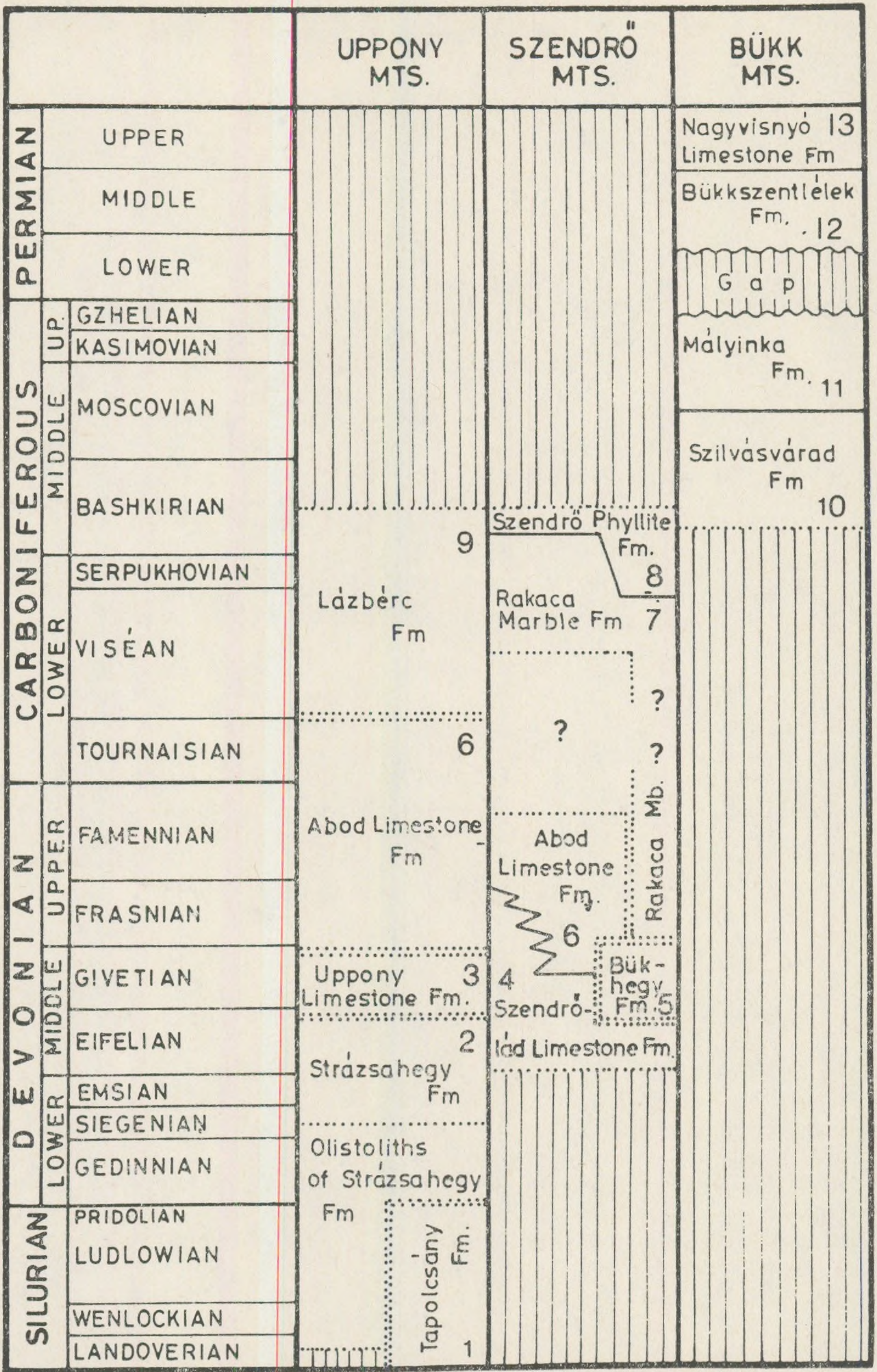

Fig. 9.: Palaezoic formations of Bükk unit (Kovács and Péró, 1983). Numbers refer to the text.

3. *Massive crystalline limestone, white, of a Devonian(?) carbonate platform (Uppony Limestone Formation)*. Probably Eifelian to Givetian.

4. *Calcareous shale with coral bioherms (Szendrőlád Limestone Formation)*. Eifelian to Frasnian. Tabulate corals: MIHÁLY (1978). Crinoid columnals and stratigraphy: MIHÁLY (1976).

5. *Limestone* deposited on a possible carbonate platform *(Bükhegy Limestone Formation)*. Givetian.

6. *"Cippolino" (Givetian to Frasnian) crystalline limestone* with basic metatuffites; green tuffite and black shale intercalations. Also contains basic volcanoclastics, which originally mixed with lime mud (KOVÁCS and VETŐ–ÁKOS, 1983).

7. Shallow-water carbonate platform, overlain by deep-water limestones *(Rakaca Limestone Formation)*. (Frasnian?-) Visean to Bashkirian.

8. *Hochwipfel flysch (Szendrő Phyllite Formation)*. Uppermost Visean to Bashkirian. 600–800 m thick shales (immature sandstone, siltstone, claystone) with calcareous olisthostromes and allodapic limestone beds. Lithology and geochemistry: RAINCSÁK–KOSÁRY (1978).

9. *Platy limestone, grey, with shales. No olisthostromes (Lázbérc Formation)*. Conodonts: KOZUR and MOCK (1977a).

10. *Shale, Bashkirian to Moscovian (Szilvásvárad Formation)*. No carbonates. Thickness: 1100 m. Stratigraphy and lithology: BALOGH (1964).

11. *Fossiliferous shale and limestone (Mályinka Formation)* Moscovian to Gzhelian. 400 m thick shale with phylloid algal – fusulinid limestone lenses, coral bioherms and conglomerate-sandstone beds. Similar to the Auernig beds of the Carnic Alps. Stratigraphy and lithology: BALOGH (1964); fossils: calcareous algae: HERAK and KOCHANSKY: 1963), NÉMETH (1974); palynoflora: GÓCZÁN (1971b); foraminifers: fusulinids: ROZOVSKAYA (1963), smaller foraminifers: SIDÓ in SIDÓ et al. (1974); bivalves, gastropods, brachiopods: RAKUSZ (1932); ostracods: KOZUR (1984b, c), holothurian sclerites: KOZUR (1984b, c); conodonts: KOVÁCS, KOZUR and MOCK (1983), KOZUR (1984b, c).

12. *Detrital and evaporitic sequence (Bükkszentlélek Formation)*. Middle Permian. Sandstone and siltstone overlain by anhydrite. (KOVÁCS and PÉRÓ, 1983).

13. *Black algal limestone (Nagyvisnyó Limestone Formation)*. Upper Permian. Similar to Bellerophon beds of the Carnic Alps. Stratigraphy and lithology: BALOGH (1964), ANTAL (1975). Carbonate microfacies: ANTAL and BALOGH (1980). Fossils: calcareous algae: HERAK and KOCHANSKY (1963); foraminifers: SIDÓ in SIDÓ et al. (1974); calcareous sponge: FLÜGEL (1973); nautiloids: SCHRÉTER in SIDÓ et al. (1974); brachiopods: SCHRÉTER (1963); ostracods: ZALÁNYI in SIDÓ et al. (1974), KOZUR and MOCK (1977b), KOZUR (1981); holothurian sclerites: KOZUR and MOCK (1977b); conodonts: KOZUR and MOCK (1977b).

Mesozoic

The Triassic is discussed after BALOGH (1981) with some modifications. keeping in mind that his formations can belong to several tectonic units (nappes). A first attempt to recognize nappes in the Triassic has been pub-

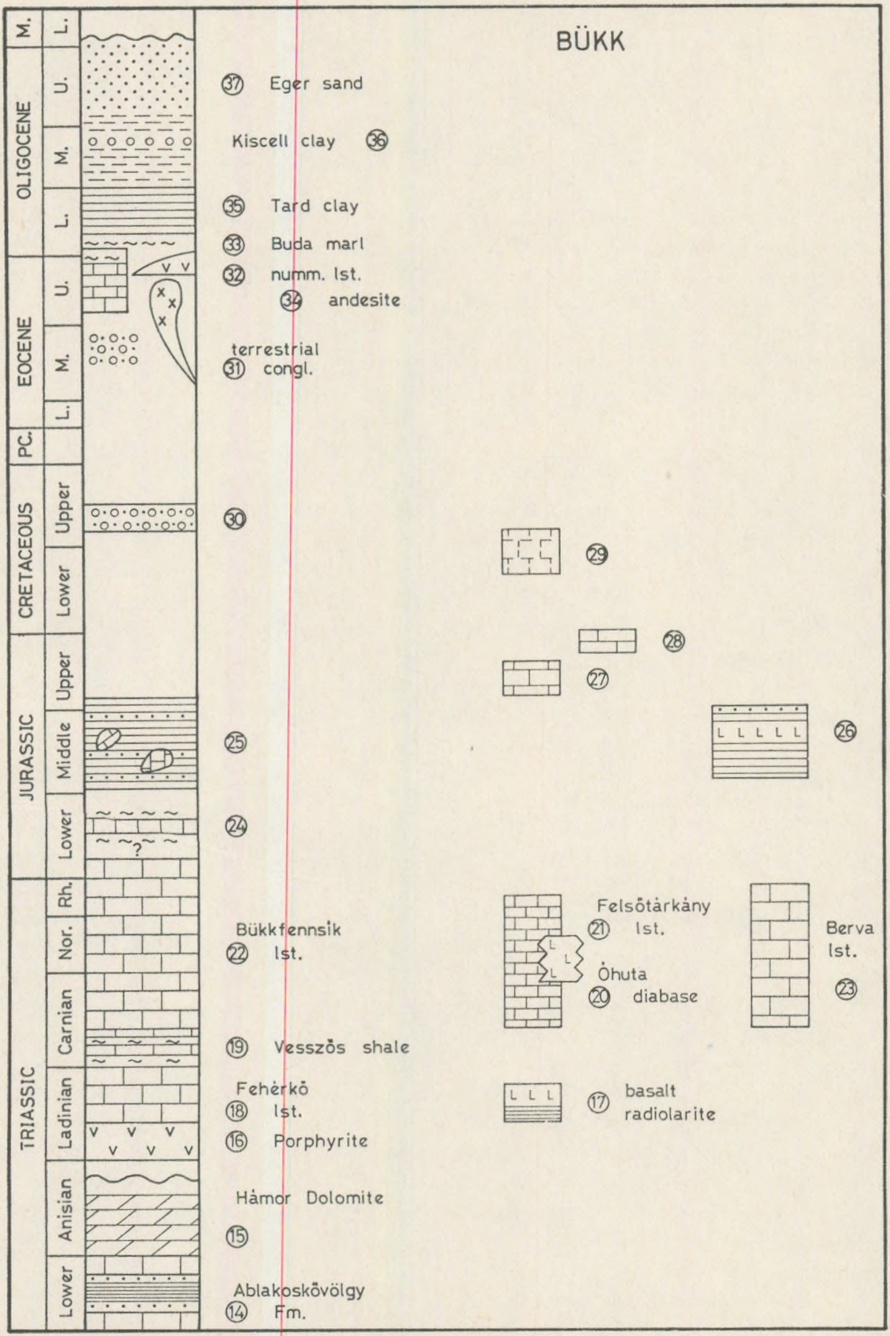

Fig. 10.: Mesozoic and Palaeogene formations of Bükk unit (Triassic after CSÁSZÁR and HAAS, 1983, modified). Numbers refer to the text.

lished by Balogh et al. (1984). Nappes in the Jurassic have been recognized by Balla et al. (1980). Lithology is after Balogh (1964).

14. *Limestone and shale (Abalakoskővölgy Formation).* Lower Triassic. Interbedded ooidic limestone and marly shale. 600 m thick. Foraminifers: Bérczi – Makk (1976).

15. *Dolomite (Hámor Dolomite Formation).* Anisian. 200 m thick. Dolomite with few foraminifers locally interfingering with neritic limestone and thin variegated (terrestrial?) shale.

16. *Andesite (Szentistvánhegy Porphyrite Formation).* Lower Ladinian. 250 m thick. Lowermost Ladinian lava rocks and pyroclastics of andesitic, rhyolitic and basaltic composition (Pantó, 1962). Petrology: Szentpétery (1934, 1937).

17. *Basalt flows (Pillow lava)* with radiolarite intercalations at Darnóhegy locality. May belong to Rudabánya unit. Ladinian radiolarians: De Wever (1983, pers. comm.) Petrology and geochemistry: Balla et al. (1980).

18. *Limestone (Fehérkő Limestone Formation)* Ladinian. Light grey, bedded, unfossiliferous, with a thin red nodular intercalation.

19. *Shaly limestone* (Balogh et al., 1984). *(Vesszős Shale Formation).* Lower Carnian.

20. *Basalt. (Óhuta Diabase Formation).* Carnian to Norian. Lava rocks and pyroclastics. Stratigraphy: Balogh et al. (1984).

21. *Cherty limestone (Felsőtárkány Limestone Formation).* Carnian to Rhaetian. Pelagic. Stratigraphy: Balogh et al. (1984).

22. *Light neritic limestone (Bükkfennsík Limestone Formation).* Carnian to Rhaetian. Probably platform facies. Stratigraphy: Balogh et al. (1984).

23. *Neritic limestones* of uncertain stratigraphic and tectonic position. (*Répáshuta Limestone Formation, Bervavölgy Limestone Formation,* etc.) Upper Triassic.

Jurassic – Cretaceous

24. *Limestone.* Liassic. Allodapic limestones and/or olisthostromes in radiolarian marl. Contains foraminifers: Bérczi – Makk and Pelikán (1984).

25. *Shale (Kisgyőr Shale Formation).* Middle to Upper Jurassic. Calcareous to siliceous shales with sandstone beds. Bajocian radiolarians: Kozur (1984a). Contains Dogger – Lower Malmian limestone olisthostromes in radiolarian shales. Foraminifers: Bérczi – Makk and Pelikán (1984).

26. *Basalt and gabbro.* Middle Jurassic (Balogh et al., 1984) mafic intrusive and volcanic rocks in the Middle – Upper Jurassic shale-sandstone complex. Field observations and map: Balla (1983). Petrology and geochemistry: Balla et al. (1980, 1983), Balla and Dobretsov (1984), Kubovics (1984). The mafic complex forms four tectonic units one above the other (Balla, 1983).

27. *Neritic limestone* Upper – Oxfordian to Kimmeridgian foraminifer limestone (pebbles in Senonian Nekézseny conglomerate). Lithology and foraminifers: Mišík and Sýkora (1980). May belong to other unit.

28. *Algal limestone.* Tithonian. Lithology and calcareous algae: Mišík and Sýkora (1980). Pebbles in Senonian Nekézseny conglomerate. May belong to other unit.

29. *Freshwater limestone.* Barremian – Lower Campanian, with calcareous algae: Mišík and Sýkora (1980). Pebbles in Senonian Nekézseny conglomerate. May belong to other unit.

30. *Conglomerate turbidites (Nekézseny Conglomerate Formation).* Campanian. Sedimentology: Brezsnyánszky and Haas (1984). Palynoflora: Siegl – Farkas (1984).

Palaeogene

For further references see the appropriate paragraphs on Eocene and Oligocene formations of Bakony unit.

31. *Terrestrial conglomerate.* Middle to Upper Eocene. Quartzite conglomerate in red clay matrix. Apparent thickness: 270 m. Lithology: Balogh (1964).

32. *Nummulites limestone.* Upper Eocene. Neritic limestone with Nummulites and coralline algae. Lithology: Kázmér and Varga (1983). Foraminifers: Zilahy (1967). For further references see No.65 in Bakony unit.

33. *Buda marl (Buda Marl Formation).* Uppermost Eocene to Lowermost Oligocene. Pelagic marl with allodapic limestone beds. For further references see No.66 in Bakony unit.

34. *Andesite (Recsk Andesite Formation).* Middle to Upper Eocene subvolcanic intrusion with copper porphyry, polymetallic and skarn ores. Stratovolcanic effusive complex with enargitic-luzonitic mineralization. Stratigraphy: Baksa et al. (1974). Intrusion: Zelenka (1975), petrology and geochemistry: Baksa (1975). Stratovolcanic complex: Földessy: (1975). Ore geology: Baksa (1983).

35. *Tard clay (Tard Clay Formation).* Lower Oligocene. Laminated clay deposited in anoxic environment. For further references see No.67 in Bakony unit.

36. *Kiscell clay (Kiscell Clay Formation).* Middle Oligocene. Bathyal foraminiferal pelite with fluxoturbidite intercalations. (Báldi, 1983). For further references see No.69 in Bakony unit.

37. *Eger sand (Eger Formation).* Upper Oligocene. Rich mollusc fauna; also pelite, (Báldi, 1973). For further references see No.72 in Bakony unit.

RUDABÁNYA UNIT

Age – Late Permian to Jurassic.

Margins – Silica unit N; Bükk unit S.

Physiography – dissected low to middle hills.

Stratigraphy – Upper Permian to Lower Triassic(?) black shale, Triassic basin and platform carbonates, Jurassic pelagic shales with olisthostromes.

Igneous activity – Middle Triassic ophiolites in the basal melange of Silica nappe may belong to Rudabánya unit.

Metamorphism – Non-metamorphic, very low grade and greenschist facies metamorphic nappes.

Deformation – Overthrust, folded nappes.

Tectonic position – allochthonous.

Connections – Meliata unit in Slovakia, Bükk Mts., Inner Western Dinarides.

Economic geology – Permian–Lower Triassic anhydrite and gypsum; metasomatic-hydrothermal siderite, copper ores and baryte in Middle Triassic limestones.

References – BALOGH K. (1982), GRILL et al. (1984).

Stratigraphic details cannot be outlined as yet. GRILL et al. (1984) gave a short account on the evolution of the Rudabánya region between Silica (their Aggtelek) unit and Bükk unit, but description of the formations has not been given yet. However, we know that the Rudabánya region contains sediments and igneous rocks formed in a Middle Triassic–Middle Jurassic spreading ocean (GRILL et al., 1984). The siderite and copper mineralisation at Rudabánya village which has been worked for centuries has been described by PANTÓ (1956), but several of his stratigraphic informations are now out of date.

SILICA UNIT (Fig. 11)

Age – Permian to Cretaceous.

Margins – Rudabánya unit to S; Gemer unit to W; extends to Czechoslovakia.

Physiography – uplifted plateau.

Stratigraphy – Upper Permian sandstones and evaporites; Lower Triassic sandstones and shales; Middle to Upper Triassic platform and basin carbonates; Jurassic limestones; unconformably overlain by Middle Cretaceous lacustrine limestones.

Igneous activity – Middle Triassic ophiolites in the evaporite melange of the basal thrust zone, probably originating from Rudabánya (Meliata) unit.

Metamorphism – None.

Deformation – Minor overthrusts; faults.

Tectonic position – Allochthonous on Meliata unit in Slovakia and possibly on Rudabánya unit in Hungary.

Connections – Upper Austroalpine.

Economic geology – Permian–Lower Triassic anhydrite-gypsum.

References – BALOGH, DOBOSI et al, (1983), MIŠÍK and SÝKORA (1980), GRILL et al. (1984).

Stratigraphic details

Studies on regional geology: Bystrický (1964), Kovács (1979), Balogh and Dobosi et al. (1983), Grill et al. (1984).

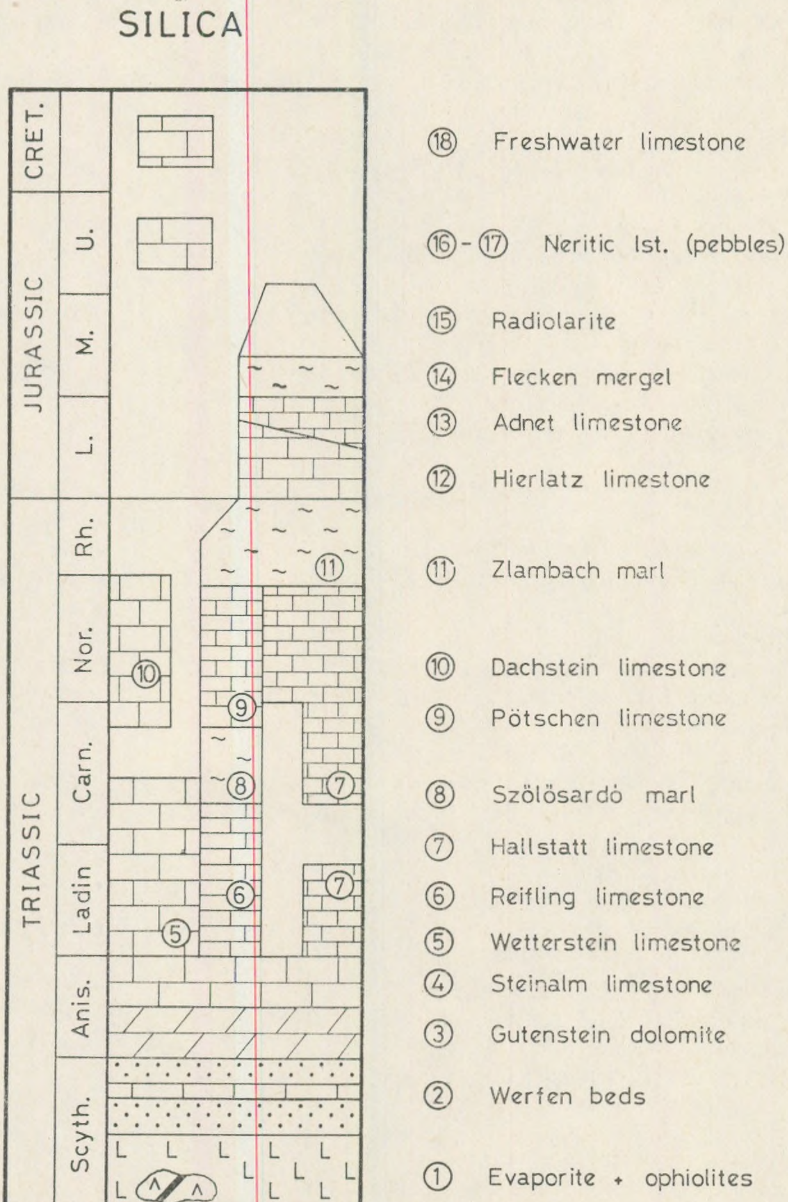

Fig. 11.: Stratigraphic column of Silica nappe in Hungary (after Mišík and Sýkora, 1981, Császár and Haas, 1983, Grill et al., 1984). Numbers refer to the text.

1. *Perkupa evaporite with ophiolites (Perkupa Anhydrite Formation).* Lowermost Triassic(–Upper Permian). Gypsum and anhydrite in siltstone-sandstone beds. Workable. Contains pillow basalt, gabbro and serpentinite bodies of Ladinian age. Petrology and geochemistry of ophiolites: Réti (1984).

2. *Werfenian sandstone, siltstone, shale and limestone.* Also dolomite. Deposited in lagoonal environment. Scythian.

3. *Gutenstein dolomite and limestone.* Dark, without fossils, deposited in shallow marine restricted environment. Lower Anisian.

4. *Steinalm limestone.* Upper Anisian. Fossil-rich platform limestone. Lithology and sedimentology: Balogh and Kovács (1981). Sphinctozoan calcareous sponges: Kovács (1978a).

5. *Wetterstein limestone and dolomite.* Ladinian to Lower Carnian. Fossil-rich platform and reef limestone. No fossils in the dolomite. Reef studies, microfacies, calcareous algae, sphinctozoans, brachiopods, molluscs: Scholz (1972). Sphinctozoans: Balogh and Kovács (1976), Kovács (1978a, b).

6. *Reifling and Nádaska limestone.* Ladinian to Lowermost Carnian. Reifling: deposited in a relatively deep, restricted basin. Nádaska: syndiagenetic slope breccia. Lithology and sedimentology: Balogh and Kovács (1981). Conodonts: Kovács (1977).

7. *Hallstatt limestone.* Ladinian to Norian. Open marine nodular limestone. Bivalves: Balogh (1976).

8. *Szőlősardó marl.* Carnian. Open marine carbonate sedimentation with terrigenous influx. Lithology, sedimentology and conodonts: Balogh and Kovács (1981).

9. *Pötschen limestone* deposited in a restricted basin. Upper Carnian to Norian. Lithology and sedimentology: Balogh and Kovács (1981).

10. *Dachstein reef limestone.* Upper Carnian to Norian. Local name: Furmanec limestone. Platform and reef.

11. *Zlambach marl.* Rhaetian. Basin carbonates with terrigenous influx.

12. *Hierlatz limestone.* Lower Jurassic. Coarse, sparitic carbonate sandstone deposited on platform edges and slopes.

13. *Adnet limestone.* Lower Jurassic. Open marine nodular limestone.

14. *Fleckenmergel.* Lower Middle Jurassic. Mottled marl, deposited in open marine basin with terrigenous influx.

15. *Radiolarite.* Possibly Middle Jurassic, deposited below CCD.

16. *Shallow marine limestones* with foraminifers. Upper Oxfordian to Kimmeridgian. Occur as pebbles in Upper Cretaceous conglomerates. Derived from Bükk or Silica unit. Lithology and palaeontology: Mišík and Sýkora (1980).

17. *Algal limestone.* Tithonian. Neritic, occurs as pebbles in Upper Cretaceous conglomerates. Derived from Bükk or Silica unit. Lithology and palaeontology: Mišík and Sýkora (1980).

18. *Lacustrine limestone.* Deposited in Barremian to Lower Campanian interval. Derived from Bükk or Silica unit. Lithology and palaeontology: Mišík and Sýkora (1980).

GEMER UNIT

Age – Cambrian – Permian (– Triassic ?)
Margins – E: Silica nappe, separated by an overthrust(?) fault; S: Bükk unit, boundary unknown; W: Vepor unit, boundary unknown; N: extends to Czechoslovakia.
Physiography – subsurface unit below thick Neogene cover.
Stratigraphy – (in Czechoslovakia); Palaeozoic pelites and sandstones with acidic and basic volcanics; unconformably overlain by marine Upper Carboniferous shales and limestones and fluviatile Permian sandstone. Pelagic Triassic cover may be autochthonous or allochthonous.
Igneous activity – Early Palaeozoic acidic and basic magmatism (incl. formation of ophiolitic complex); Variscan and Cretaceous granitoids; Triassic ophiolitic complex.
Metamorphism – Variscan greenschist facies; Alpine blueschist and greenschist facies.
Deformation – Strongly folded; forms Variscan and Alpine nappes.
Tectonic position – Autochthonous.
Connections – Marine Upper Carboniferous shows Western Dinaride affinities.
Economic geology – various base metal mineralization; magnesite in limestone bioherms.
Reference – GRECULA (1982)

Stratigraphic details

Shale, phyllite and sandstone (BALOGH, 1966, p. 20) as xenoliths in Miocene andesites and Pliocene – Quaternary basalts. Subsurface occurrences proven by boreholes are in Slovakia at Lucenec, etc. Belongs to Gemer unit of the Innermost Western Carpathians. Presence of this unit in Hungary is highly hypothetic.

ZEMPLÉN UNIT (Fig. 12)

Age – Palaeozoic to Jurassic.
Margins – W: Bükk unit, separated by Miocene(?) Hernád wrench fault; S: Mecsek unit, separated by Miocene(?) Zagreb – Zemplén wrench fault; N and E: extends to Czechoslovakia and Soviet Union.
Physiography – Low hills and alluvial plains.
Stratigraphy – Upper Precambrian or Lower Palaeozoic pelites and volcanics, granitoids and sandstones; unconformably overlain by Upper Carboniferous terrigenous rocks, Permian and Lower Triassic clastics and evaporites, Triassic carbonates, Triassic and possibly Jurassic pelites.
Igneous activity – Palaeozoic acidic volcanism and granitoids.
Metamorphism – Variscan greenschist and amphibolite facies.

Deformation – Alpine thrusts of SW vergence.
Tectonic position – Autochthonous.
Connections – SW end of Mecsek unit.
Economic geology – Minor Upper Carboniferous coal deposits.
References – Grecula and Együd (1977), Lelkes–Felvári and Sassi et al. (1981).

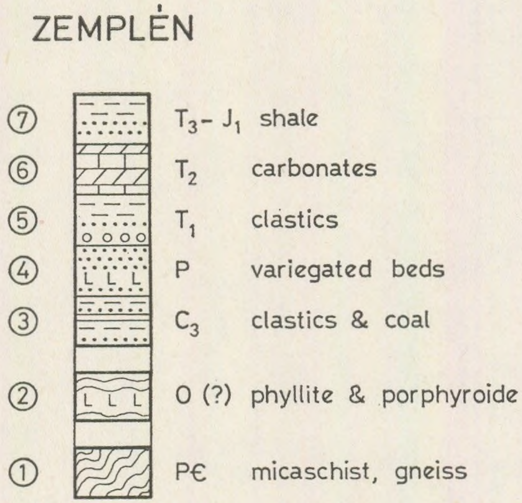

Fig. 12.: Stratigraphic column of Zemplén unit. Numbers refer to the text.

Stratigraphic details

1. *Micaschist.* Precambrian(?). Micaschist, gneiss, amphibolite metamorphosed in amphibolite facies with Variscan retrograde overprint. Stratigraphy: Pantó (1965). Petrology: Lelkes–Felvári et al. (1981). Rb–Sr cooling age 962 ± 39 m.y. (Pantó et al., 1967).

2. *Porphyroide and phyllite.* Possibly Ordovician acidic pyroclastics and pelitic sediments affected by greenschist facies metamorphism. Stratigraphy and petrography: Pantó (1965). K–Ar cooling ages: 222 ± 9 m.y., 307 ± 14 m.y. (Lelkes–Felvári et al. 1981).

Upper Palaeozoic and Triassic lithology is summarized after Grecula and Együd (1977). Megaflora and palynoflora are described by Planderová et al. (1981).

3. *Upper Carboniferous greywacke.* Stephanian psephite, psammite and pelite with black shale intercalations containing coal seams. Deposited in a deltaic to littoral environment. 1800 m thick.

4. *Permian variegated sandstone.* Terrestrial to lagoonal variegated beds and rhyolitic volcanics. 600 m thick.

5. *Lower Triassic conglomerates, sandstone and quartzite,* higher up with dark marly shale. 80 m thick.

6. Middle Triassic *dark limestone and dolomite*. 300 m.

7. Upper Triassic(?) to Lower Jurassic(?) *dark sandstone and black shale*. 150m thick.

MECSEK UNIT (Figs. 13 – 14)

Age – Early Palaeozoic to Oligocene.

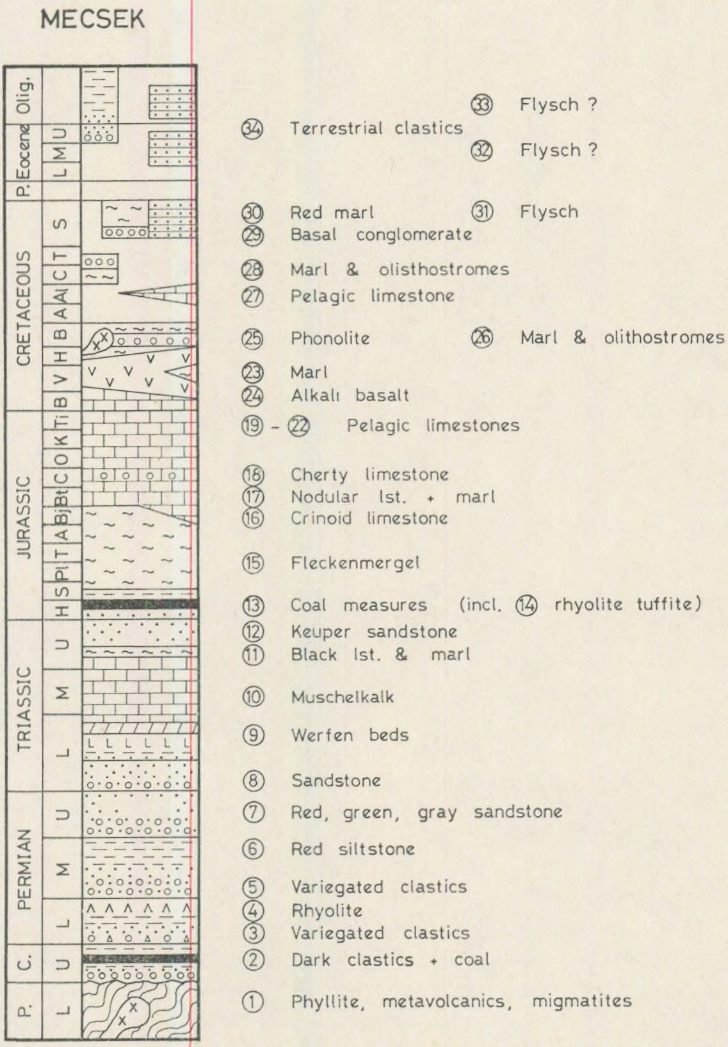

Fig. 13.: Palaeozoic to Triassic formations of Mecsek unit. Numbers refer to the text.
Fig. 14.: Jurassic to Palaeogene formations of Mecsek unit. Numbers refer to the text.

Margins – Igal, Bükk and Zemplén units to N, separated by Miocene(?) Zagreb–Zemplén wrench fault; Villány unit to S, separated by faults of unknown character; SW extends to Yugoslavia, eastwards extends to Romania and Soviet Union.

Physiography – Dissected low to middle hills; mostly alluvial plains.

Stratigraphy – Lower Palaeozoic metapelites, metavolcanics and Variscan granitoids and migmatites; unconformably overlain by Upper Carboniferous and Permian fluviatile clastics, germano-type Triassic and Lower Jurassic, Middle Jurassic to Cretaceous pelagic shales and limestones with basalt intercalations, Palaeogene flysch and lacustrine sediments.

Igneous activity – Early Palaeozoic acidic to mafic volcanism, Variscan migmatization, Early Jurassic tuffites, Early Cretaceous submarine alkaline basaltic volcanism.

Metamorphism – Variscan zeolite, greenschist and amphibolite facies; Variscan migmatization.

Deformation – Strong Variscan folding; weak Late Mesozoic folding in the west; Miocene folding in the east.

Tectonic position – Probably autochthonous in the west; possibly allochthonous in the eastern part.

Connections – Maramureş flysch units in Romania; Pieniny Klippen Belt of the Carpathians.

Economic geology – Permian uraniferous sandstones; Liassic coal deposits; oil and gas reservoirs in Upper Cretaceous and Palaeogene flysch.

References – WEIN (1968).

Stratigraphic details

1. *Crystalline basement.* Four groups of rocks are distinguished following LELKES–FELVÁRI et al. (1981) in decreasing metamorphic order.

a) *Granitoid-migmatitic complex* formed by anatexis and high-grade (cordierite, sillimanite, staurolite) metamorphism.

b) *Low to high grade metamorphic complex* (chlorite to sillimanite zones) showing all metamorphic zones with an extremely complex history (for a metamorphic evolution see ÁRKAI, 1984). Eclogite occurs. Source rocks: pelites-semipelites with carbonate intercalations and mafic volcanics.

c) *Greenschist* (to amphibolite?) complex. Source rocks: pelites-semipelites, carbonate intercalations, mafic and acid volcanics. Also serpentinized pyroxenites (harzburgite: BALLA, 1981).

d) *Low grade complex.* Pumpellyite-prehnite facies. Source rocks: siliceous shales, lydites with volcanic agglomerates and tuffs of mafic to intermediate composition. Fossils: Silurian conodont and acritarchs: GÓCZÁN (1971a), KOZUR (1984a).

These four complexes form the crystalline basement of Mecsek and Villány units. Their boundaries in the basement cannot be determined as yet, as most localities are subsurface.

Age of the complexes is disputed, but available radiometric data (Árva–Soós and Balogh, 1979, Svingor and Kovács, 1981; Balogh, Árva–Soós and Buda, 1983) indicate Carboniferous cooling ages.

Reviews are provided by Szederkényi (1977) and Árkai (1984). Regional studies supplying petrographical-mineralogical data: Juhász (1969) with subsurface map, Szepesházy (1973, 1976), Szalay (1977) and Jantsky (1979). Regional studies discussing petrology and geochemistry: Ghoneim and Szederkényi (1977), Buda (1981), Szederkényi (1983).

2. *Upper Carboniferous clastics (Téseny Sandstone Formation)*. Dark, polymictic conglomerate, sandstone and shale with thin coal seams. Fluviatile. Lithology: Jámbor (1969), Hetényi and Ravasz–Baranyai (1976). Fossil plants: Soós and Jámbor (1960), Wéber (1964). Spore and pollen: Góczán (1971b), Review paper: Balogh and Barabás (1972). Tetrapod footprint: Barabás–Stuhl (1975).

Permian

A summary of Permian is given by Balogh and Barabás (1972) and by Barabás (1979). Lithology and sedimentology: Kassai (1976).

3. *Coarse, polymictic clastics (Korpád Sandstone Formation)*. Lower Permian. 340 m thick, variegated sandstone, siltstone and polymictic conglomerate. Subsurface. Fluviatile. Palynoflora: Barabás–Stuhl (1975, 1981a).

4. *Rhyolite (Gyűrűfű Quartz Porphyry Formation)*. Lower Permian. 150 m thick lava rocks. Subsurface. Petrography: Kassai (1976).

5. *Conglomerate (Cserdi Conglomerate Formation)*. Lower Middle Permian. 750 m thick. Variegated, coarse-grained conglomerate and sandstone of mostly quartz porphyry composition. Deposited in torrential fluviatile environment. Unfossiliferous.

6. *Red siltstone (Boda Siltstone Formation)*. Upper Middle Permian. 900 m reddish brown siltstone and mudstone with dolomite intercalations. Lacustrine. Spores and pollen: Barabás–Stuhl (1981a).

7. *Sandstone (Kővágószőlős Sandstone Formation)*. Upper Permian. 200 to 1200 m thick. Variegated, gray, green, or red sandstone or conglomerate. Fluviatile. Contains secondary payable uranium mineralization. Sedimentology: Barabás–Stuhl (1981b). Spores and pollen: Barabás–Stuhl (1975, 1981a). Fossil woods: Simoncsics (1955), Greguss (1967). Phyllopods: Várszegi (1961).

Triassic

Detailed stratigraphy, lithology of all formations and lists of fossils are given by Nagy E. (1968). Stratigraphy is revised by Balogh (1981).

8. *Conglomerate and sandstone (Jakabhegy Sandstone Formation)*. Lower Triassic. Fluviatile. 400 m thick. Lithology and sedimentology: Nagy E. (1968), Kassai (1976). Palynoflora: Barabás–Stuhl (1981a).

9. *Werfen beds (Werfen Formation: Patacs Member, Magyarürög Anhydrite Member, Hetvehely Dolomite Member, Viganvár Limestone Member)*. Lower Triassic. 400 m thick. Sandstone, siltstone, evaporites, dolomite, limestone. Deposited in a fluviatile to lagoonal environment. Mineralogy and lithology: of clastic beds: Noske–Fazekas (1970).

10. Muschelkalk (Misina Formation) Middle Triassic. 600 m.

- 20 m red dolomite (Vöröshegy Dolomite Member)
- 125 m thin-bedded dolomitic limestone (Báránytető Limestone Member) with bivalves
- 100 m small-nodular limestone (Lapis Limestone Member). Alternating beds of grey limestones with small nodules, of crinoid limestone, of laminated limestone, of fossil-rich limestone (bivalves. gastropods, crinoids) and of limestone with "S–Faltung" (conspicuous cross-bedding).
- 65 m bedded limestone (Tubes Limestone Member) with slumping structures
- 35 m nodular marl (Bertalanhegy Limestone Member) with rich brachiopod fauna, conodonts and rare ammonoids (DETRE, 1973).
- 125 m limestone with yellow spots (Dömörkapu Limestone Member)
- 125 m thick-bedded limestone with rare ooids (Kozár Limestone Member)
- 2 m limestone with oncoids (KÓKAI and RÁLISCH–FELGENHAUER, 1981)
- 2 m limestone with bivalves (Trigonodus beds)
- 15 m limestone and marl with small gastropods (Mánfa Beds): WÉBER, 1978)
- siderite-kaolinite beds (NAGY and RAVASZ–BARANYAI. 1968).

11. *Black limestone and marl (Kantavár Formation)* with gastropods and ostracods. Upper Triassic. 120 m thick. Deposited in a restricted lagoon.

12. *Sandstone: Keuper (Karolinavölgy Sandstone Formation).* Upper Triassic 350 m. With pelitic intercalations and and rare coal seams (WÉBER, 1984). Mineralogy, lithology and geochemistry: NOSKE–FAZEKAS (1966, 1968). Spores and pollen: BÓNA (1984).

Jurassic–Palaeogene

Up to now the most complete description of Jurassic formations including extensive lists of fossils has been made by VADÁSZ (1935).

13. *Coal measures (Mecsek Coal Formation).* Hettangian to Lower Sinemurian. 200 to 1200 m thick sandstone and shale with up to 38 workable coal seams. Gresten facies (NAGY E. 1971). Stratigraphy: NAGY E. and NAGY J. (1969). Lithology: NOSKE–FAZEKAS and NAGY–MELLES (1969). Structural and economic geology: NAGY E. (ed. 1971). Spores and pollen: BÓNA (1969, 1983, 1984). Molluscs: NAGY I. Z. (1970).

14. *Rhyolitic tuffite.* 10 m thick, intercalated in the coal measures. Petrography: NOSKE–FAZEKAS and NAGY–MELLES (1969), RENDEKI et al. (1983). Probably Hettangian.

15. *Fleckenmergel (= Mottled marl)* Upper Sinemurian to Bajocian. *(Vasas Marl Formation, Hosszúhetény Calcareous Marl Formation, Mecseknádasd Sandstone Formation, Kecskehát Limestone Formation, Óbánya Siltstone Formation, Komló Calcareous Marl Formation).* Modern

descriptions available for the lowermost part only, immediately overlying the coal measures. Otherwise the reader is referred to the volume by Vadász (1935). Stratigraphy: Nagy E. and Nagy J. (1969). Lithology: Noske – Fazekas and Nagy – Melles (1969).

16. *Crinoid limestones*. Bajocian. *(Pusztakisfalu Limestone Formation)*. Lithology and Sedimentology: Kaszap (1963), Pataky et al. (1982).

17. *Red nodular limestone and marl, ammonitico rosso*. Bathonian. *(Óbánya Limestone Formation)*. Lithology and sedimentology: Pataky et al. (1982). Stratigraphy and ammonoids: Galácz (1984).

18. *Cherty limestone*. Callovian *(Dorogó Calcareous Marl Formation)*. Mostly unfossiliferous. Chert beds and nodules.

19. *Nodular limestone*. Oxfordian. *(Fonyászó Limestone Formation)*. Rare fossils. Planktonic microfossils: Nagy I. (1971a).

20. *Nodular, fossiliferous limestone, red*. Kimmeridgian to Lower Tithonian. *(Kisújbánya Limestone Formation)*. Planktonic microfossils: Nagy I. (1966, 1971a, b).

21. *White cherty limestone*. Upper Tithonian. *(Márévár Limestone Formation)*. Planktonic microfossils: Nagy I. (1964, 1966, 1971).

22. *Grey, marly limestone*. Berriasian. *(Márévár Limestone Formation)*. With abundant intraclasts. Planktonic microfossils: Nagy I. (1964, 1971).

23. *Marl*. Valanginian. This marl and marly limestone contains most of the products of the alkaline basalt volcanism. Stratigraphy of the volcanic rocks within the marl: Bilik (1974). Description of resedimented volcanic rocks: Horváth A. (1968). Ammonoids: Horváth A. (1968).

24. *Alkali basalt and various dykes*. *(Mecsekjánosi Diabase Formation)*. Mostly Valanginian (Bilik, 1974), but traces are known since Late Jurassic (Nagy I., 1967) and it is mentioned as late as Albian (Szepesházy, 1977). Origin: alkaline rift volcanism (Bilik, 1983). Petrology and geochemistry (Bilik, 1983), geochemistry: Embey – Isztin (1980). Dyke rocks (albitediabase, keratophyre) with geochemical data: Szilágyi (1979); Rb – Sr age: Svingor and Kovách (1978). Subsurface localities in Alföld with geochemical data: Juhász and Vass (1974). Palaeogeography and tectonic relationships: Szepesházy (1977). Local limonite deposit at Zengővárkony: Pantó et al. (1955). Coprolites: Palik (1965).

25. *Marl with olisthostromes (Magyaregregy Conglomerate Formation)*. Hauterivian to Barremian. Pelagic marl with abundant basalt conglomerates, sandstones and resedimented shallow-water fossils. Stratigraphy of volcanic rocks: Bilik (1974). Resedimented volcanics: Horváth A. (1968). interpreted as a littoral sequence, and Bóna et al. (1983). Bivalves and gastropods: Horváth A. (1968), Czabalay (1971).

26. *Pelagic* limestone. Albian. With calcisphaerulids and stomiosphaeres. Mentioned by Szentgyörgyi (1984a), from Kaskantyú – 1 borehole at Alföld.

27. *Pelagic marls with olisthostromes (Vékény Marl Formation)*. Cenomanian to Turonian. Stratigraphy, lithology and palaeogeography: Szentgyörgyi (1984a), interpreted as a transgressive sequence. Foraminifers: Cenomanian: Sidó (1961), Turonian: Sidó (1969).

28. *Phonolite intrusions.* Petrography: VICZIÁN (1971), geochemistry VICZIÁN (1970). Lamprophyre dykes possibly associated with phonolite magmatism: SZILÁGYI (1981).

29. *Conglomerate and breccia (Ágasegyháza Conglomerate Formation).* Campanian. Interpreted as basal conglomerate of a transgressive sequence (SZENTGYÖRGYI, 1983); possibly olisthostrome.

30. *Red marl (Izsák Marl Formation).* Equivalent of the Carpathian Púchov marl. Campanian to Maastrichtian. Pelagic. Stratigraphy and lithology: SZENTGYÖRGYI (1983).

31. *Flysch (Debrecen Sandstone Formation).* Santonian to Maastrichtian. 500 m thick. Stratigraphy and lithology: SZEPESHÁZY (1973), SZENTGYÖRGYI (1984b). Mineralogy, lithology and geochemistry: DUDICH (1982), DUDICH and BOMBIȚA (1983).

32. *Eocene flysch. (Nádudvar Formation).* Shale and sandstone. Possibly Lower Eocene, certainly Middle to Upper Eocene. Also Upper Eocene(?) littoral clastics and carbonates along the southern margin. Mineralogy, lithology and geochemistry: DUDICH (1982), DUDICH and BOMBIȚA (1983).

33. *Oligocene sandstone.* Possibly sandy flysch. Stratigraphy: SZEPESHÁZY (1973), BÁLDI–BEKE et al. (1981). Nannoplankton: BÁLDI–BEKE et al. (1981). Palaeogeography: SZEPESHÁZY (1973). Distribution: BALÁZS et al. (1981).

34. *Terrestrial clastics.* Upper Eocene and Oligocene variegated fluviatile to lacustrine sandstone, pelite, conglomerate. Occurs SW of Mecsek Mts. only. Subsurface. Stratigraphy. lithology and spore-pollen: WÉBER (1982).

VILLÁNY UNIT (Fig. 15)

Age – Palaeozoic to Late Cretaceous.

Margins – Mecsek unit to N; Békés unit to S; extends to Yugoslavia and Romania.

Physiography – Low to middle hills and alluvial plains.

Stratigraphy – Palaeozoic polymetamorphic rocks; unconformably overlain by Upper Carboniferous, Permian and Lower Traissic, mostly terrestrial sandstones, Middle Triassic carbonates, Upper Triassic terrestrial pelites, Jurassic pelagic limestones; Lower Cretaceous bauxite and Urgonian limestone, Middle Cretaceous marl and flysch; unconformably overlain by Senonian conglomerates, limestones and marls.

Igneous activity – Minor Palaeozoic metavolcanites; Lower Cretaceous basaltic volcanism.

Metamorphism – Variscan polymetamorphism.

Deformation – Strong Variscan folding; Middle Cretaceous(?) overthrusts.

Tectonic position – Probably autochthonous with minor internal, overthrusts.

Connections – Bihor autochthonous of Apuseni Mts. in Transylvania, Romania.

Economic geology – Lower Cretaceous bauxite; oil and gas reservoirs in fractured metamorphic aned sedimentary rocks.

Reference – Wein (1968).

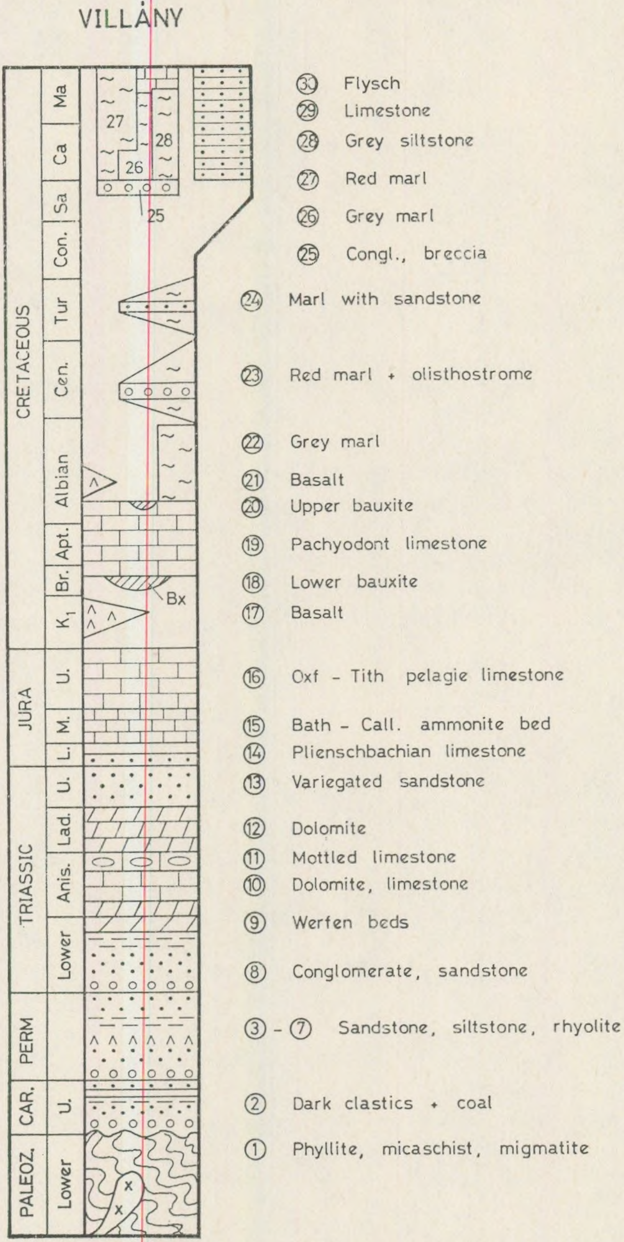

Fig. 15.: Stratigraphic column of Villány unit. Numbers refer to the text.

Stratigraphic details

1. *Crystalline basement.* For descriptions and references the reader is referred to No. 1 in Mecsek unit. The separation of Mecsek and Villány units in the basement rocks has not been carried out as yet.

2. *Upper Carboniferous clastics* (see Mecsek unit).

3 – 7. *Permian sandstone, siltstone, rhyolite* (see Mecsek unit).

Triassic

8. *Conglomerate and sandstone (Jakabhegy Sandstone Formation).* Lower Triassic. Subsurface. Fluviatile. 300 m thick. Lithology and sedimentology: KASSAI (1976).

9. *Werfen beds (Túrony Member and Vokány Member).* Lower Triassic. Subsurface. 90 m thick. Lagoonal sandstone, siltstone, dolomite, anhydrite. limestone.

10. *Dolomite and limestone (Rókahegy Dolomite Formation and Gyüd Limestone Formation).* Lower Anisian. 200 m thick. Thin-bedded, shallow marine dolomite and limestone with rare foraminifers and bivalves. Stratigraphy and lithology: NAGY E. and NAGY I. (1976).

11. *Mottled limestone (Zuhánya Limestone Formation).* Upper Anisian. 130 m thick. Thick-bedded limestone, rarely dolomitic, with green, gray and yellow spots (slumping and other resedimentation structures). Probably slope sediment. Stratigraphy and lithology: NAGY E. and NAGY I. (1976). Conodonts and holothurian sclerites: BÓNA (1976).

12. *Dolomite (Csukma Dolomite Formation and Templomhegy Dolomite Formation).* Ladinian. 300 m thick. Shallow marine to lagoonal dolomite and dolomitic marl with rare foraminifers and brachiopods (*Lingula*). Stratigraphy and lithology: NAGY E. and NAGY I. (1976).

13. *Variegated sandstone with dolomite intercalations (Mészhegy Sandstone Formation).* Upper Triassic. 20 m thick. Carpathian Keuper (CSÁSZÁR and HAAS 1984a). Lacustrine: VÖRÖS (1972).

Jurassic

14. *Pliensbachian sandstone to crinoid limestone* (lower part of Villány Formation). Stratigraphy: AGER and CALLOMON (1971), VÖRÖS (1972). Lithology: VÖRÖS (1972). Bivalves: VÖRÖS (1971). Ammonoids: GÉCZY (1984). Brachiopods: AGER and CALLOMON (1971).

15. *Red limestones, Bathonian to Callovian (upper part of Villány Formation).*

- 0,08 m sandy limestone: Upper Bathonian
- 0,1 m limestone with limonite ooids: Lower Callovian
- 0,4 m red ammonitic limestone with stromatolites: Callovian. All beds strongly condensed, with rich ammonite fauna. Stratigraphy and lithology: VÖRÖS (1972). Stromatolites: RADWAŃSKI and SZULCZEWSKI (1966). Bivalves: VÖRÖS (1971). Ammonoids: GÉCZY (1984). Belemnites: GALÁCZ and VÖRÖS (1969). Coprolites: KASZAP (1964).

16. *Grey limestones (Szársomlyó Limestone Formation).* Oxfordian to Tithonian. Pelagic. Lithology and microfacies: Kaszap (1963b). Pelagic ooids: Kaszap (1976b), Jenkyns (1972).

17. *Basalt lava and tuffite (Mecsekjánosi Diabase Formation).* Beginning of volcanism: Latest Tithonian. End: unknown. Thickness ca. 200 m. Petrography: Császár et al. (1983).

18. *Bauxite (Harsányhegy Bauxite Formation).* Barremian. Once worked karstic bauxite. Mineralogy and geochemistry: Dudich and Mindszenty (1984). Lithology: Fülöp (1966). Stratigraphy: Károly et al. (1970). Review: Haas (1984).

19. *Pachyodont limestone (Nagyharsány Limestone Formation).* Upper Barremian to Aptian (+Lower Albian?). Thick-bedded, shallow marine limestone with abundant bivalves (pachyodonts) and foraminifers (Orbitolina). Lowermost bed: freshwater limestone with Characeae. Stratigraphy, lithology, sedimentology and microfacies: Fülöp (1966). Orbitolines: Méhes (1964). Calcareous algae: Peybernès and Conrad (1979).

20. *Bauxite.* Indications of an upper Bauxite horizon overlying Albian pachyodont limestone: Császár and Farkas (1982).

21. *Basalt (Mecsekjánosi Diabase Formation)* of Császár et al., 1983 and Nagybaracska Diabase Formation of Juhász, 1983). Lower Albian. The relevant papers does not state if there are one or two volcanic complexes, while providing ages for two.

22. *Albian grey silty marl (Bisse Marl Formation).* Middle Albian. Contains rich planktonic foraminifer fauna (listing: Sidó in Fülöp, 1966) Palynostratigraphy: Juhász (1983).

23. *Cenomanian marl with olisthostromes (Vékény Marl Formation).* Subsurface. Stratigraphy and lithology: Szentgyörgyi (1984a).

24. *Turonian silty marl with sandstone intercalations. (Gátér Clayey Marl Formation).* Stratigraphy and Lithology: Szentgyörgyi (1984a).

Senonian formations occur subsurface at the Great Hungarian Plain (Alföld). Stratigraphy, lithology and palaeogeography is discussed by Szentgyörgyi (1982, 1983).

25. *Conglomerate and breccia (Ágasegyháza Conglomerate Formation).* Campanian. Interpreted as basal conglomerate of a transgressive sequence (Szentgyörgyi, 1983); possibly it is an olisthostrome.

26. *Grey marl with Inoceramus (Csikéria Marl Formation).* Campanian. 120 m.

27. *Red marl with Globotruncana (Izsák Marl Formation).* Campanian to Maastrichtian. Equivalent of the Carpathian Púchov marl. 330 m.

28. *Grey siltstone with conglomerate (Mélykút Formation).* Campanian to Lower Maastrichtian. 390 m.

29. *Limestone with rich benthonic and planktonic fauna. (Bácsalmás Formation).* 420 m. Maastrichtian.

30. *Pelites with sandstone (Körös Group).* Campanian to Maastrichtian. Siltstone, claystone, marl with alternating sandstone intercalations (flysch). 1000 m thick.

BÉKÉS UNIT

Age – Precambrian to Cretaceous.
Margins – Villány unit to N; southwards extends to Yugoslavia.,
Physiography – Lowlands.
Stratigraphy – Precambrian and Palaeozoic metamorphic rocks; unconformably overlain by Carboniferous sandstone and shale, Permian quartz porphyry; overlain by Triassic sandstones, carbonates and shales, Jurassic marls and limestones, Lower Cretaceous bathyal pelites; unconformably overlain by Upper Cretaceous flysch.
Igneous activity – Precambrian or Palaeozoic granites; Permian quartz porphyry volcanism.
Metamorphism – Pre-Variscan(?) and Variscan polymetamorphism.
Deformation – Variscan and Middle Cretaceous(?) folding and faulting.
Tectonic position – Probably allochthonous on the Villány unit.
Connections – Codru nappe system of Apuseni Mts. in Romania.
Economic geology – Oil and gas reservoirs in fractured metamorphic rocks and Upper Cretaceous sandstones.
References – T. Kovács and Kurucz (1984), Szepesházy (1980).

Stratigraphic details

Biostratigraphically dated rocks are extremely rare in this subsurface unit; most identifications come from comparisons with the Codru nappe system of Mts. Apuseni in Romania (Szepesházy, 1980).

Rocks of the Finiş nappe (local name: Battonya nappe) are found at Battonya, Mezőkovácsháza, etc; Precambrian – Palaeozoic granitoids, migmatites, micaschists, Permian rhyolite and Lower Triassic quartzite (Szepesházy, 1977; T. Kovács and Kurucz, 1984; Szalay, 1977).

Rocks of Dimbraviţa nappe occur north of Battonya nappe: Precambrian – Palaeozoic metamorphic rocks: diaphthorized gneisses, micaschists (local name: Pusztaföldvár unit) (Szepesházy, 1980). Mesozoic (after T. Kovács, 1977) (local name: Tótkomlós – Pusztaföldvár unit):

- Lower Triassic variegated sandstone and shale, grey dolomitic shales (max. 190 m).
- Middle Triassic dark dolomite (max. 680 m).
- Jurassic sediments are absent (T. Kovács, 1977) or present (Szepesházy, 1980).
- Lower Cretaceous (Barremian – Albian) limestone and marl (may belong to Villány unit)
- Upper Cretaceous (see description of Villány unit, Nos. 25 – 29).

Neogene and Quaternary (Figs, 16 – 20)

During Oligocene and Neogene time the territory of Hungary formed part of the more or less restricted basin named Paratethys, a direct descendant of the already closed Tethys ocean (Báldi, 1980, 1982). A special set of regional stage names is applied to different parts of this region

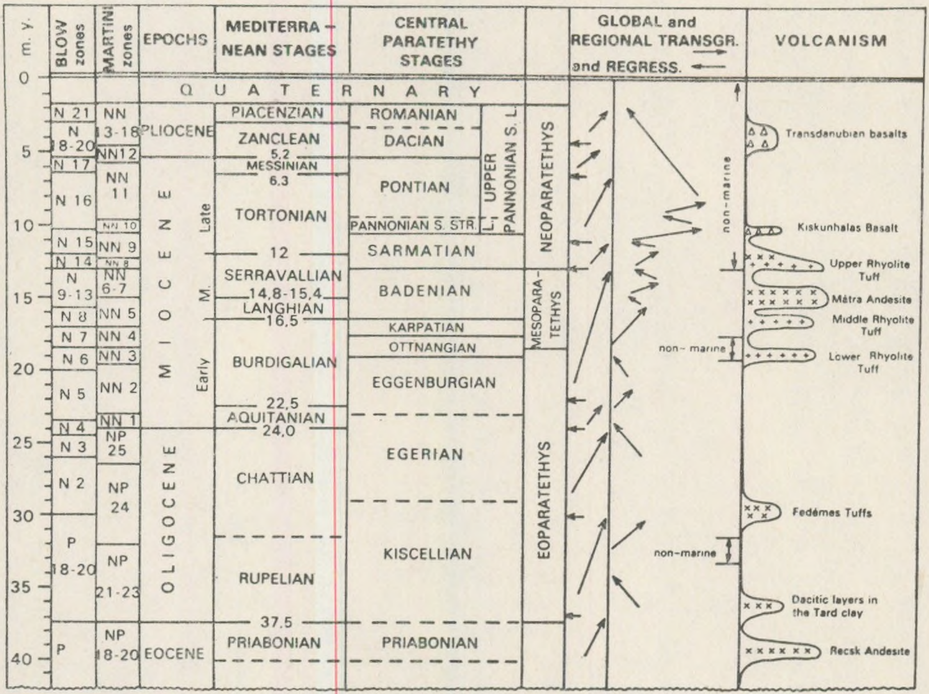

Fig. 16.: Correlation of Mediterranean and Central Paratethyan stages (Nagymarosy, 1981a)

(Rögl and Steininger, 1983). A short review of Central Paratethyan stages – applicable in Hungary – are given by Nagymarosy (1981a) for the Oligocene – Pliocene interval. Earlier Hungarian papers – mainly before 1970 – used Mediterranean stage names for considerably older rocks; equivalents are given by Nagymarosy (1981a) (Fig. 16). Correlation of Central and Eastern Paratethyan stages with Mediterranean ones, completed with planktonic foraminifer, nannoplankton and vertebrate zones, vertebrate stages, magnetostratigraphic epochs and geochronological time scale are provided by Rögl and Steininger (1983, Abb. 2) for the Miocene and Pliocene.

Miocene and Pliocene palaeogeographic maps for the Paratethys, for the Carpathian – Pannonian region and for the Mediterranean were drawn by Rögl and Steininger (1983). However, a detailed palaeogeographic and tectonic reconstruction is badly needed.

No distinct tectonic units have been recognized in the Pannonian region for Late Cenozoic (Miocene – Pliocene – Quaternary). The exact outlines of Mesozoic units are somewhat blurred in Early Cenozoic and almost fade in Late Cenozoic. This is a consequence partly of facies interpretation problems in imperfectly known deep molasse basins, partly of a change in tectonic regime.

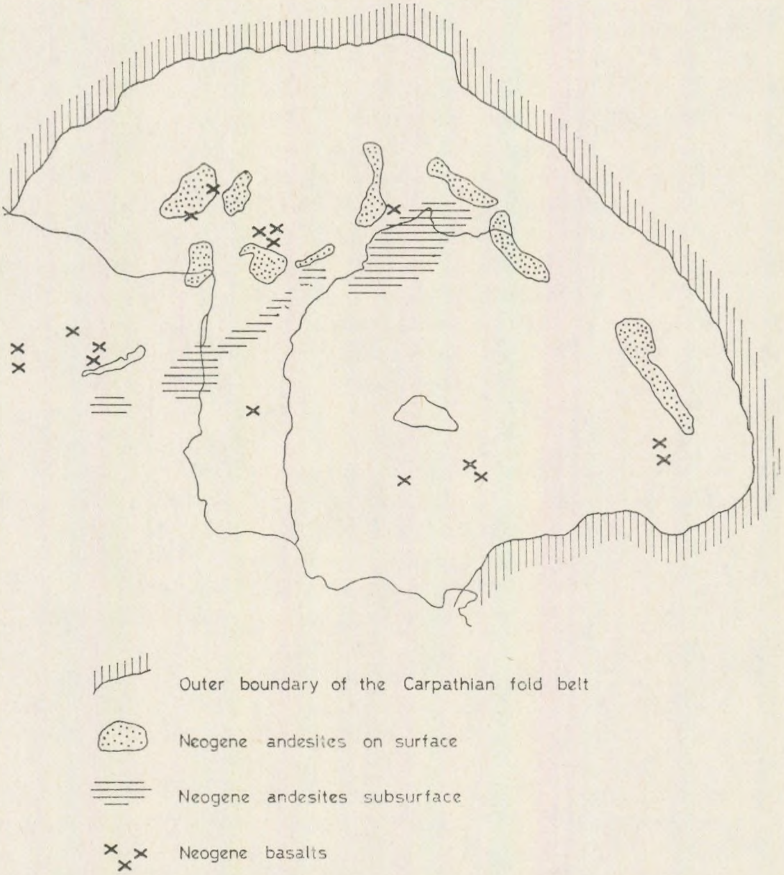

Fig. 17.: **Neogene and Quaternary volcanism in the Pannonian basin (after Balla, 1981, simplified)**

Three different intervals of subsidence and basin filling can be recognized: a Middle Miocene, a Late Miocene – Pliocene and a Quaternary (Pogácsás, 1985).

(Lower to) Middle Miocene

Thickness of upper Middle Miocene (Badenian) and lower Upper Miocene (Sarmatian) sediments is shown on the map of Kőrössy (1980): great variability in thickness – and probably in facies – is shown but neither of them exceeds some hundred metres (Nagymarosy, 1981b). Filling of the basins kept up with subsidence (Pogácsás, 1985). Elongation of troughs is parallel with the Zagreb – Zemplén lineament, i.e. directed ENE – WSW (Pogácsás, 1984a, b, c.). However, several kilometres of Badenian and Sarmatian sediments were encountered in the neighbouring peripheral basins: in the Vienna basin (Jiříček and Tomek, 1981), in the Transcarpathian depression (Rudinec et al., 1981) and the Sava depression.

Stratigraphy and facies is summarized in a stratigraphic table (Császár and Haas, 1983). Some regional monographs and papers emphasizing stratigraphy: Tiszántúl (eastern Great Plain): Szepesházy (1971), Szentgyörgyi (1978); Northern Hungary: Hámor (1983); southern Great Plain: Mucsi and Révész (1975); Tolna region: Halmai et al. (1982); Mecsek: Hámor (1970). Short papers on the distribution of sediments and facies for each stages: Egerian: Báldi et al. (1975); Eggenburgian: Papp et al. (1971); Ottnangian: Bohn – Havas (1973), Kókay (1973), Seneš (1973); Karpatian: Horváth M. and Nagymarosy (1979); Badenian: Hámor (1978a, b); Sarmatian: Boda (1974).

A concise review of Hungarian Miocene stratigraphy and facies distribution is outlined by Hámor and Szentgyörgyi (1981). K – Ar radiometric ages of volcanic and sedimentary formations are given by Hámor et al. (1980).

A conspicuous feature of the Hungarian Badenian and Sarmatian is the extensive calc-alkaline volcanism (Balla, 1981a) (Fig. 17). Several mountains consist of or contain andesites, less rhyolites and much pyroclastics: Dunazug Mts. (Balla and Korpás, 1980) Börzsöny (Balla, 1978) Cserhát (Árkai, 1973), Mátra (Varga et al., 1975, Baksa et al., 1981), Tokaj Mts. (Széky – Fux, 1970, Gyarmati, 1977). However, the larger part of the Miocene volcanic rocks is buried under thick Miocene and Pliocene sediments below the Pannonian basin. Petrology: Juhász, 1971, Székyx – Fux and Kozák, 1984, Balla, 1981. Distribution: Bérczi et al. (1981). This intermediate volcanism is interpreted as an intracontinental island arc connected with the Carpathian subduction (Bleahu et al., 1973) or product of several smaller subductions (Balla, 1981).

Reconstructions of (Middle) Miocene tectonic regimes have gone to two extremes. Balla (1981, 1982) suggested several active subduction zones associated with island arc volcanism, while Császár et al. (1982) proposed alternating compressional and extensional block tectonics. The latter hypothesis is supported by seismic data of Pogácsás and Varga (1983) and Pogácsás (1984b, 1985).

Late Miocene – Pliocene (Pannonian s.l.)

Generally the stage name Pannonian (s.l.) is used instead of Uppermost Miocene and Pliocene stages. The Pannonian stage (s.l.) contains all formations above Sarmatian (properly Lower Sarmatian) brackish marine sediments and below Pleistocene formations (Balázs and Barabás et al., 1981). Stratigraphy (Jámbor, 1980a) of the mostly lacustrine and fluviatile sediments is based on molluscs (Bartha and Kleb et al., 1971, Korpás – Hódi, 1983) and dinoflagellates. According to classical stratigraphic ideas, Lower Pannonian contains pelitic sediments, while Upper Pannonian is formed of psammitic deposits (Balázs and Barabás et al.. 1981). (Some papers on sedimentology: Balogh, 1973, Bérczi and Viczián, 1973, Szónoky, 1978). However, seismic stratigraphic observations and borehole data (Pogácsás, 1984a, b, 1985; Bérczi and Geiger et al.. 1984) indicate that fast Early Pannonian subsidence was not followed by sedimentation; later, these large, deep basins were filled up by psammitic sediments forming deltas prograding over the pelites (Gajdos et al.. 1983). (For thickness of Neogene, see Fig. 18). Detailed descriptions of formations are given by Jámbor (1980a, b) for mountainous regions and their surroundings and by Gajdos et al. (1983) for basins.

Oil and gas reserves of Hungary are mostly contained in Pannonian rocks. Hydrocarbon geology is reviewed by Dank (1983).

The Late Miocene – Pliocene – Pleistocene alkali basaltic volcanism is discussed in the following papers: distribution: Jámbor, Partényi and Solti (1981); radiometric age: Balogh and Jámbor et al. (1982); geochemistry: Embey – Isztin (1983); tectonic interpretation: Balla (1981), Embey – Isztin (1981, 1983).

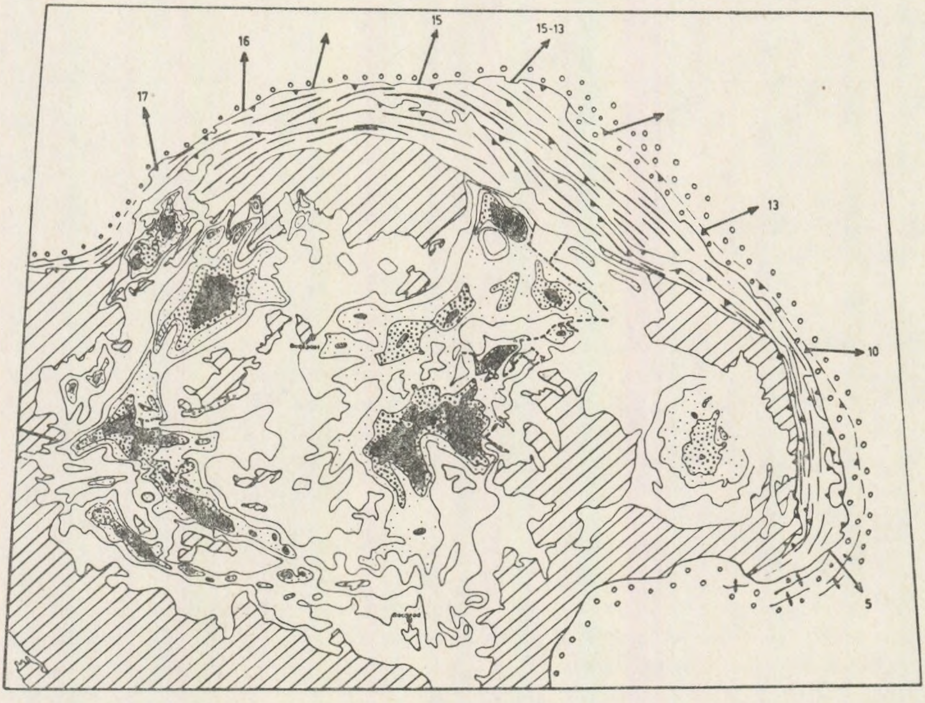

Fig. 18.: Thickness of Neogene and Quaternary sediments in the Pannonian basin (after Horváth and Royden, 1981).

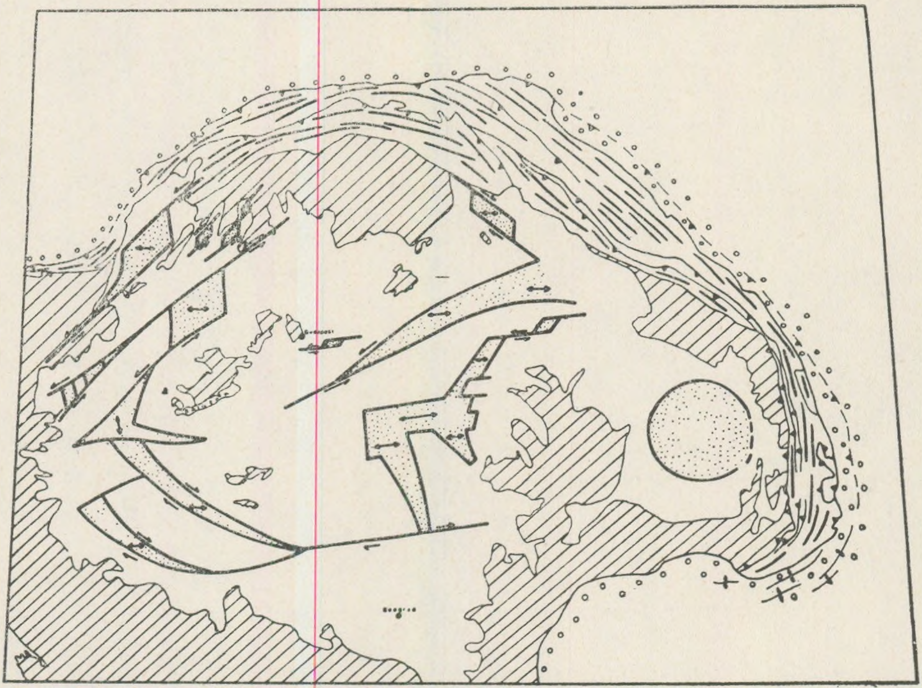

Fig. 19.: Location of extensional basins in the Pannonian basin (Horváth and Royden, 1981.)

The Late Miocene and Pliocene Pannonian basin was an E–W trending extensional regime (Horváth and Royden, 1981; Royden, Horváth and Burchfiel, 1982; Royden, Horváth and Rumpler, 1983) (Fig. 19). A diffuse system of normal and strike-slip faults (Fig. 20) (Horváth, 1984) caused significant differences in subsidence of relatively small basins (Royden, Horváth, Nagymarosy and Stegena. 1983; Nagymarosy, 1981b). Seismic evidences are given by Pogácsás and Varga (1983), Rumpler and Horváth (1984), Pogácsás (1984a, b). The extension was associated by thinning of the crust (Posgay et al., 1981) due to the formation of a mantle diapir (Stegena, Géczy and Horváth, 1975; Horváth and Stegena, 1977).

Quaternary

Pleistocene and Holocene sediments were deposited in lacustrine. fluviatile, terrestrial (loess) and cave environments. Basin boundaries fit present-day geographic units (Pogácsás, 1985). Lithology is described by Rónai (1972), mollusc biostratigraphy by Krolopp (1983), vertebrate biostratigraphy by Jánossy (1979) and magnetostratigraphy by Rónai (1981, 1983).

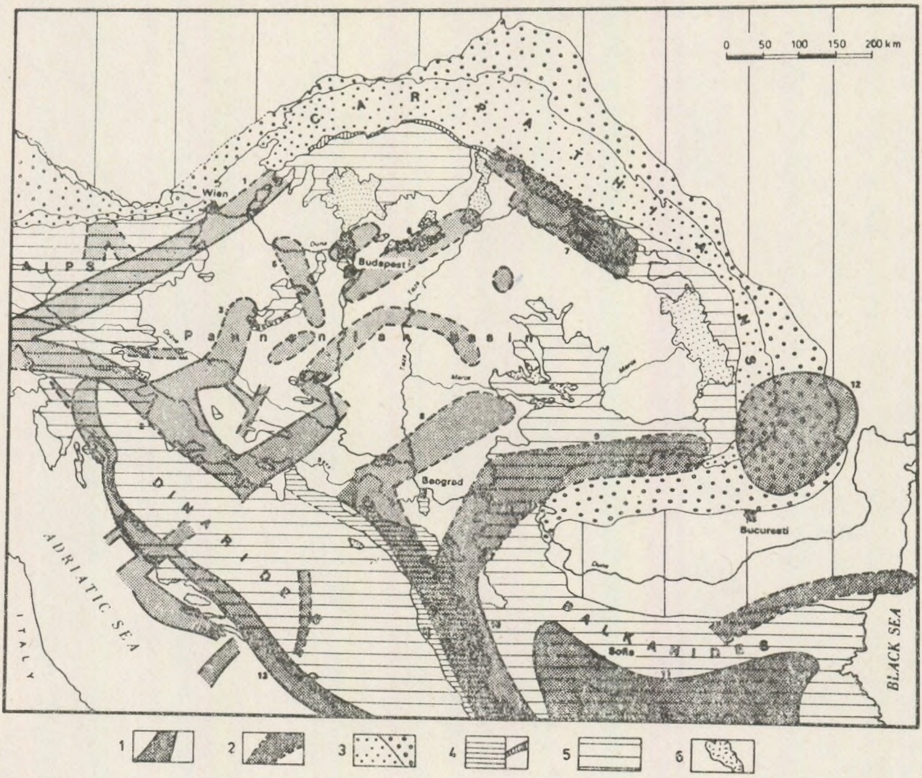

Fig. 20.: The diffuse Neotectonic regime of the Pannonian basin (Horváth, 1984).

Appendix 1

Books on the geology of Hungary

Telegdi Roth Károly (1929): Magyarország geológiája I. rész. A magyar föld és az azt környező területek hegyszerkezetének kialakulása. – Tudományos Gyűjtemény 104, 170 p., 10 ábra, 1 térképmell., Danubia, Pécs

Vadász Elemér (1954): Magyarország földtana. – Akadémiai Kiadó, Budapest, 380 p., 100 á., 18. fényképt.

Vadász Elemér (1960): Magyarország földtana. 2., bővített kiadás. – Akadémiai Kiadó, Budapest, 646 p., 213 ábra, 51 fényképt., 18 tábl.

Vadász, E. (1964): Geologija Vengrii. (Russian). – Mir, Moszkva, 530 p.

Trunkó, László (1969): Geologie von Ungarn. – Beiträge zur regionalen Geologie der Erde 8, 257 p.,109 Abb., 55 Fotos, Borntraeger, Berlin (with English summary)

Juhász Árpád (1983): Évmilliók emlékei. Magyarország földtörténete és ásványi kincsei. – Gondolat, Budapest, 512 p., 153 ábra, 8 színes és 44 fekete-fehér fényképtábla

Appendix 2

Review papers on periods

Crystalline rocks and metamorphics: Szepesházy (1973c)
Upper Carboniferous and Permian: Balogh and Barabás (1972)
Triassic: Balogh (1981)
Jurassic: (Fülöp (1971)
Cretaceous: Császár and Haas (1979)
Cretaceous and Palaeogene: Balla (1981b)
Oligocene: Báldi (1983)
Miocene: and Pliocene: Balázs and Barabás et al. (1981)
Quaternary: Rónai (1972)

Appendix 3

Maps

Geological map of Hungary 1 : 900.000 (1922) out of (print)
Geological map of Hungary 1 : 300.000 (1956) (out of print)
Geological map of Hungary 1 : 500.000 (1984)
Geological map of Hungary without Cenozoic formations 1 : 500 000 (1985)

Maps in scale of 1 : 10.000 and 1 : 25.000 or 1 : 20.000 are mostly published for official use, so these are not listed here.

Current periodicals of geology in Hungary

Földtani Közlöny 1871 –
Annales Instituti Geologici Publici Hungarici 1871 –
Annual Report of the Hungarian Geological Institute 1882 –
Annales Historico-Naturales Musei Nationalis Hungarici 1903 – (1947 –)
Geologica Hungarica series Geologica 1914 –
Geologica Hungarica series Palaeontologica 1928 –
Acta Mineralogica-Petrographica, Szeged 1943 –
Acta Geologica Hungarica 1952 –
Annales Universitatis Scientiarum Budapestinensis de Rolando Eötvös Nominatae, Sectio Geologica 1957 –
Földtani Kutatás 1958 –
Őslénytani Viták (Discussiones Palaentologicae) 1963 –
Fragmenta Mineralogica et Palaeontologica 1969 –
Általános Földtani Szemle 1971 –
All periodicals are published in Budapest, except Acta Min.-Petr. in Szeged.

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Albani, R., Lelkes-Felváry, Gy., Tongiorgi, M. (1985): First record of Ordovician (Upper Arenigian) beds in Bakony Mts., Hungary. – N. Jb. Geol. Paläont. Abh 170/1, 45 – 65, 6 figs., Stuttgart

Andreánszky G. (1962): Calamites-Rest vom Bányahegy bei Füle (West Ungarn). – Acta Biologica, N. S. 6, 1 – 4, Szeged

Antal S. (1973): Micromineralogical and textural features in relation to the genesis of bauxite of Iszkaszentgyörgy. – Acta Min.-Petr. 21/1, 3 – 16, 6 figs., Szeged

Antal S. (1975): Subdivision of the Upper Permian sequence of the Bükk Mountains in Northern Hungary. – Acta Min.-Petr. 22/1, 113 – 118, 4 figs., Szeged

ANTAL S., BALOGH K. (1980): Über die Lithologie und Alter der Nagyvisnyó Formation (Oberperm, Bükk-Gebirge, Nordungarn). – In: Vozár, J., Vozárová, A. (eds.): Permian of the West Carpathians, pp. 25 – 32, 8 pl., Geol. Ústav D. Stúra, Bratislava

ÁRKAI P. (1973): Geochemical study on the Early Tortonian andesitic volcanism of the central and south-western Cserhát hills. – Annales Univ. Sci. Budapest, Sect. Geol. 16, 19 – 33, 8 figs., 4 t.

ÁRKAI P. (1983): Very low- and low-grade Alpine regional metamorphism of the Paleozoic and Mesozoic formations of the Bükkium, NE-Hungary. – Acta Geol. Hung. 26 – 12, 83 – 101, 8 figs., 1 map

ÁRKAI P. (1984): Polymetamorphism of the crystalline basement of the Somogy-Drava basin (Southwestern Transdanubia, Hungary). – Acta Min.-Petr, 26/2, 129 – 153, 6 figs., 2 pl., 7 t., Szeged

ARTHABER, G. v. (1911): Neue Funde in den Werfener Schichten und im Muschelkake des südlichen Bakony und Revision der Cephalopodenfauna des Muschelkalkes. – Resultate wiss. Erforsch. Balatonsees, Paläont. Anhang III/3, 26 p., 2 Taf., 1 Tab., Hölzel, Wien

ÁRVA-SOÓS E., BALOGH K. (1979): [K-Ar investigations on Mecsek granites and surrounding metamorphics] (Hungarian). – Földtani Kutatás 22/4, 33 – 36, Budapest

BADINSZKY P. (1973a): Sedimentologische Untersuchung des oberkarnischen Dolomits aus der Umgebung von Veszprém (Hung., with German abstract). – A Veszprém megyei Múzeumok Közleményei 12, 53 – 73, 13 figs., 3 t., Veszprém

BAKSA Cs. (1975): The subvolcanic andesite body of Recsk and its dikes (Hung. with English abstract). – Földtani Közlöny 105/Supp., 612 – 624, 2 pl., 4 figs., Budapest

BAKSA Cs. (1983): The genetic framework of the Recsk ore genesis. – Acta Min.-Petr. 26/1, 87 – 97, 10 figs., Szeged

BAKSA Cs., CSILLAG J., FÖLDESSY J. (1974): Volcanic formations of the NE-Mátra Mountains. – Acta Geol. Acad. Sci. Hung. 18/3 – 4, 387 – 400, 12 figs., 1 t., Budapest

BAKSA Cs., CSILLAG J., FÖLDESSY J., ZELENKA T. (1981): A hypothesis about the Tertiary volcanic activities of the Mátra Mountains, NE Hungary. – Acta Geol. Acad. Sci. Hung. 24/2 – 4, 337 – 349, 5 figs., Budapest

BALÁZS E. (1971): Altpaläozoische Gesteine des Beckenuntergrundes der Kleinen Ungarischen Tiefebene (Hung. with English abstract). – Annual Report Hung. Geol. Inst. for 1969, 653 – 673, 1 t., 3 figs., Budapest

BALÁZS E. (1975): Paleozoic formations of the Little Plain's basin (Hung. with Russian abstract). – Földtani Kutatás 18/4, 17 – 25, 3 figs., Budapest

BALÁZS E., BÁLDI T., DUDICH E., GIDAI L., KORPÁS L., RADÓCZ GY., SZENTGYÖRGYI K., ZELENKA T. (1981): [Structural and facies outline of Eocene/Oligocene boundary formations in Hungary] (Hungarian). – Földtani Közlöny 111/1, 145 – 156, 8 figs.

BALÁZS E., BARABÁS A., 30 co-authors (1981): Excursion guide of Molasse Formations in Hungary. – Hung. Geol. Inst. 185 p., 71 figs., Budapest

BÁLDI T. (1973): Mollusc fauna of the Hungarian Upper Oligocene (Egerian). Akadémiai Kiadó, Budapest, 511 p., 55 figs., 4 t., 51 pls.

BÁLDI T. (1976): Correlation between the Transdanubian and N-Hungarian Oligocene (Hung. with English abstract). – Földtani Közlöny 106/4, 407 – 424, 19 figs., 9 t., Budapest

BÁLDI T. (1980): The early history of the Paratethys. – Földtani Közlöny 110/3 – 4, 456 – 472, 7 figs., 1 pl., Budapest

BÁLDI T. (1982): Mid-Tertiary tectonic and paleogeographic evolution of the Carpathian-East Alpine-Pannonian system (Hung. with English abstract). – Őslénytani Viták 28, 79 – 155, 20 figs., Budapest

BÁLDI T. (1983): Magyarországi oligocén és alsómiocén formációk. [Oligocene and Lower Miocene Formations of Hungary]. (Hungarian). Akadémiai Kiadó, Budapest, 293 p., 131 figs.

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BÁLDI T., HORVÁTH M., NAGYMAROSY A., VARGA P. (1984): The Eocene-Oligocene boundary in Hungary. The Kiscellian stage. – Acta Geol. Hung. 27/1 – 2, 41 – 65, 12 figs., Budapest

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Báldi T., Nagymarosi A. (1976): Silificiation of the Hárshegy Sandstone and its hydrothermal origin (Hung. with English abstract). – Földtani Közlöny 106/3, 257 – 275, 6 figs., 4 pl.

Báldi T., Seneš, J. (eds.) (1975): Chronostratigraphie und Neostratotypen, Miozän der Zentralen Paratethys 5, OM-Egerien. VEDA, Bratislava, 577 p.

Báldi-Beke M. (1965): The genus Nannoconus (Protozoa, inc. sedis) in Hungary. – Geol Hung. ser. Pal. 30, 107 – 179, 2 pl., 8 figs., 9 t., Budapest

Báldi-Beke M. (1972): The nannoplankton of the Upper Eocene bryozoan and Buda marls. – Acta Geol. Acad. Sci. Hung. 16/1 – 3, 211 – 228, 3 figs., 1 t., 4 pl., Budapest

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A NEW SPECIES OF MOLLISTEPHANUS (STEPHANOCERATIDAE, AMMONITINA) FROM THE MIDDLE JURASSIC OF LÓKÚT HILL (BAKONY MTS, HUNGARY)

by

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ABSTRACT

The fossiliferous Bajocian profile of Lókút (Bakony Mts.) yielded a new species of the stratigraphically important genus *Mollistephanus (M. kondai* sp. nov.) Detailed morphological description is given, with remarks on the general features of the genus. Geographical distribution and stratigraphic significance is similarly discussed.

Introduction

During the work on the Bajocian ammonite fauna of the Lókút Hill (Bakony Mountains), the large-scale, layer-by-layer collections were completed with repeated control collecting and detailed sampling of beds of special interest. In the course of these field-work, a well-preserved ammonite has been found in the loose of the section. Fortunately enough, the infilling material made possible to identify the original horizon of the specimen. Previously this same horizon yielded two juvenile specimens, of the same form. Thus the two *in situ* collected incomplete specimens. together with the adult form found in the debris were sufficient to identify a species, which belongs to the poorly-known Lower Bajocian genus *Mollistephanus*. The species is new, and came from the basal Sauzei Zone of the sequence. All data on previously incompletely known ammonites are of value, thus a short description of morphology and stratigraphy warrants more than usual interest.

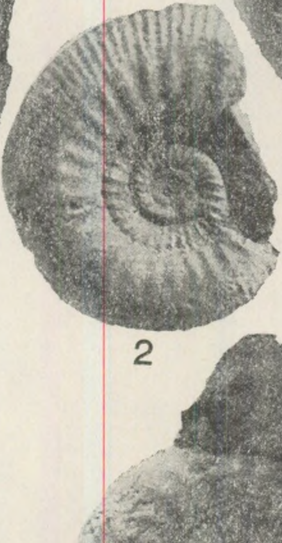
Systematic description

Order Ammonoidea ZITTEL, 1884
Suborder Ammonitina HYATT, 1867
Superfamily Stephanocerataceae NEUMAYR, 1875
Family Stephanoceratidae NEUMAYR, 1875
Subfamily Stephanoceratinae NEUMAYR, 1875

Genus *Mollistephanus* BUCKMAN, 1922
Mollistephanus (Mollistephanus) kondai n. sp.
Pl. I. figs. 1–3.

1a

1b



2

1c

3a

3b

Plate I.

Fig. 1. *Mollistephanus (Mollistephanus) kondai* n. sp. Holotype, Lókút Hill, a loose specimen from the basal Sauzei Zone. 1.a: ventral view; 1.b: lateral view (both natural size); 1.c: inner whorls (2x).

Fig. 2. *Mollistephanus (Mollistephanus) kondai* n. sp. 1st paratype, Lókút Hill, Bajocian profile, Bed. 21, basal Sauzei Zone. (natural size)

Fig. 3. *Mollistephanus (Mollistephanus) kondai* n. sp. 2nd paratype, Lókút Hill, Bajocian profile, Bed 21, basal Sauzei Zone. 3.a: lateral view; 3.b: ventral view (both natural size).

Material: 3 specimens; the holotype and two paratypes, the latters are juvenile middle-whorls.

Holotypus: An almost complete adult form, figured here in Plate I, figs. 1.a – c.

Locus typicus: Lókút Hill, northern Bakony Mountains, Transdanubia. Hungary.

Stratum typicum: The holotype is from loose material of the Bajocian profile, however the infilling material and the *in situ* collected two paratypes date as Bed 21, i.e. basal Sauzei Zone, Lower Bajocian.

Diagnosis: Relatively large *Mollistephanus*, with comparatively rare ribbing, constant number of primary and secondary ribs throughout the middle and outer whorls, and with *Skirroceras*-type suture line.

Measurements (in millimetres):

	max. D	D	Wh	Wb	Uw	Wb/Wh	pr	sr	sr/pr*
holotype	104	102	25.5(25.3)	25(24.5)	58(56.9)	0,98	17	45	2.64
		65	16 (24.6)	22(33.8)	32(49.2)	1.37	15	37	2.46
	length of the body chamber: 405°								
1st para-type	61	57	18(31.6)	19(33.3)	27(47.4)	1.05	16	43	2.52
		49	15(30.6)	18(36.7)	24(49.0)	1.20	16	42	2.62
	length of the preserved body chamber: 165°								
2nd para-type	40	39	13(33.3)	14(35.9)	16(41.0)	1.07	16	43	2.68
	length of the preserved body chamber: 120°								

* Abbreviations: max. D: maximal preserved diameter; D: diameter at the measurements; Wh: whorl-height; Wb: whorl-breath; Uw: umbilical width;pr: primary ribs per half-whorl; sr: secondary ribs per half-whorl.

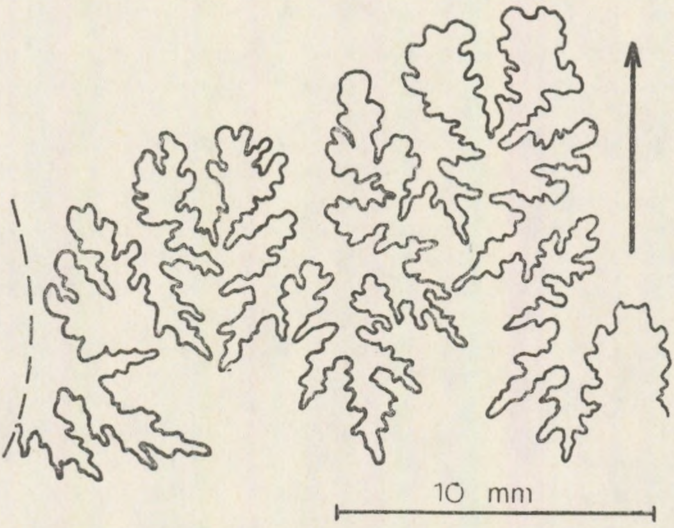
Description:

The holotype is a medium-sized, well-preserved serpenticone macroconch. The coiling is evolute, with shallow, broad umbilicus becoming even wider on the last whorl. The whorl-section is subcircular in the middle whorls, while becomes somewhat compressed on the last half-whorl because of the slight body chamber contraction. The sculpture consists of regular ribbing with radial primaries and straight, radial or slightly rectiradiate secondary ribs. The primaries, arising at the umbilical seam, are slender but rounded, and terminate in elongated swells bearing small, pointed tubercules occasionally. The number of primary ribs is fairly constant, being 14 – 17 per half-whorl throughout the middle and outer whorls. Somewhat below the half of the flanks, the primaries branch into rounded secondary ribs. The secondary/primary rib ratio is constantly 2.4 – 2.6, i.e. most inner ribs bifurcate, with some freely-arising intercalatory outer ribs.

In contrast to that of the middle and outer whorls, the sculpture of the nucleus shows rare lamellar, prorsiradiate primaries with bifurcations high on the ventrolateral margin (Pl. I, fig. 1.c). The rather sharp secondaries arise consequently in twins, without intercalatories. The change of the ribbing-style appears suddenly, around 20 mm diameter, corresponding to c. 10 mm umbilical width.

The body chamber is remarkably long, occupying more than an entire whorl. The holotype is a fully-grown specimen indicated by suture line crowding. Its ribbing does not change on the body chamber of 405° length. The end of the body chamber shows deep, broad preapertural constriction, and has a flared peristomal edge with projected smooth collar on the venter.

The suture-line is well-shown on the larger paratype, which is a juvenile specimen. The suture is of *Skirroceras*-type, with high lateral saddle, deep, narrow and slightly outwardly-projected lateral lobe and strongly retracted umbilical lobe (text-fig. 1.). The visible portions shown in the holotype are similar.



Text-fig. 1. Suture line of *Mollistephanus kondai* n. sp., 2nd paratype.

Stratigraphic horizon:

As stated above, the holotype came from the loose debris of the section, however its infilling material, a reddish, clayey calcareous marl matches well to that characterizes all ammonites, including the two paratypes, of Bed 21. In a preliminary evaluation of the fauna of the Bajocian of Lókút (GALÁCZ 1976. pp. 178–180) this bed was ranged into the Sauzei Zone, and detailed studies indicated the Sauzei/Laeviuscula zonal boundary just below, between beds 21 and 22. Bed 21 is characterized by a rich and diversified *Witchellia* assemblage, and this is the horizon of the first *Kumatostephanus*.

Comparisons:

There is only a single figured specimen of this genus in the literature, and this is the genotype, *Mollistephanus mollis* BUCKMAN, 1922 (in 1909–30, pl. 344, figs. 1–2). This ammonite, kept in the collections of the Institute of Geological Sciences, London (GSM 47148, see in CLARK 1982) is a small-sized form of 78.5 mm diameter as measured on the apertural margin. Its specific feature is the rather dense ribbing.

PARSONS (1974, pp. 159, 168) recorded the occurrence of new forms (incl. microconchs) from Normandy and Southern England, however informations on morphology are not given yet.

The forms described by MARIOTTI et al. (1980, pp. 230–231, pl. IV, figs. 3.4) as *Mollistephanus mollis* are different, belonging probably to other stephanoceratid genus.

Remarks on genus Mollistephanus

Generic features and evolutionary position

The generic features of *Mollistephanus* are the slender primary and the rounded, straight secondray ribs, and the style of furcation, where many secondaries arise almost independently or "tangentially" at the furcation points with occasional pointed tubercules. Other characteristic is the long body chamber occupying more than an entire whorl. The aperture and the suture line is of *Skirroceras*-type.

All these features correspond to a small-sized and finely-tuberculated variant of *Skirroceras*. However, the morphology of the group seems coherent, easily distingished from all other Stephanoceratidae, so to maintain it as an independent genus seems to be justified.

ARKELL (1951–59. p.74) suggested *M. mollis* as a connecting form between certain *Docidoceras* and *Skirroceras*. The same view is held by SANDOVAL (1983. pp. 171, 180). While the connection down to forms as *Docidoceras planulatum* BUCKMAN, 1921 (in 1909–30, pl. 264) cannot be excluded, the stratigraphic gap between *Docidoceras* (mainly Discites Zone) and the horizons of *Mollistephanus* (upper Laeviuscula Zone to lowermost Sauzei Zone) needs infilling with further transitional forms. On the other hand, *Skirroceras* appears slightly earlier than *Mollistephanus*, so an interpretation of *Mollistephanus* as an early offshoot of *Skirroceras* seems rather possible.

PAVIA (1983. fig. 24) suggested *Mollistephanus* as a possible stem-form of *Skirroceras*, *Kumatostephanus* and *Phaulostephanus* (*sensu* PAVIA). Of these three genera, *Kumatostephanus* appears as closest relative, however it shows many "perisphinctid" features, calling for ancestral early stephanoceratids of perisphinctid morphology (or *vice versa*).

Distribution

The type specimen of *M. mollis* came from Southern England, its horizon is within the Laeviuscula Subzone. BUCKMAN made a reference to

Clatcombe Farm section, bed 5 (see Buckman 1893, p. 499, Witchelliae hemera), which is Laeviuscula Subzone in age (Parsons 1976, p. 135). The source of stratigraphic informations on other *Mollistephanus* is the references made by Parsons. Accordingly, the genus occurs in Southern England in the Laeviuscula Subzone (Sandford Lane, basal part of the "Fossil bed" = 6 b in Parsons 1974; Oborne Wood, bed 3 in Parsons 1976; Dundry, bed 9 in Parsons 1979; Milborne Wick Lane section, bed 2 b in Parsons 1976; Bruton, "Pecten bed" in Parsons 1979). The single reference to the genus from higher horizon, i.e. from the lower Sauzei Zone is made also by Parsons (1974. p. 159), indicating two new species in a faunal list from the "couche verte" of Normandy. A recent reference from the same place and horizon is that made by Rioult (1980, p. 79), who listed "*Docidoceras perfectum* Buckm." with typical lower Sauzei Zone forms. This latter ammonite is that mentioned by other authors as the nearest morphological ally of *Mollistephanus*, so Rioult's reference may be interpreted as a record of this genus.

All these above data suggest that *Mollistephanus* is a good guide form to identify the Laeviuscula Subzone, though some forms might survive into the Sauzei Zone. The here described form indicates an extended areal distribution of the genus, being a record from the Mediterranean region. Further studies may reveal other occurrences, which can be used as tools in the correlation of Laeviuscula/Sauzei Zone faunas.

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CHANGES OF THE VIEW OF EVOLUTION AND THE PRACTICE OF STRATIGRAPHY

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ABSTARCT

The recognition of evolution is an integral and incontrovertible part of the human culture. The stubborn anti-evolution attacks of the last decade are supported by well-organised social quarters. These attacks indirectly jeopardize the credit and significance of natural sciences. Regrettably, some biologists of ahistoric concept, in favour of their speculations, deliberately renounce that new and well-founded body of knowledge, which has been given by the practically-oriented stratigraphy, geology and paleontology. This makes, willy-nilly, easier the propaganda of the anti-evolution camp.

The extending of evolutionary studies is the aim of specialized field of science. On the other hand, emphasizing the importance of evolution does grow out of this scope, and is an obligation of philosophers, as well as all progressive intellectuals.

Introduction

Evolutionary investigations are aimed to understand the phylogenesis of the living world and the causes behind. Stratigraphy investigates the temporal and spatial relationships of rock bodies building up the outermost zone of the Earth: the lithosphere. Evolution studies belong into the sphere of biology, while stratigraphy is one of the supporting columns of geology. It is reasonable to say, that in biology everything is meaningless without evolutionary view, and similarly obvious, that methodical raw-material exploration would be unconceivable without stratigraphy.

It remains to be seen whether these two, apparently independent scientific branches have anything in common under the cover – culture.

To give a definition of culture unequivocally and correctly is out of the scope of specialized fields of sciences. It would be difficult to taking stock of the knowledge which is essential part of humanity on the eve of the 21st century. However, it is demandable from an educated man to know that the Earth is spherical, it is revolving and has a long history. The first two statements are hardly to be challenged. On the other hand, it is justified to take note of those recent views which throw discredit the historicism of the Earth and life. The main brunts of the attack are geology and paleontology studying phylogeny by means of fossils. Because secondary education in Hungary strangely pays no regard to these fields of sciences, the innocently uninformed laymen need orientation. To make the problem easier to understand, it is worthy to point out the social background and efficiency of the recent anti-evolution campaign.

European geologists were astonished to learn the response by NORMAN D. NEWELL, world-known paleontologist in 1979, for the award of the American Paleontological Society, when he unexpectedly adverted to the deterious effect of that "handful of religious fanatics taking advantage of the current rise of superstition and anti-intellectualism across America", who has initiated a "Holy War" against geology and paleontology. The crusade was declared on the evolution theory and the fossil record. According to NEWELL, the group has political aims and seeks control on schools and colleges. It would be a mistake to believe "that this campaign is naive and of no significance to [the American] society."

Since these words of NEWELL the anti-evolution camp has been gaining power and changed its strategies. ERBEN, the Bonn paleontologist noted their organization with surprise, and he emphasized that they obtain significant financial support from high quarters. Because they have the majority of newspapers, magazines, radio and television stations under their influence, the assault is more effectual. The Creation Research Society, casting off the guise of religion, calls itself as "scientific" and demands equal time within biological education both for creationism and for the discreditably denounced "supposition" of evolution. It sounds incredible, but more than 600 well-educated researcher spare no trouble to prove the six-day Creation story of the Bible! In 1984, on the exhibition of the American Museum of Natural History in New York, showing the 4,000 million years prehistory of man, the imposing Hall of Dinosaurs was occupied by speakers on Sundays, claiming that these giant reptiles were killed some thousand years ago in the Noah's Flood or were faked by paleontologists.

One would regard this agressive devotion of creationists as an isolated, characteristically American phenomenon, but the effect reached Europe, too. Otherwise the notorious book of WILDER-SMITH, titled provokingly as "Die Naturwissenschaften kennen keine Evolution" would have been hardly ran into its third edition since 1980 in Basel.

In spite of the fact, that the creationism has a latent literature in Hungary, this deserves no contravencing those statements distorted by retrograde orders of society. This would but make easier their work, dealing with their ridiculous arguments as scientific assertions. The facts of creationists are negatives: the Earth cannot be older than 6,000 – 10,000 years; the extinct organisms cannot be considerably older than man; there was no extinction except that of the Deluge; evolution cannot exist or at least cannot be proved; etc.

This is an absurd demand to sink branches of morden sciences (e. g. geology, geophysics, astronomy, paleontology, etc.) back to the pre-18th century level. Pure speculation and rhetoric argumentation are Middle Age traditions. On the other hand, respecting ARISTOTLE cannot be imply a return to scholasticism. It is justified to turn towards the facts, especially in those cases when these are supported by the practice.

In the following, three issues are concerned:

- how stratigraphy was formed and what part could be assigned to it in the establishment of evolution theory;
- what extremist school of biology denies evolution;
- what help modern stratigraphy can render to modern biology.

The development of stratigraphy and its evolutionary relationships

In the development of stratigraphy the landmarks can be summarised as follows:

- the recognition of successive deposition of layers (second half of 17th century);
- the realization of stratigraphic value of fossils (end of 18th century);
- subdivisioning of successions according to the state of development of the contained fossils (first half of 19th century);
- codification of stratigraphic nomenclature (second half of 19th century);
- the geochronological enlightening of stratigraphic subdivisioning (first half of 20th century);
- the precisioning of the stratigraphic scale by means of different physical, chemical, astronomical, etc. methods (second half of 20th century).

These stages illustrate, on the one hand, the past and the continuous, more and more complex development of stratigraphy, on the other, these attest that this has been a science focussing on time since the beginnings.

Stratigraphy was born well before the emergence of evolution theory. This is an important argument against creationists, who claim that the sequences of fossils were constructed subsequently by paleontologists to prove evolution! The law of superposition of layers were formulated by STENO. He was a Dane physician living at the court of Medicis in Florence. In 1666, when fishermen cought a man-eating shark in the Ligurian sea, this aroused general curiosity. Duke Ferdinand comissioned STENO to dissect the shark. He recognized that the extant shark's teeth are similar to the tongue-stones *(Glossopetrae)* collected from rocks. Thus he supported the observations of PLINY and other ancient naturalists: fossils are not *lusi naturali*, but remains of past organisms. STENO was interested not only in fossils, but in fossiliferous strata, too. He wrote his pioneering work on these. It was published in 1669, titled as "De Solido intra Solidum naturaliter Contento Dissertationis Prodromus" (Forerunner of dissertation on a solid naturally enclosed within a solid), and this is the eraliest scientific treatise on geology. The importance of the Forerunner is marked by the fact that it was reprinted after 300 years. The most important perception of STENO is that stratified rocks were not formed simultaneously, but subsequently in time. When the lower layer was deposited, the upper one could not be existed, the sediment grains floating above the consolidate layer could form a new layer afterwards. This is the principle of superposition of layers. STENO emphasized also, that while the lower plain of a bed may imitate the surface of the previously solidified bottom, the upper plain is always flat and originally horizontal. Strata may move subsequently, but from the law of their origin one can infer the stages of displacements. Thus STENO arrived from empirical observation at abstract, rational conclusions. He is not only the founder of stratigraphy, but also of tectonics.

STENO claimed only that the superposed layers have been formed in temporal succession. He did not dwell on that how much time was taken up by the formation of rock sequences. Nearly a century had passed, when BUFFON made an annual estimation for the time of deposition. It was then that geology came into conflict with the Bible the first time. BUFFON was a naturalist of the French Enlightment. In his "Théorie de la Terre", published in 1759, on the basis of great thicknesses of successions, he estimated the age of the Earth as more than 74,000 years, instead of the current 6,000. It should be mentioned, that in his notices he was bolder, counting in millions of years. The recognition of geological time occasioned a cultural shock, just as in the case of the astronomical revolution of COPERNICUS, KEPLER, GALILEI and NEWTON. Though BUFFON had to withdraw his heretic statements, his views did not remain ineffectual. Both LAMARCK, the founder of evolution theory, and CUVIER, the founder of paleontology, were students of BUFFON.

BUFFON regarded fossils but documents preserved in nature's archives. W. SMITH deserves credit for understanding the practical use of fossils. As an engineer, in surveying the coal basins of England he noticed that each bed has particular fossil assemblages, and the fossils can be used in tracing the coal seams! He was little more than 27 years old when he first referred to the "wonderful order and regularity" of distribution of fossils (1796). Before SMITH, many people were dealing with fossils, they collected, described and classified them, without taking notice of their stratigraphic position. This is the way most amateur fossil hunters are collecting. SMITH liked fossils but he had been not dealing with them in detail. He was not interested in the explanation of his concise statement: "particular fossils are characteristic of particular strata". In contrast to BUFFON, ha was creationist, regarding each stratum, together with its fossils, as independent work of creation.

LAMARCK came to quite different conclusions from studying recent and fossil invertebrates. He was director of Department of Worms and Insects in the Natural History Museum of Paris. He had been studying botanics until his age of fifty, and even in 1797 he believed the constancy of species. However, in the spring of 1800 he was lecturing on the development of the living world. Between these two dates LAMARCK had made geological studies. He published an essay on fossils and he summarised his geological thoughts – under the title Hydrogeology – in 1802. In the formation of his evolutionary theory his stratigraphical-paleontological studies played undoubtedly an important role. LAMARCK went further than BUFFON. He regarded the age of the Earth as nearly inestimable. He estimated the deposition of layers of oceanic origin as 900 million years. This is the order of magnitude of the turning point in the fluourishing of multicellular marine organisms (570 million years – the beginning of the Phanerozoic). Though he regarded fossils as "extremely interesting documents" in studying of changes on the Earth's surface, in his large-scale synthesis he did not take the opportunity to conclude from the ,,successions". This is why his theory appeared as unfounded and this could partly be the cause of his tragedy.

The increasing raw material needs of the industrial revolution promted stratigraphical researches. In 1812 W. SMITH published the earliest geological map of England, and in 1816 appeared his classic, the "Strata identified by organized fossils, containing prints on colored paper of the most characteristic specimens in each stratum". Subsequently atlases of "Leitfossilien" were published successively, being of great help to mining. Descreptive paleontology emerged from the museum, and paleontologists studied with growing interest the temporal distribution of fossils.

In 1812 CUVIER divided Earth history to only two bigger temporal units. These were the Age of fish and reptiles and the Age of mammals and man. The Age of fish and reptiles might have been equal to Mesozoic and smaller and bigger mammals and man could have characterized the Cenozoic. However, in 1828, A. SEDGWICK recognised, that older rocks – the Devonian Old Red Sandstone – also contained fish remains. PHILLIPS, in 1841, on the basis of these facts grouped the fossiliferous geological formations into three units, and these are used up to now. The Paleozoic corresponds to the Ages of invertebrates and fish, Mesozoic is euqivalent of the Age of reptiles, and Cenozoic is the Age of mammals.

Based on fossils, the greater time intervals were subdivided into shorter units. In the 1840's the large-scale subdivisioning of the Earth history was established. In 1850 d'ORBIGNY recognised that the periods can be subdivided farther into "stages". The first to split stages into zones was OPPEL (1858). It is of primary importance, that before the publication of "On the Origin of Species" (1859) the history of living world was essentially elucidated by the brilliantly developed stratigraphy and paleontology.

The question arises: how this all is reflected in the revolutionary "Origin of Species" of DARWIN?

DARWIN was an excellently educated geologist. SEDGWICK introduced him into geological mapping and he himself collected fossils while travelling around the world. As his real master he acknowledged LYELL, the greatest geologist of the 19th century. According to DARWIN, half of his thoughs he could owe to LYELL. Whether this influence was positive? Hardly. LYELL – correctly – emphasized regularity in geological processes, laying particular stress on actualism. Accordingly, the present is the key to the past. The past of the Earth is immeasurable. The geological processes are characterized by slowness and permanence. LYELL, as contrasted with his contemporaries, disclamined catastrophes and re-creations, and denied a progression directed by dispensation of the Creator. He strived to shear geology of all mystic elements, however he considered species replacement a subject which is beyond our comprehension. Being a believer, he refuted the evolution theory of DARWIN, but as an exeptional scientist, he used every means to encourage the publication of the "Origin of Species". DARWIN translated the Lyellian concept of geology into biology, and regarded evolution after all as a slow, gradual process. It is true enough, that this view subserved the public opinion of the Victorian bourgeoisie.

DARWIN, in the first sentence of "Origin of Species" referred to that paleontological discoveries had a part in shaping up his theory. On the other hand, in this masterpiece he did not pay too much attention to the fossil record, and he based the evidences of evolutionary theory mainly on recent organisms. Because his gradaulistic speciation concept and the fossil record appeared inconsistent from the very first, he separately dealt with the imperfection of the geological data and the scarcity of paleontological collections in his famous 10th chapter. According to DARWIN the breaks in the evolutionary lineages and the lack of transitional forms are apparent, and can be due to the subsequent destruction of the documents. This is an assumption hard to make consistent with the results of modern stratigraphy. Simultaneously, but independently of DARWIN, WALLACE recognised the importance of natural selection in evolution. WALLACE, just as DARWIN, could not avoid the results of paleontology. According to his notebook, he regarded the following regularities as most important in evolution:

– species have particular temporal distribution;
– the older is a fauna, the greater is its difference from the recent ones;
– the succession of appearances of species is similar to their grade of development;
– there are no gaps between appearance and extinction of species, genus and family (i.e. the fossil record is continuous);
– the structure of fossil animals resembles that of the recent ones.

WALLACE also respected LYELL, and he regarded his work "immortal". On the basis what he emphasized from the results of contemporaneous paleontology, one can imply that he denied both catastrophism and continuous, gradual speciation. Eventually he attached greater importance to the fossil record than DARWIN.

At the time of the third edition of the Origin of Species the best-known "missing link", the *Archaeopteryx* was discovered. T. H. HUXLEY, who, as a pugnaceous evolutionist was nicknamed the "Bulldog of Darwin", pointed out the place of the find. The ancient bird is an intermediate from small dinosaurs to birds. In 1879, i.e. in DARWIN's lifetime, the rich North American fossil material served as basis to construct the phylogenetic tree of horses from the fox-sized Eocene "*Orohippus*" to the living horse *(Equus)*. Being in possession of evolutionary views, paleontologists paid even more attention to the bed by bed changes of fossils, and prepared even more detailed subdivisions within the rock sequences. In 1881 the International Geological Congress in Bologna – with the contribution of Hungarian geologists – codified the stratigraphical nomenclature.

At the turn of century the "ideal stratigraphic column" was roughly completed, i.e. stratigraphers made clear the order of layers and successions of fossil floras and faunas. Books on historical geology written in those times are readible and informative even today. There is, however, one viewpoint from which these are completely useless, namely these give no information on how the ideal geological column or the inferred progress of geological events can be fitted into the abstract framework of time given in millions of years. Although this question was a great trouble even to Darwin.

LORD KELVIN, the rightly distinguished physicist of the 19th century, calculated the age of the Earth by means of cooling an iron sphere and supposing the gradual cooling down of the Solar system. His result – approximately 20 million years (in 1897) – was inconsistent with the gradualistic concept of DARWIN. "I feel a conviction – wrote DARWIN to his friend HOOKER, the botanits – that the world will be found older than THOMSON [LORD KELVIN] makes it". Furthermore KELVIN refused geology with the confidence of an eminent mathematician. Characteristic is the title of his lecture read in 1865: "The Doctrine of Uniformity in Geology Briefly Refuted".

Ironically, he not only lived to see the denial of his own doctrine, but he was in the audience of that lecture, where E. RUTHERFORD reported on the great energy release during radioactive decay. But all this happened in 1904, well after the death of DARWIN. The stability of the half-time of radioactive decay was discovered by CURIE in 1903, before RUTHERFORD. This ultimately made a way to geochronology of approximate accuracy succeeding the former extreme estimates.

According to the notorious calculation of Archbishop USSHER (1650), the date of world's origin is 9 p.m., 22nd of October in 4004 B.C. As it is well-known today, the age of the Earth is approximately 4.6 milliard years. "Some creationists, recoiling from [this] fearsome prospects of time's abyss, have toppled backward into the abyss of ignorance" (ALBRITTON, 1980).

The revolution of systematics in biology

It is a matter of common knowledge, that science of this century resulted in imposing accomplishments in rather different fields. As examples, one can only refer the spectacular advancements in microelectronics or genetic engineering. On the other hand it is little known, what revolutionary changes took place in systematics after World War II.

The new systematics arised from old contradictions. Modern systematists were well aware of the evolution of organic world, yet essentially they used that systematic framework which had been constructed by LINNÉ in the 17th century. LINNÉ based his work on created types. The Linnean categories (species, genus, family, order, class, phylum) appear arbitrarily if one takes the constant organic evolution into consideration. If species evolve continuously, what was the ground to set up their limits? One can wonder if the milestones divide roads into natural units.

Hennig deserves credit for making efforts to resolve the contradiction between the commonly arbitrary or eclectic practice of systematics, and evolution theory. Hennig aimed to establish an objective phylogeny, which should be reflected in classification. Even Darwin predicted, that classification will be converted some day into genealogy. The Hennigian system is the genealogy of organisms. It is understandable that many regard Hennig as the succesor of Darwin and at the same time as Darwin of our century. Why he is a comparatively little-known scientist?

Hennig was a German entomologist, who wrote his main work in 1950, in hard times on the morrow of World War II. It was not till 1966 that his work – somewhat revised – has been published in English. His success and influence can be considered practically from that time.

According to Hennig, only groups descended from common species can be regarded as natural, related units. Speciation always takes place by dichotomy (two-branching). Because "branch" is *clados* in Greek, the Hennigian systematists are called as cladists, too. From the originated two branches one retains larger number of primitive characters, while the other has advanced ones. Bacause of this, the Hennigian school was attacked by antimarxists, since it appeared, that cladists would view the world in the "progressive – reactionary" contradiction! When the British Museum (Natural History) exhibited dinosaurs in cladistic system, the burgeois press and the radio showered vehement reproaches on the directors, because they let Marxism within the walls of the Museum...

One can conclude that all these are nothing to do with creationsim, since the essence of Hennig's taxonomy is its phylogenetic base. However, in recent years a group of cladists turned off the Hennigian track. This school is commonly referred as "objective cladism", non-canonic cladism, "New York school", "natural order systematics", etc.

These various labels cover relatively uniform attitude.

This new school can be characterised mainly with that it regards its master rather Popper than Hennig. The idealistc phylosophy of Popper excluded historical sciences from the sphere of "good sciences", because their reults cannot be tested experimentally. According to Popper, Darwinism "is not a scientific theory, but metaphysical". It is true, that Popper later slightly relented the rigour of his judgement, acknowledging the "scientific character" of paleontology, and the scientific value of metaphysic research programs. However, this back down did not influence the strategy of the new school.

According to them, because evolution is unprovable or an unprovable assumption, it has no room within systematics and related fields of biology. The base of taxonomy is exclusively the grade of distribution of homologue characters as observed in extant organisms. The collection and grouping of these characters "does not demand belief in or knowledge of evolution". In taxonomy common ancestor should be replaced by "relation characterizing natural group". All these are deliberate return to the pre-Darwinian "ideal morphology", to the idea-theorem of the German romantic natural philosophy, or simply to the fixist Linnean system-concept.

One of their perplexing additional argument is that the living world was systematized even before formulating evolution theory. One could similarly argue that mankind existed for several century without sciences!

Modern stratigraphy, modern biology

The question arises: whether the total split of neontology and paleontology will come about? The theoretic answer is: yes, and practically at the expense of both. Paleontology will certainly not be able to do without the astonishing knowledge of biology on recent living world.

It would be an apparently easy matter to suggest that biologists systematize organisms on the basis of recent characters, and paleontologists study the fossils. However, living world has a *single* phylogenesis. And the purpose of a natural system is to reflect the developed relationships. In spite of the unquestionable methodological independency, the goal of both paleontology and neontology is the better scientific cognition of the living world. A headstone of these researches is evolution. KONRAD LORENZ, in 1983, designated "blank senseless" (blanker Unsinn) the refusal of evolution, and rightly pointed out, that we have more documents on the history of living world than on the history of mankind! He also realised, that the tumbling down of the wall between humanities and natural sciences is only a matter of time.

If one acknowledges the role of historical concept in biology, the modern stratigraphy retrieves its evolutionary significance.

In the second half of the 20th century, in addition to the classical biostratigraphy, several new braches have been developed in stratigraphy. Lithostratigraphy, magnetostratigraphy, diastratigraphy, seismostratigraphy, volcanostratigraphy, oceanostratigraphy, isotope stratigraphy, climatostratigraphy, rithmostratigraphy, together with chronostratigraphy place the rocks within the ideal stratigraphical column with increasing precision, and give continuously refined framework for fossils. Paleontology, being supported by stratigraphical results, gives informations of full value not only on the past of recent organisms, but also on the lower limits of their temporal distributions, former frequencies, geographic distributions, and last but not least, on the developmental order of their characters. The conclusion on the grade of advancement of characters could be rather subjective if one disregards the fossil record completely.

It is true, that the past cannot be tested experimentally, but this does not involve its denial. One cannot lock an *Archaeopteryx* into a laboratory, yet we know that it did exist. We cannot claim that it was the ancestor of all birds, yet it gives invaluable information on the very history how reptiles turned into birds. It is conceivable, that modern biology, some day, will experimentally manufacture an *Archaeopteryx* by genetic manipulation. However, this would not even touch the historical facts revealed by paleontology, e.g. that *Archaeopteryx* has been living ca. 150 million years before, on beaches fringing tropical lagoons.

These last sentences possibly sent us off far beyond reality. The science and culture of our century is characterised jointly by differentation and integration. Hennig was an adherent of comprehensive approach, and his guidance would be a standard for his followers as well.

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ENVIRONMENTAL CHANGES IN EOCENE/OLIGOCENE BOUNDARY STRATOTYPES IN HUNGARY BASED ON OSTRACOD FAUNAS

by

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ABSTRACT

Changes in ostracod faunas during the Late Eocene – Early Oligocene interval can be traced in profiles containing or lying near to the Eocene/Oligocene boundary. We could recognize and separate assemblages of ancient habitats utilizing published data of recent and fossil faunas. Quantitative changes of distribution helped to interpret geological events which have changed the palaeoenvironments of ostracods.

Introduction

Hungarian investigations on uninterrupted Eocene/Oligocene sequences are part of IGCP Project 178: Terminal Eocene Events. The Hungarian working group held an international symposium in 1983 to present the results (BÁLDI et al., 1983; Preprints et Abstracts, 1983). Following the description (MONOSTORI, 1985a) and stratigraphical interpretation (MONOSTORI, 1985b) of the ostracod fauna, this paper contains palaeoecological analysis. Geological interpretation will be published elsewhere (MONOSTORI, 1986).

Methods

The environmental reconstruction is mainly based on statistical evaluation of the fauna. For a detailed description see the monograph of MONOSTORI (1984) on the Middle Eocene ostracods of Dorog Basin, Hungary.

Generic composition

1. The lowermost of the examined formations is the Buda Marl (NP 20 – 21). Appreciable ostracod faunas have been yielded from Alcsútdoboz – 3, Kiscell – 1 and Cserépváralja – 1 boreholes and from an outcrop at Pusztaszeri út, Budapest. The following genera have been described (MONOSTORI, 1985a):

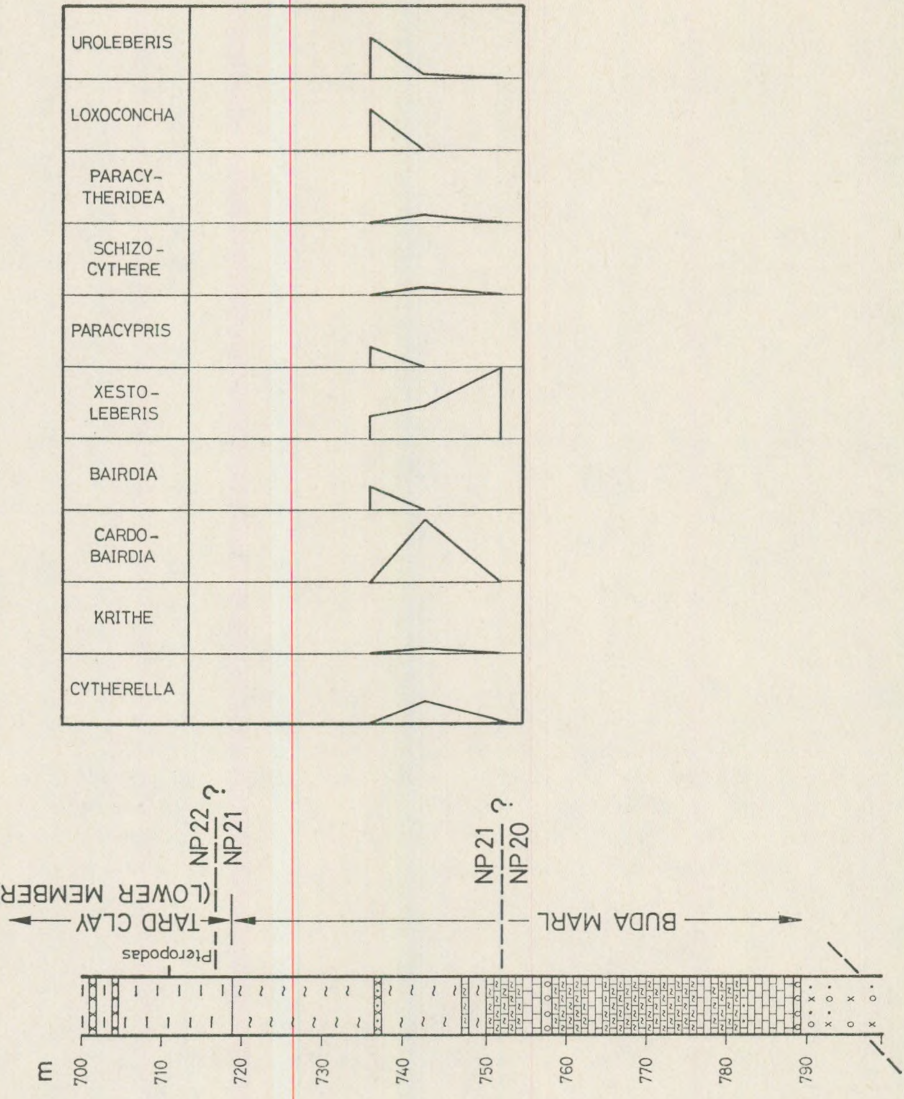

Fig. 1: Percentage of specimens among genera in Alcsútdoboz – 3 borehole (Profile after BÁLDI, HORVÁTH, NAGYMAROSY and VARGA, 1983)

Cytherella
Cardobairdia
Bairdia
Schizocythere
Clithrocytheridea
Parakrithe
Quadracythere
Occultocythereis
Loxoconcha
Paracytheridea
Eucytherura
Semicytherura

Krithe
Agrenocythere
Costa
Pterygocythereis
Pokornyella
Hermanites
Xestoleberis
Uroleberis
Abyssocypris
Argilloecia
Paracypris

According to published data, these genera can be ranged into the following environmental groups.

A. Euryhaline forms dominant in littoral – shallow sublittoral zones:

Clithrocytheridea
Pokornyella
Loxoconcha
Xestoleberis
Uroleberis

B. Stenohaline forms dominant in the littoral–sublittoral zones:

Schizocythere
Hermanites
Quadracythere
Occultocythereis
Paracytheridea
Eucytherura
Semicytherura

C. Stenohaline forms dominant in sublittoral and bathyal zones:

Bairdia
Costa (see note)
Cytheropteron
Pterygocythereis
Paracypris

D. Stenohaline forms dominant in bathyal zone:

Cytherella (see note)
Cardobairdia
Parakrithe
Krithe
Agrenocythere
Abyssocypris
Argilloecia

Notes:

a) The genus *Loxoconcha* contains a few stenohaline species living in deeper water. Similar data (i. e. species living on the outher shelf edge) on *Xestoleberis* are given by Keen (1971).

b) *Schizocythere* species known from the Hungarian Palaeogene were dominant in the deeper sublittoral region, while contemperaneous *Hermanites* and *Quadracythere* species rather occurred in shallow sublittoral zone in largest quantities.

c) The species *Costa hermi* occurring in the profiles discussed here has been adopted to deep water (Monostori, 1982). Possibly it was a dominant species in the bathyal region during Late Eocene–Late Oligocene.

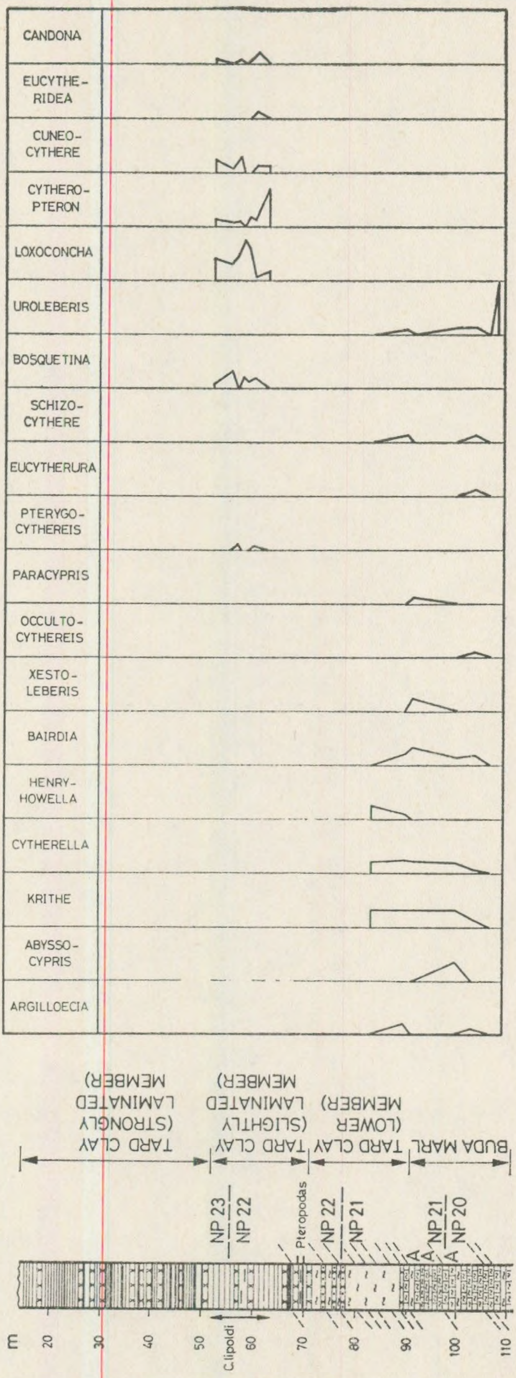

Fig. 2: Percentage of specimens of genera in Kiscell – 1 borehole (Profile by Báldi, Horváth Nagymarosy and Varga, 1983)

d) Species of the genus *Cytherella* are wide-spread in all depth zones. Altogether, the faunas, where most specimens are *Cytherella*, indicate deeper sublittoral – bathyal region. This is proven by published data and by investigations of Palaeogene faunas in Hungary. The *Cytherellas* examined here are morphologically very similar to forms characteristic for the bathyal zone, described from France (Ducasse, 1981).

e) The genus *Krithe* contains species characteristic for the sublittoral zone. Our most frequent species is cut at the posterior end; this feature is characteristic for deep-water forms (Ducasse, 1974).

Frequency of genera are shown on Figs. 1 – 4.

2. The lower, non-laminated member of Tard Clay formation (NP 21 – 22) – which lies conformably on Buda Marl – contains an ecologically well characterizable fauna in boreholes Kiscell – 1 and Cserépváralja – 1. Genera:

Cytherella
Bairdia
Schizocythere
Krithe
Henryhowella
Uroleberis
Argilloecia

Note:

The genus *Henryhowella* is dominant in bathyal, normal saline environments.

Frequency of genera is shown in Figs. 2 and 4.

3. The middle, weakly laminated member of Tard Clay Formation (NP 22 – 23) contains an appreciable ostracod fauna in Kiscell – 1 and Cserépváralja – 1 boreholes and in outcrops at Zugliget (Budapest) and Kiseged (Eger). Genera:

Cytheromorpha
Eucytheridea
Schuleridea
Cuneocythere
Pterygocythereis
Leguminocythereis
Megahemicythere
Bosquetina
Loxoconcha
Cytheropteron
Xestoleberis
Macrocypris
Candona

According to published data,

A. from dominant in fresh-water or very low salinity environment:
Candona

B. euryhaline forms dominant in littoral-shallow sublittoral zones:

Cytheromorpha
Eucytheridea
Schuleridea
Cuneocythere
Megahemicythere
Loxoconcha
Xestoleberis

C. stenohaline form dominant in littoral – sublittoral zones:

Leguminocythereis

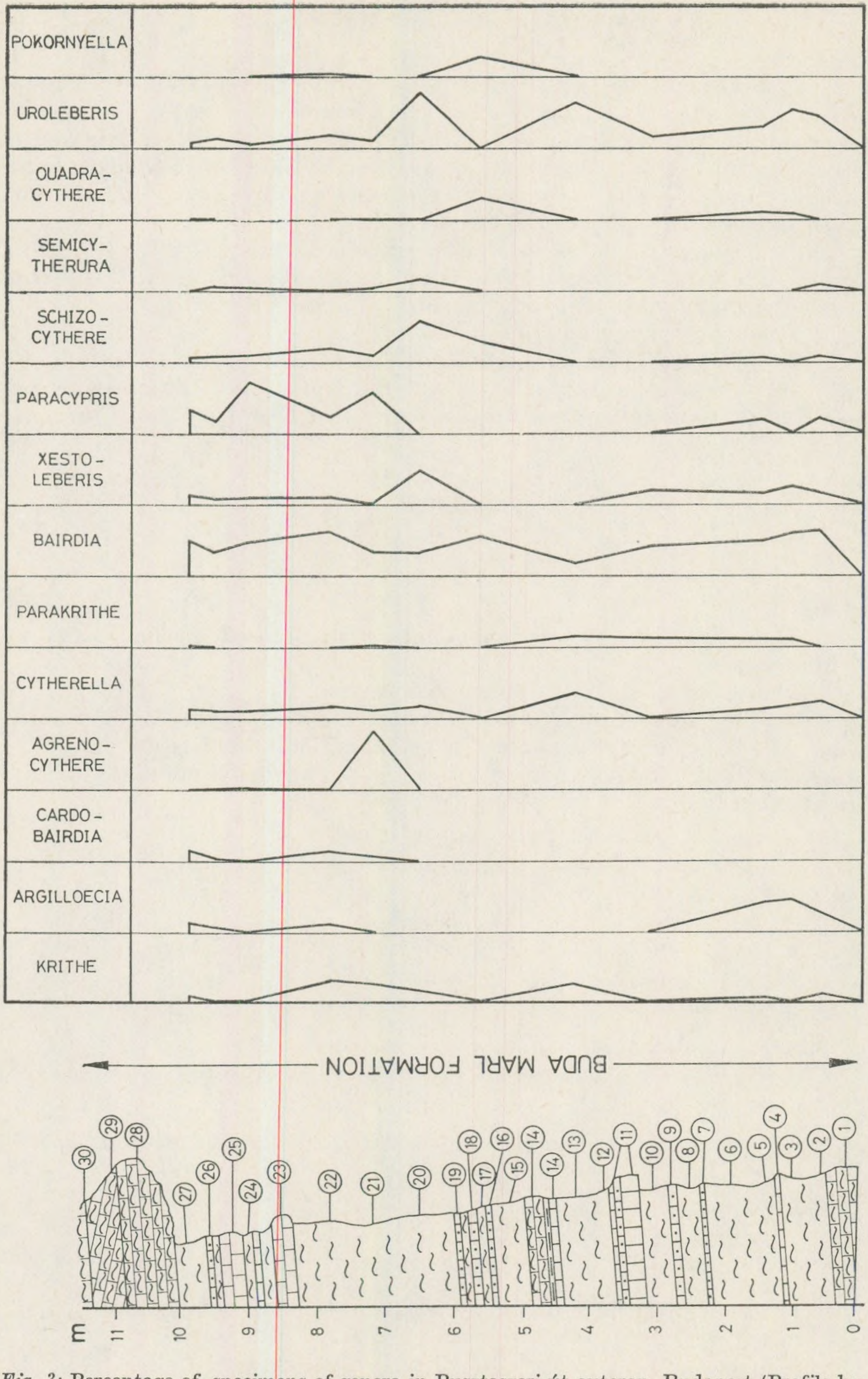

Fig. 3: Percentage of specimens of genera in Pusztaszeri út outcrop, Budapest (Profile by Nagymarosy and Varga, 1983)

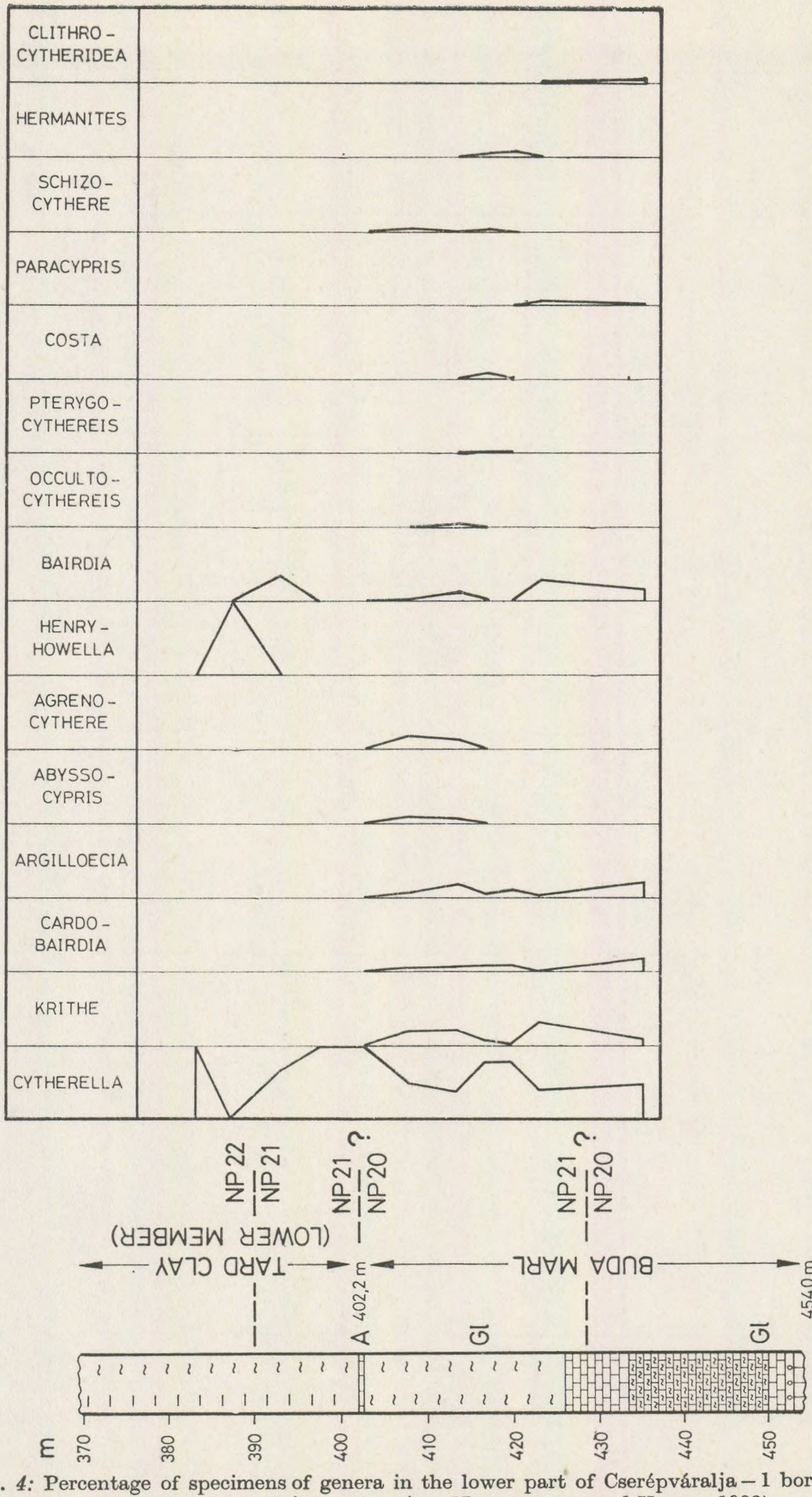

Fig. 4: Percentage of specimens of genera in the lower part of Cserépváralja – 1 borehole (Profile by Báldi, Horváth, Nagymarosy and Varga, 1983)

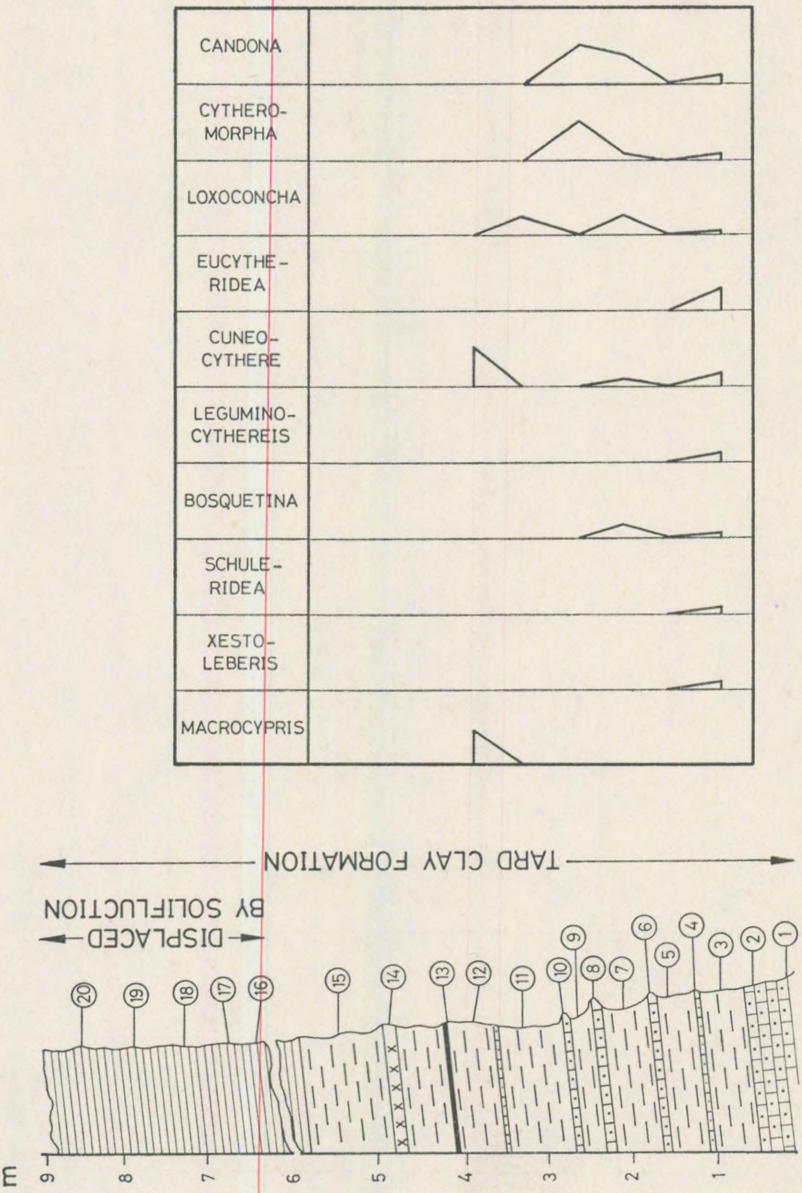

Fig. 5: Percentage of specimens of genera in the Zugliget outcrop, Budapest (Profile by Báldi, Horváth, Kázmér, Nagymarosy and Varga, 1983)

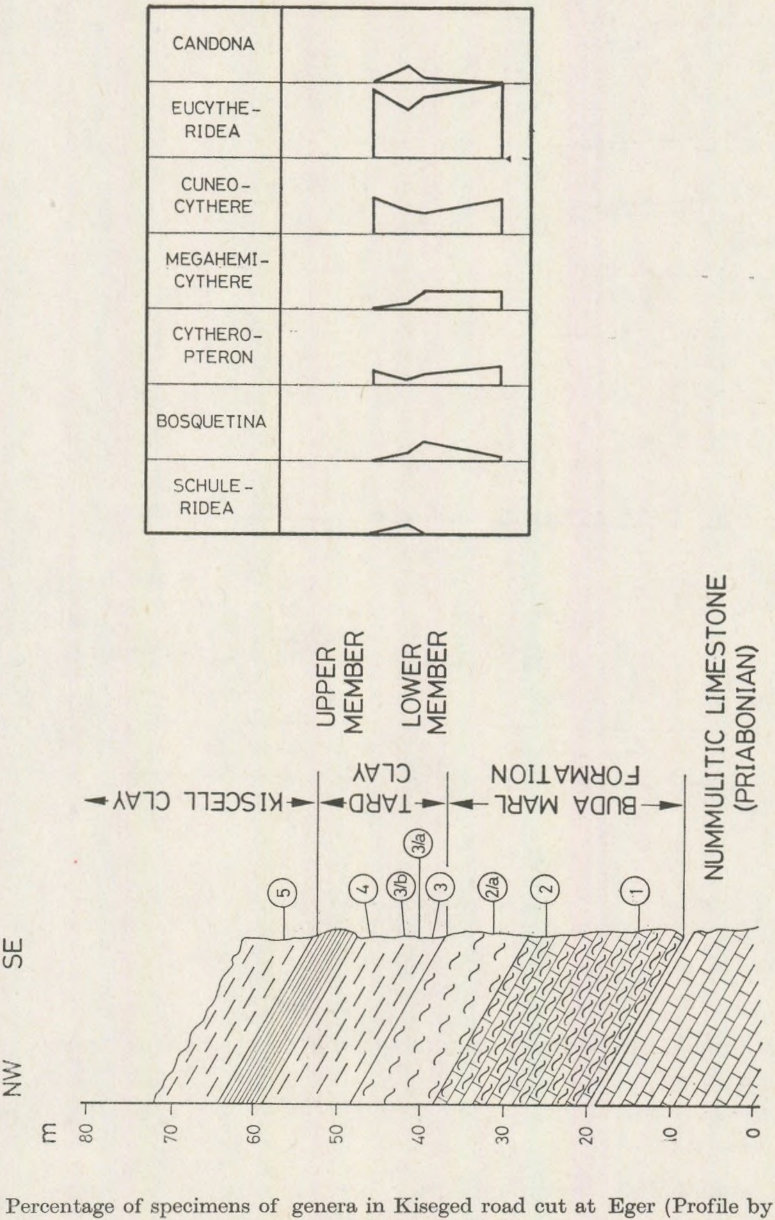

Fig. 6: Percentage of specimens of genera in Kiseged road cut at Eger (Profile by NAGYMAROSY and VARGA, 1983)

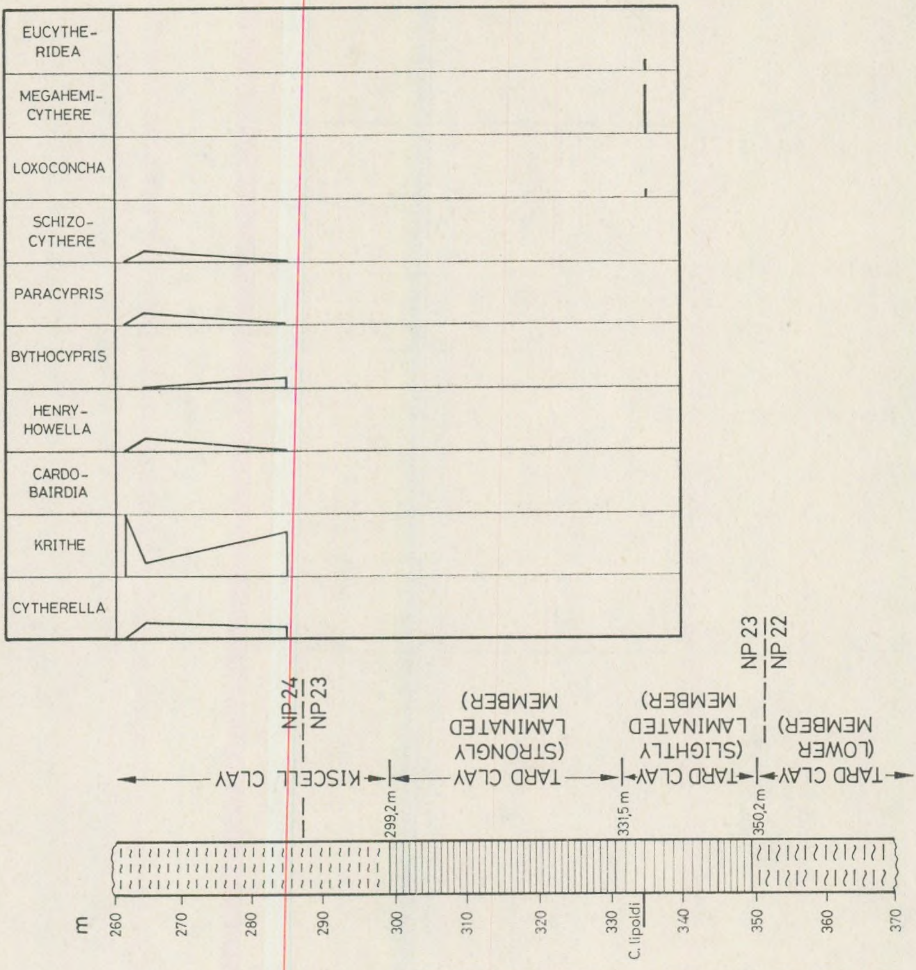

Fig. 7: Percentage of specimens of genera in the upper part of Cserépváralja – 1 borehole (Profile by BÁLDI, HORVÁTH, NAGYMAROSY and VARGA, 1983)

D. stenohaline forms dominant in sublittoral – bathyal zones:

Cytheropteron
Pterygocythereis
Bosquetina

E. stenohaline form dominant in bathyal zone:

Macrocypris.

Notes:

a) Generic determination and, – consequently –, ecological evaluation of the most frequent *Candona* species from here is uncertain. Presence of fresh-water forms can be proven by another species, which certainly belongs to the genus *Candona* and by other fresh-water forms *(Curvopsis, Moenocypris)* from outcrops not discussed here.

b) According to published data, the genera *Cytheromorpha* and *Eucytheridea* are frequent in very low salinity environments, while *Schuleridea* and *Cuneocythere* may be dominant in either brackish or normal saline marine environments.

Frequency of genera is shown on Figs. 2, 5, 6, 7.

4. The Kiscell Clay Formation (NP 23–24) (overlying Tard Clay) yielded appreciable fauna from Cserépváralja – 1 borehole only. Evaluation of abundant material of outher outcrops not discussed here, see MONOSTORI (1982). Genera:

Cytherella	*Krithe*
Bythocypris	*Henryhowella*
Schizocythere	*Paracypris*

According to published data, these genera can be attributed to the following environments.

A. Stenohaline form dominant in littoral–sublittoral zones:
Schizocythere (see Note 6) at Buda Marl Formation.
B. Stenohaline form dominant in sublittoral–bathyal zones:

Paracypris

C. Stenohaline forms dominant in bathyal zone:

Cytherella	*Krithe*
Bythocypris	*Henryhowella*

Frequency of genera is shown in Fig. 7.

Reconstruction of ecological changes in the profiles

Based on ecological groups delineated above, diagrams have been compiled to present the percentage of these groups in the faunas of profile samples.

Alcsútdoboz – 3 borehole (Fig. 8)

Upper part of Buda Marl Formation may have been deposited in a relatively deep (outer sublittoral – bathyal) basin with permanent influx of sediments from littoral – shallow sublittoral regions. This is indicated by dominant occurrence of the genus *Cardobairdia.*

Budapest, Pusztaszeri út, outcrop (Fig. 9)

The Buda Marl Formation is exposed here. Oscillating mixing of shallow and deep marine assemblages is characteristic. Resedimentation from

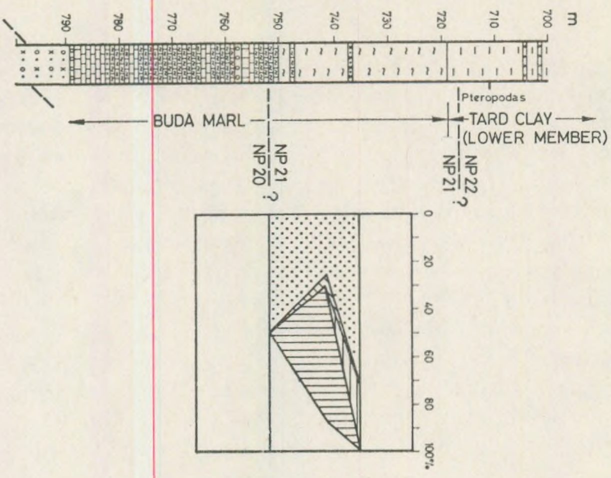

Fig. 8: Specimen percentage of ecological groups in Alcsútdoboz – 3 borehole (Profile by BÁLDI HORVÁTH, NAGYMAROSY and VARGA, 1983) Legend see Fig. 11.

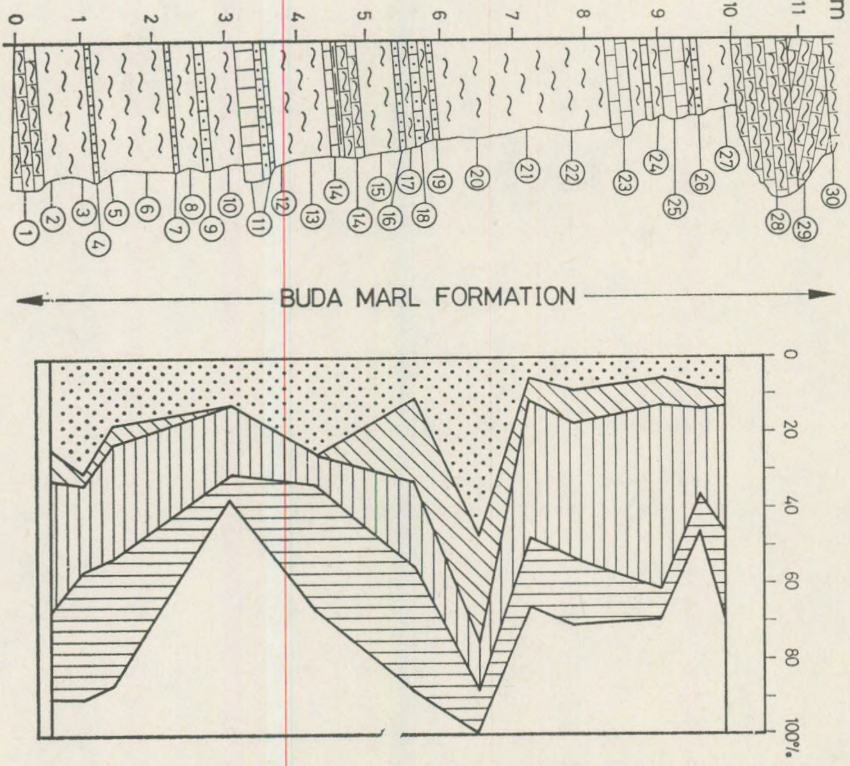

Fig. 9: Specimen percentage of ecological groups in Pusztaszeri út outcrop in Budapest (Profile by NAGYMAROSY and VARGA, 1983) Legend see Fig. 11.

a nearby littoral zone to the deep basin via a steep slope is proven by allodapic limestone intercalations. These are characterized by shallow sublittoral faunal and floral elements. Presence of littoral-shallow sublittoral ostracods is oscillating, due to changes in sediment influx.

Budapest, Kiscell – 1 borehole (Fig. 10)

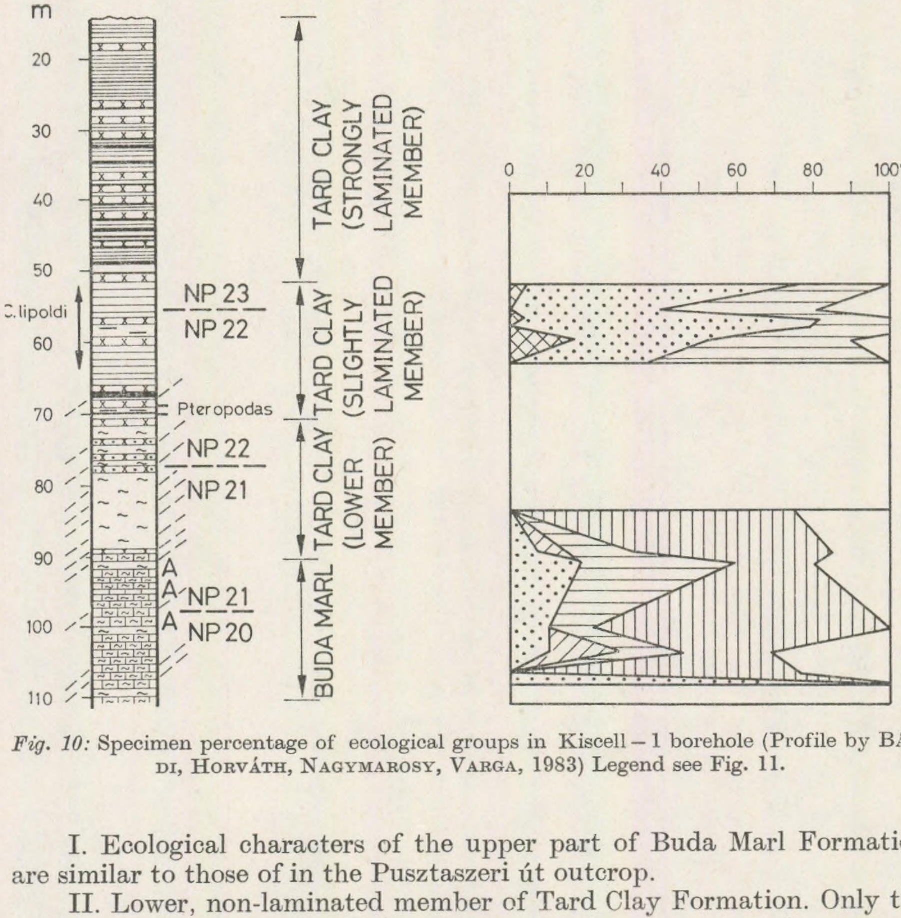

Fig. 10: Specimen percentage of ecological groups in Kiscell – 1 borehole (Profile by Báldi, Horváth, Nagymarosy, Varga, 1983) Legend see Fig. 11.

I. Ecological characters of the upper part of Buda Marl Formation are similar to those of in the Pusztaszeri út outcrop.

II. Lower, non-laminated member of Tard Clay Formation. Only the lower part contains ostracods. Shallow marine forms are strongly repressed by bathyal ones. Shallow marine influx decreased.

III. Middle, weakly laminated member of Tard Clay Formation. These beds yielded a special fauna without transitions towards the under- and overlying ones. The characteristic species are dominant in several environments ranging from fresh-water to bathyal marine. Their probable common character is the great ecological valence. Several other faunistical and sedimentological features indicate that sea water was different from normal oceanic water physically and chemically during sedimentation of the middle member. These differences were much more complicated than is common in brackish marine basins. It is indicated by absence of characteristic brackish-water genera (e.g. *Cytheridea* and *Neocyprideis* and related forms). This might have been a deeper basin too, with much forms redeposited from nearshore environments.

Budapest, Zugliget, outcrop (Fig. 11)

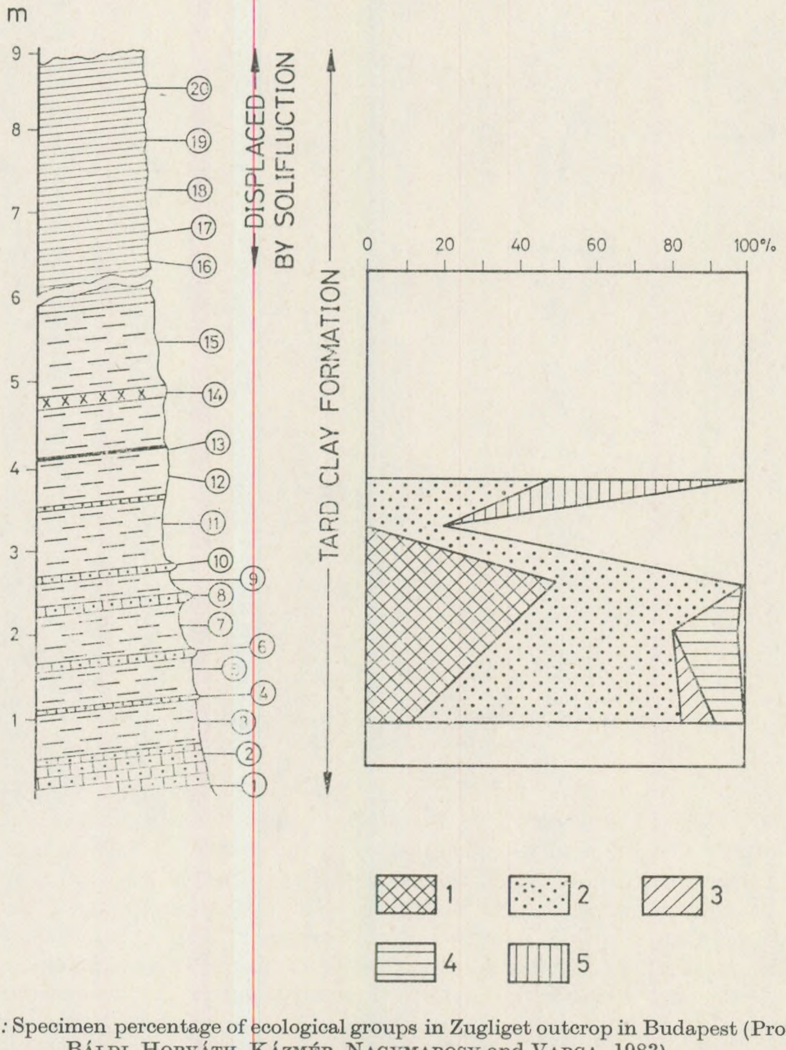

Fig. 11: Specimen percentage of ecological groups in Zugliget outcrop in Budapest (Profile by Báldi, Horváth, Kázmér, Nagymarosy and Varga, 1983)

Legend: 1. Forms dominant in fresh water or very low salinity water. – 2. Euryhaline forms dominant in littoral – shallow sublittoral zones. – 3. Stenohaline forms dominant in littoral – sublittoral zones. – 4. Stenohaline forms dominant in sublittoral – bathyal zones. – 5. Stenohaline forms dominant in bathyal zone

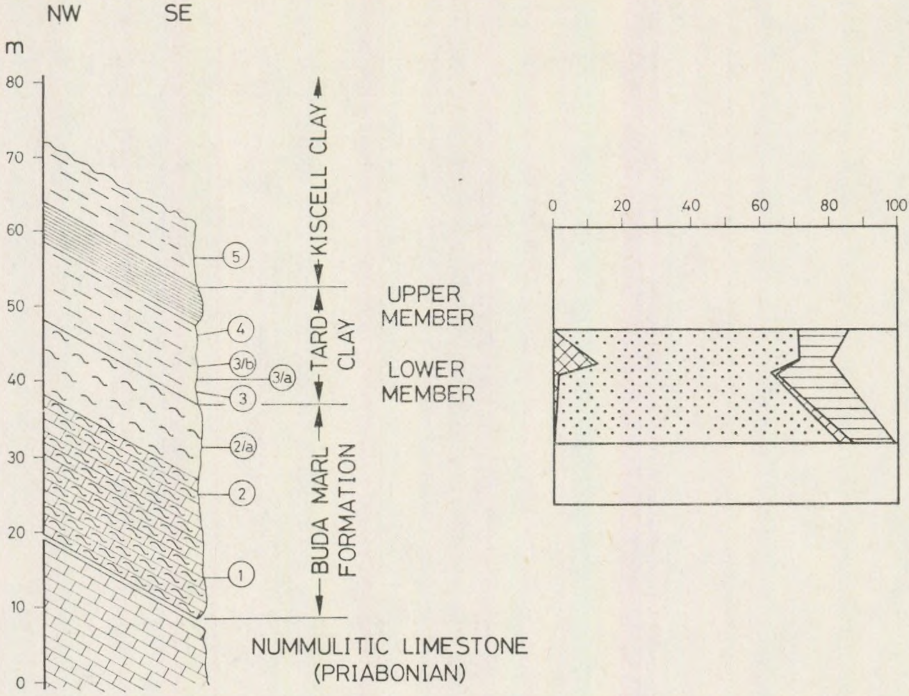

Fig. 12: Specimen percentage of ecological groups in Kiseged road cut at Eger (Profile by NAGYMAROSY and VARGA, 1983) Legend see Fig. 11.

Middle, weakly laminated member of Tard Clay Formation. Character of fauna is the same as in contemporaneous beds of Kiscell – 1 borehole.
Eger, Kiseged, road cut (Fig. 12)

Middle, weakly laminated member of Tard Clay Formation. Character of fauna is the same as in contemporaneous beds of Kiscell – 1 borehole and Budapest, Zugliget outcrop.

Cserépváralja – 1 borehole (Fig. 13 – 14)

I. Buda Marl Formation. The ostracod fauna indicates without doubt, that this deep, bathyal basin of normal oceanic salinity was farther offshore during sedimentation of the upper part of the formation than profiles of Alcsútdoboz – 3, Kiscell – 1 borehole and Budapest, Pusztaszeri út outcrop. Forms dominant in littoral – sublittoral environments are subordinate; genera dominant in normal saline bathyal environment form majority of the fauna.

II. Lower, non-laminated member of Tard Clay Formation. Ecological properties of the fauna are similar to those of in Kiscell – 1 borehole, excepting the total absence of forms dominant in littoral sublittoral environments.

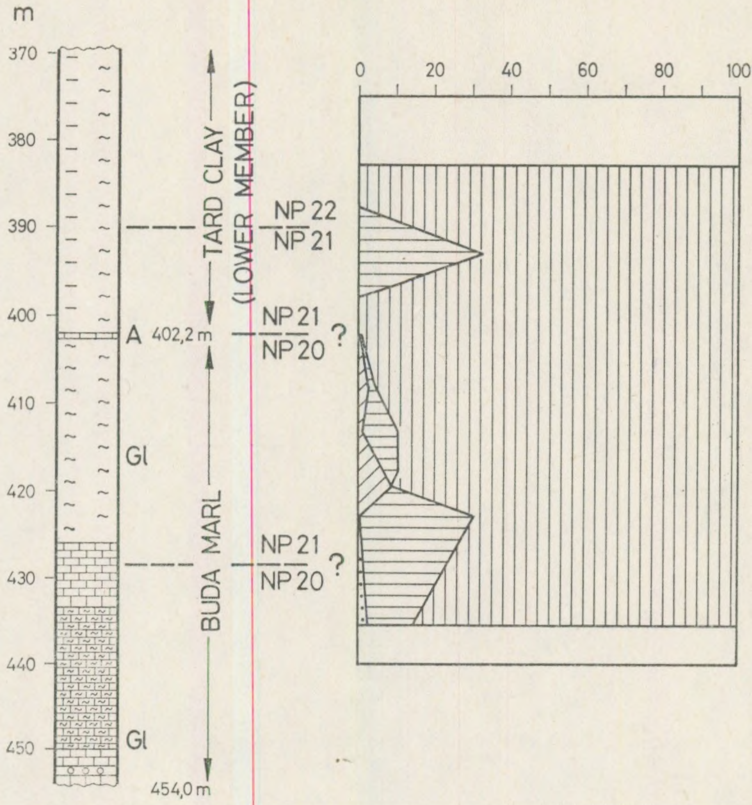

Fig. 13: Specimen percentage of ecological groups in the Lower part of Cserépváralja – 1 borehole (Profile by BÁLDI, HORVÁTH, NAGYMAROSY and VARGA, 1983) Legend see Fig. 11.

III. Middle, weakly laminated member of Tard Clay Formation. The only one, poor sample fits the character of this formation described in other exposures.

IV. Kiscell Clay Formation. The fauna indicates re-establishment of normal marine conditions. Dominant forms are characteristic for bathyal environments of oceanic salinity. Shallow marine – obviously redeposited – forms occur as accessory elements.

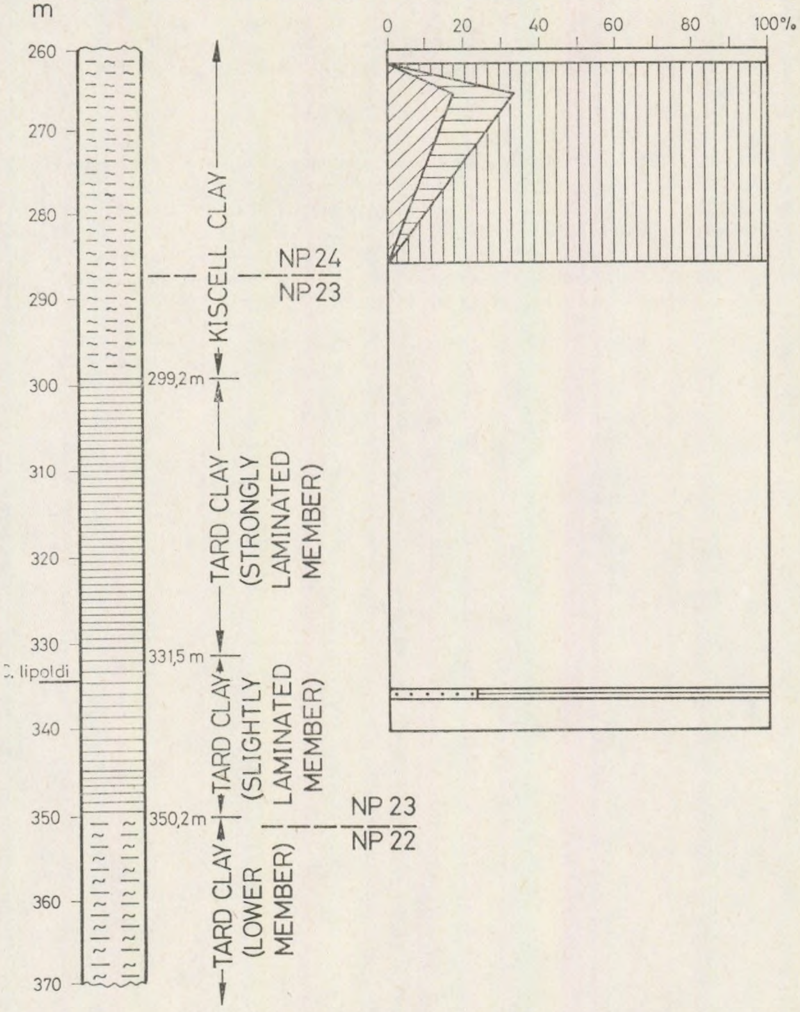

Fig. 14: Specimen percentage of ecological groups in the upper part of Cserépváralja – 1 borehole (Profile by Báldi, Horváth, Nagymarosy and Varga, 1983) Legend see Fig. 11.

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A JURASSIC–LOWER CRETACEOUS PROFILE IN ÓBÁNYA VALLEY (MECSEK MTS., HUNGARY)

by

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ABSTRACT

The marine Jurassic–Lower Cretaceous sequence of Óbánya valley in Eastern Mecsek Mts. (Southern Hungary) contains a rich micro- and megafauna. Most important fossils are: a Bajocian decapod (the first Jurassic decapod in Hungary), Bathonian index ammonites and Tithonian-Lower Cretaceous radiolarians. Micromineralogical investigations indicate contemporaneous volcanism.

Changes in fauna and sedimentation display the following trend. Aalenian-Bathonian: benthonic and pelagic forms together, followed by mostly pelagic forms. Deepening of the basin at least until Oxfordian-Kimmeridgian. Further change of depth is unknown. The significant amount of terrigenous influx decreases to a minimum after Bathonian.

Introduction

Few Mesozoic key profiles have been investigated and published from the Mecsek Mountains, so we present here a detailed description of the long known Óbánya profile (Fig. 1)

This valley lies in the Eastern Mecsek Mountains, between Óbánya and Kisújbánya and provides excellent exposures of a continuous Aalenian-Lower Cretaceous sequence. It is nearly non-tectonized, compared to other profiles of Eastern Mecsek (Hidas Valley, Szén Valley) of the same age. A rich fossil assemblage has been collected; the Bathonian ammonites are especially valuable as this locality is considered as a classical one.

Micromineralogy, microfacies and carbonate content were studied besides the fossils (fig. 2)

The first detailed description or this area was published by Böckh (1980–81). Vadász (1935) also mentioned it briefly. Regular geological survey was made by Hetényi and I. Nagy from 1963 to 1965 in a scale 1 : 10.000.

Description of the profile

The single outcrop of Óbánya valley extends from Óbánya to Kisújbánya in 2,8 km length, parallel with SW–NE faulting trends of the middle and eastern parts of the Mecsek.

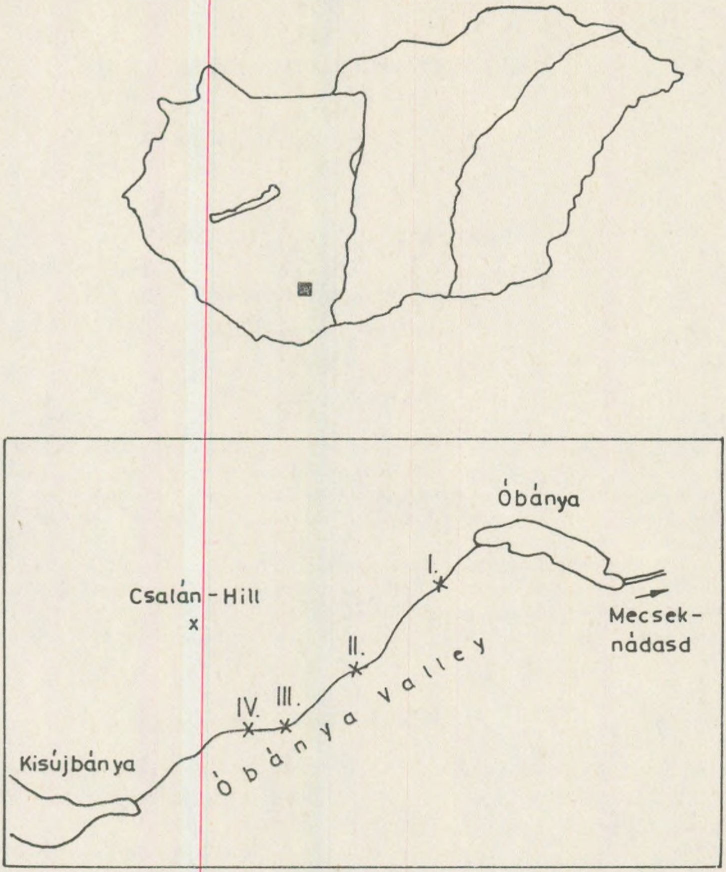


Fig. 1: Location of Ófalu valley.

Aalenian. Rhythmically alternating thick-bedded and laminated beds: a dark grey, spotted, bituminous, micaceous marl weathered to yellow in 20–50 cm thick beds (45% carbonate content) alternates with dark grey, micaceous silty marl in 20–30 cm thick, laminated beds (35% carbonate content). Both are poor in megafauna: besides some bivalve and plant imprints an ammonite *(Ludwigia* sp.) has been found, indicating Aalenian age. Total thickness: 75 m.

Bajocian. Alternating, thick-bedded marl and laminated, silty, clayey marl beds, 0,5–1,5 m thick. Similar to the Aalenian beds; the boundary between them is undistinct. The lower part is poorer, the upper part is rich in fossils. The beds become lighter upwards, with rather expressed spots. The laminated beds become harder upwards with growing carbonate content (from 36 to 55%). Total thickness: 170 m. Fossils from the lower part: Phylloceratidae, Lytoceratidae, *Stephanoceras* sp., bivalve moulds, carbonized plant fragments.

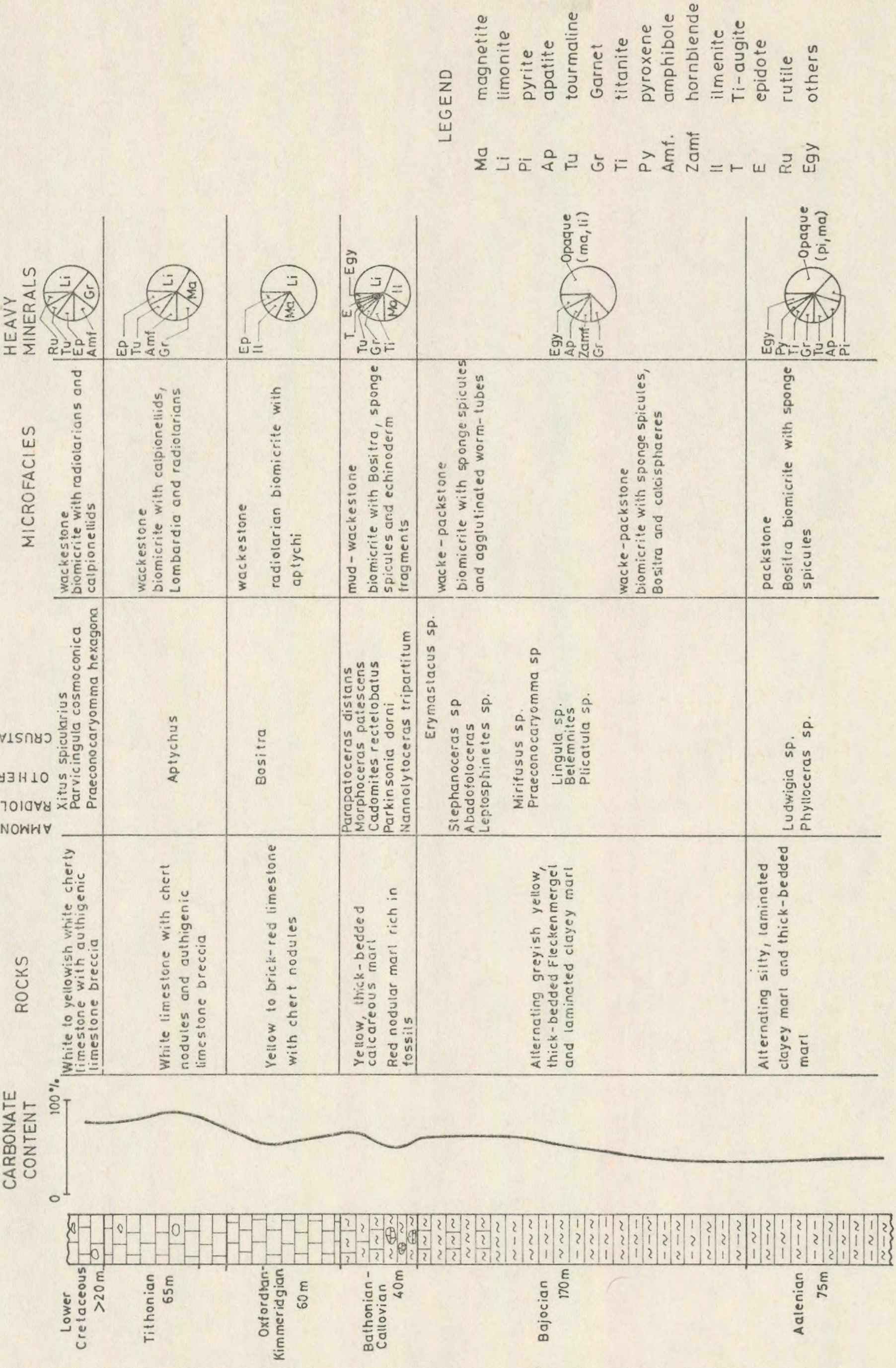
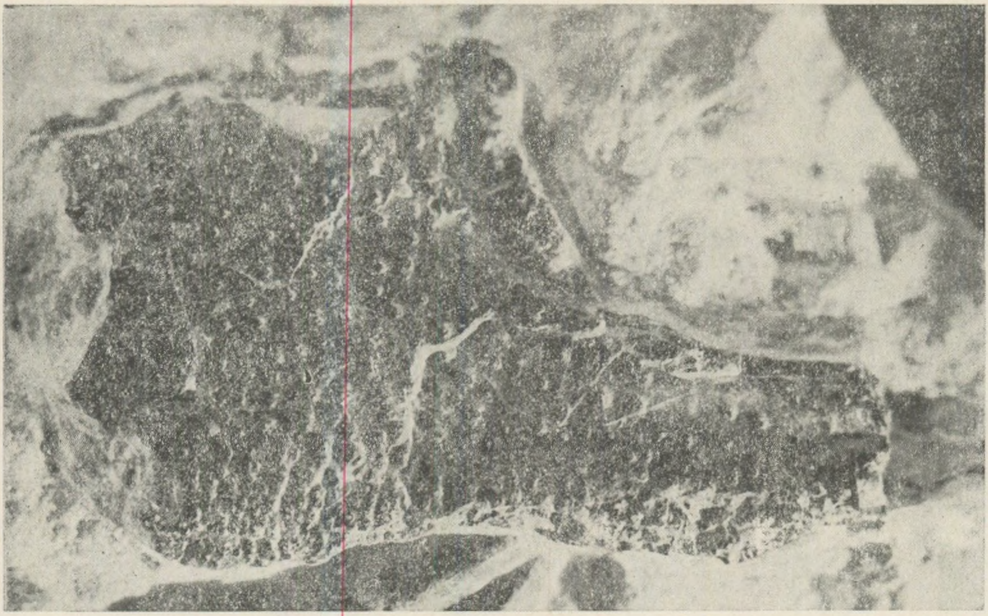


Fig. 2: Stratigraphic column and fossils of Óbánya valley profile



Pl. I. *Erymastacus* sp. Bajocian, Niortense zone 3,5x (photo by L. KLINDA)

Fossils from the upper part: *Phylloceras* spp., *Adabofoloceras* sp., *Caumontisphinctes* sp., *Leptosphinctes* sp. Radiolarians also occur: *Mirifusus* sp. and *Praeconocaryomma* sp. have been determined by H. KOZUR.

A decapod claw have been found, too. It was determined by J. ORAVECZ as *Erymastacus* sp. (Plate I). This is the first Jurassic crab in Hungary. Ammonites helped to determine its precise age: Late Bajocian Niortense zone.

Bathonian-Callovian. The lower 10 metres contain alternating 5 – 10 cm thick, red and green, nodular layers, without sharp boundaries in between. This marl bears rounded or irregular, hard nodules 1 to 8 cm in diameter. The layers can be divided into thin laminae. Bedding surfaces display irregular, indistinct red and green spots. Some 5 to 10 cm thick clay layers are intercalated among the marl beds. Carbonate content: 50%.

The following 30 metres contain thicker, more calcareous marl beds up to 60 cm thickness, separated by cm-thick clay intercalations. Carbonate content: 66%.

Lower part of the Bathonian-Callovian strata are extremely rich in fossils; their abundance decrease upwards. The lower 14 metres contained ca. 300 fossils (complete or fragmentary), including 250 ammonites (fig. 3). Above 9 metres of the profile the fauna gradually becomes poorer; above 14 metres some ammonite fragments can be found besides a large number of *Bositra*. Both Tethyan and Northwestern European ammonite genera are present. The Tethyan elements are dominant, including Lytoceratidae

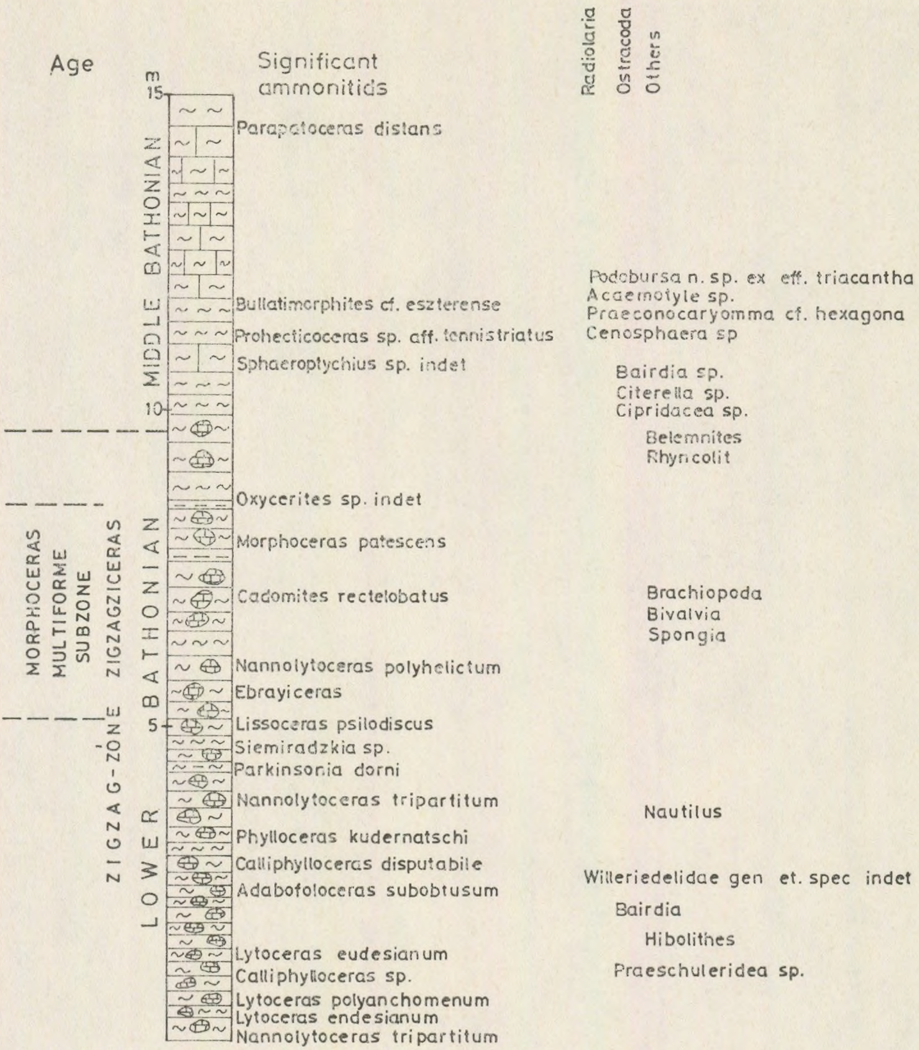
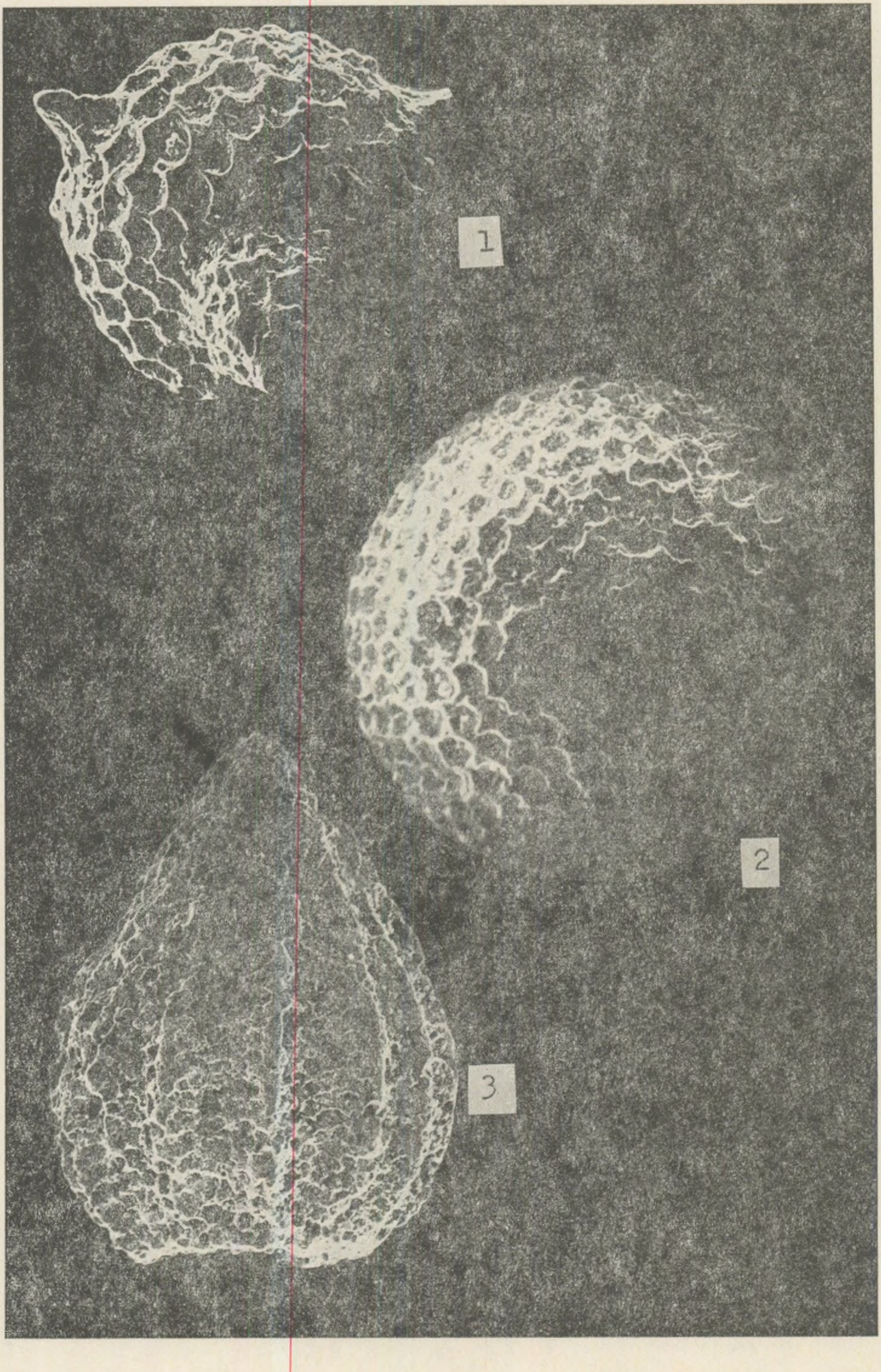


Fig. 3: Significant fossils in the lower, fossil-rich part of the Bathonian- — Callovian beds.

and Phylloceratidae. The most frequent form is *Nannolytoceras tripartitum.* Some species from among the NW-European elements are very important providing the possibility of a highly precise age determination (e.g.: *Parkinsonia dorni*, *Morphoceras patescens).* Other mega- and microfossils in order of frequency: *Bositra*, sponges, Echinoidea, Crinoidea skeletal elements, Radiolaria, *Belemnites.* Comparing the fauna of Mecsek with that of the same age of Bakony Mts. we can observe a much higher frequency of benthonic forms and NW European ammonite genera in the Mecsek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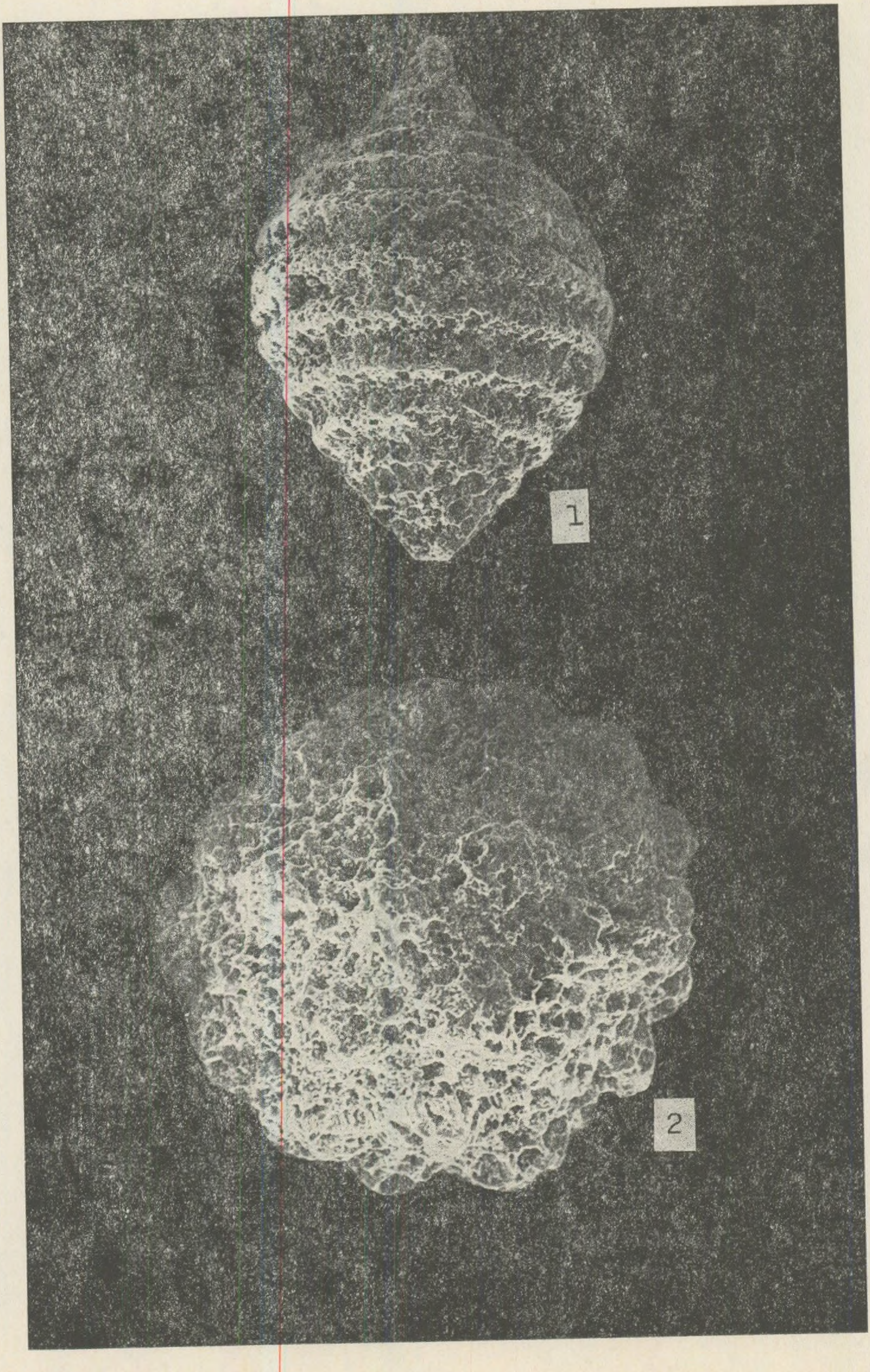
Pl. II. *fig. 1:* *Podobursa* sp. ex aff. *triacantha* Bathonian 321x
fig. 2: *Cenosphaera* sp. Bathonian 261x
fig. 3: *Thanarla* sp. Lower Cretaceous 321x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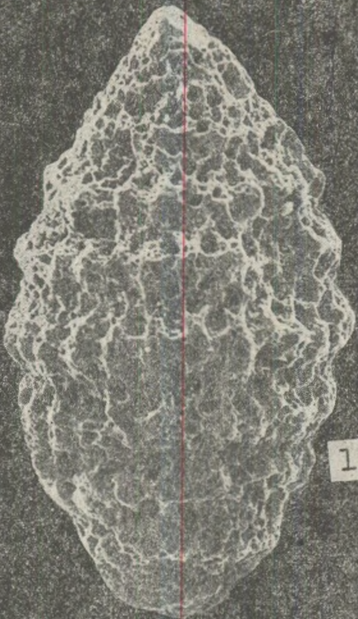
Pl. III. *fig. 1:* *Mirifusus mediodilatus* (RÜST)
Oxfordian – Hauterivian 201x
fig. 2: *Praeconocaryomma hexagona* (RÜST)
Upper Tithonian – Lower Cretaceous 361x



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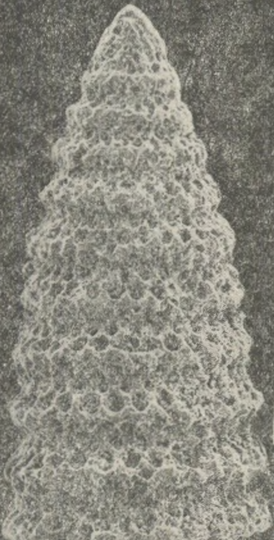

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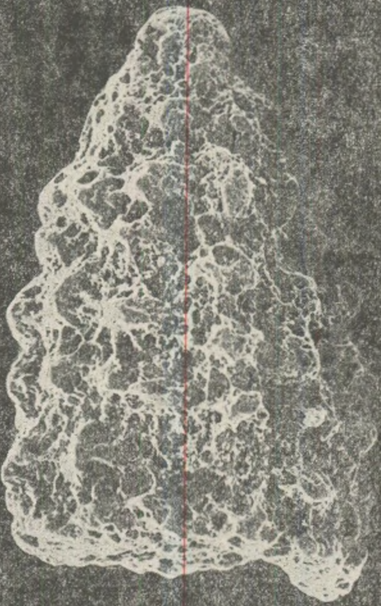

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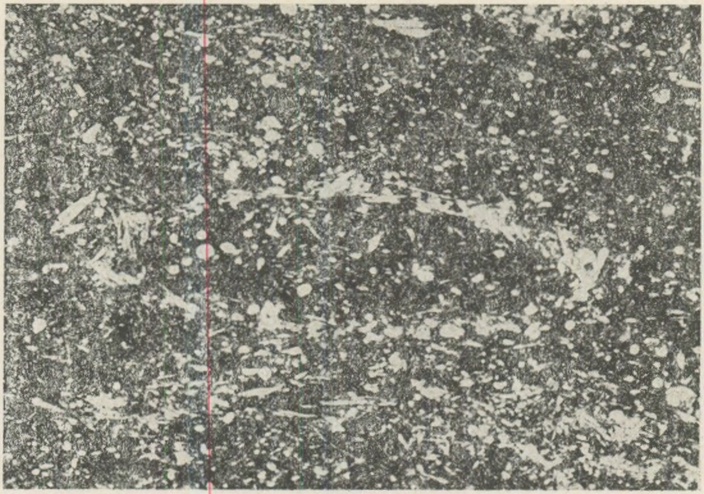
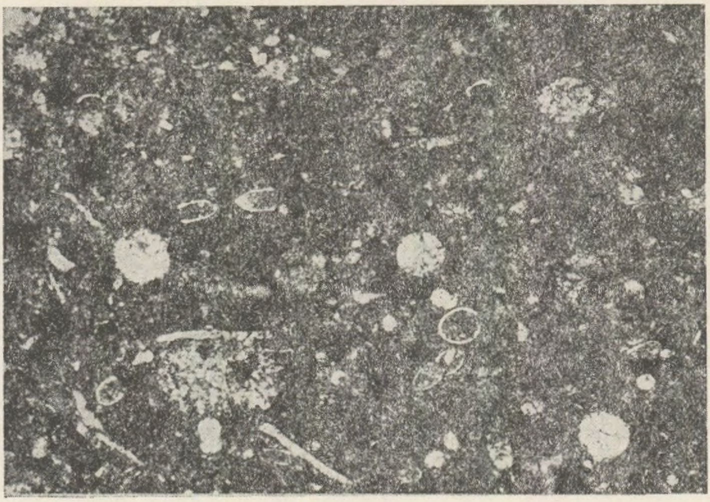
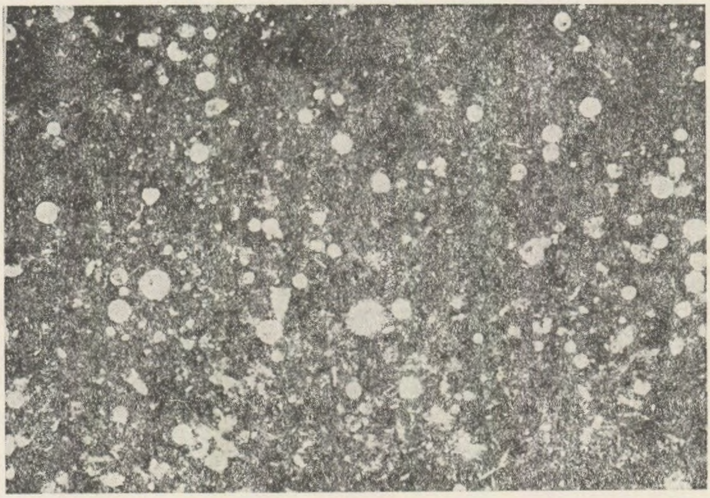
Pl. IV. *fig. 1:* *"Parvicingula" bvesii* (PARONA)
Upper Oxfordian – Hauterivian 321x
fig. 2: *Foremanina cosmoconica* (FOREMAN)
Berriasian – Hauterivian 321x
fig. 3: *Xitus spicularius* (ALIEV) Early Cretaceous 301x



Pl. V. *fig. 1:* wackestone packstone biomicrite with sponge spicules and agglutinated worm tube (Bajocian) 9x

fig. 2: mudstone-wackestone, *Bositra* biomicrite with a brachiopod (Bathonian – Callovian) 9x





Pl. VI. *fig. 1:* wackestone, biomicrite with radiolarians and calpionellids (Tithonian) 40x
Pl. VI. *fig. 2:* wackestone with much and variable radiolarians (Lower Cretaceous) 40x

(Géczy, 1972, 1973). Three new radiolarian species have been found by H. Kozur: *Mirifusus* n. sp., *Podobursa* n. sp., *Podobursa* n. sp. ex aff. *triacantha* (Plate II. fig. 1.). Total thickness: 40 m.

Oxfordian-Kimmeridgian. Brick-red, marly, limestones with chert nodules. Chert nodules are red or brown. Bed thickness: 15–30 cm. Carbonate content: 55%. No megafossils have been found. Age is determined by microfacies and lithostratigraphic correlation. Thickness: 60 m. Gradual transition into the Tithonian formations.

Tithonian. White to yellowish white, nodular, cherty limestone with angular clasts of the same rock. Bed thickness: 10 to 40 cm. Cherts are brown and gray. Carbonate content: 75–80%. No megafossils have been found. Age is determined by microfacies and lithostratigraphic correlation. Thickness: 65 m.

A new outcrop has been found E from Kisújbánya, along the tourist path directed northwards, 100–150 m from the creek: a 100–120 m long profile can be observed. White to yellowish white limestone containing chert and angular limestone clasts of the same material. Bed thickness 20–40 cm. Carbonate content: 75%. Total thickness: more than 20 metres. No megafossils have been found. Solution residues are formed by radiolarians only, of extremely good preservation (1 to 2% of the weight of the rock!). Several genera lived in the Late Jurassic–Early Cretaceous, some during Early Cretaceous only, but no Jurassic index forms were found (H. Kozur, pers. comm.). However, further investigations are needed for an exact age determination. Common genera: *Emiluvia, Tritrabs, Mita, Parvingicula, Podobursa, Spongocapsula, Tetracapsa, Thanarla* n. sp. (Plate II, fig. 3.). Late Jurassic–Early Cretaceous species:

Mirifusus meddiodilatus (Rüst): Oxfordian–Hauterivian (Plate III, fig. 1).

Praeconocaryomma hexagona (Rüst) Late Tithonian–Early Cretaceous (Plate III, fig 2).

Sethocapsa cetia Foreman: Late Kimmeridgian–Hauterivian

Podocapsa cf. amphitreptera Foreman: Kimmeridgian–Berriasian

"*Parvicingula*" *bvesii* (Parona): Late Oxfordian–Hauterivian (Plate IV, fig. 1).

Early Cretaceous species:

"*Parvicingula*" *cretacea* Baumgartner: Berriasian–Early Valanginian

Foremanina cosmoscomica (Foreman): Berriasian–Hauterivian (Plate IV, fig. 2).

Xitus spicularicus (Alier) Early Cretaceous (Plate IV, fig. 3).

Microfacies investigations

Aalenian. Packstone, containing a lot of calcitized sponge spicules, echinoderm fragments, *Bositra*, foraminifers, muscovite and quartz grains. Bioturbation occurs.

Bajocian. Wackestone-packstone, containing *Bositra*, sponge spicules, calcisphaera, some radiolarians, bivalves and unidentifiable biogenic detritus. Terrigenous fragments: quartz, muscovite, epidote. In some places bedded texture. Darker and lighter spots, probably originated from bioturbation. Agglutinated worm tubes containing the surrounding biogenic detritus. (Plate V, fig. 1).

Bathonian – Callovian. Mudstone-wackestone. The decrease of megafossil abundance can be observed in the microfacies elements also. The lower, red nodular part is a radiolarian wackestone with abundant *Bositra*, containing sponge spicules, echinoderm fragments, foraminifers, bivalve shell fragments. The upper part contains more micrite; it is mostly mudstone. Preservation of biogenic components is poor, only some Bositra, foraminifers, radiolarians and brachiopods can be observed (Plate V, fig. 2).

Oxfordian – Kimmeridgian. Wackestone without *Bositra.* Many radiolarians, some planktonic foraminifers and aptychi. Irregular siliceous spots.

Tithonian. Wackestone with abundant radiolarian fauna of great variability and with abundant appearance of calpionellids. Other fossils: calcisphaera, *Bositra*, *Lombardia*, aptychus. Neither benthonic forms nor terrigenous grains have been observed. (Plate VI, fig. 1).

Micromineralogy

All members of the sequence have been investigated. The whole profile contains minerals indicating metamorphic source rocks: epidote, tourmaline, garnet, hornblende. However, some members contain heavy minerals indicating volcanic source rocks.

The Middle Bajocian contains brown amphibol, aegirine-augite, Ti-augite, leukoxene, ilmenite in larger quantities. These grains are not rounded contrary to the grains indicating metamorphic source rocks. They indicate a contemporaneous, basic, alkaline basic volcanism with a not very near centre.

Clay intercalations in the Bathonian – Callovian an enrichment of the above mentioned volcanogenic heavy minerals could be observed.

The upper part of the Bathonian – Callovian members is extremely interesting, where the quantity of volcanogenic components grows by magnitudes. Heavy fraction: brown amphibole, ilmenite, Ti-augite, magnetite. Light fraction: plagioclase, sanidine, zeolite and also a volcanic rock fragment has been found containig biotite and basic plagioclase.

Our conclusion is that a basic volcanic activity occurred contemporaneously with sedimentation. This result is in accordance with the investigations of FŐZY et al. (1983), VÁRSZEGI (1973) and BALOGH S. (1964).

Faunal changes

The Aalenian – Bajocian contains frequent benthonic forms: epibenthic sponges, foraminifers, a decapod and inbenthonic trace fossils (bioturbation).

Benthonic and pelagic fossils together can be found in the Bathonian. Most characteristic are the ammonites, but large quantities of bivalves, sponges, echinoids, crinoids, brachiopods, ostracods and gastropods have been found also.

In the upper part of the Bathonian–Callovian a radical decrease of ammonites can be observed, but bositras are present in extremely great percentage. The Bathonian ostracod assemblages does not contain sublittoral forms. The great number of *Cytherellas* indicates bathyal depth. After the Bathonian–Callovian all bethonic forms disappear from the fauna and their place is occupied by pelagic forms.

Radiolarians are dominant in the Oxfordian–Kimmeridgian.

In the Tithonian and Lower Cretaceous the only fossils are caplionellids and radiolarians.

Pelagic forms are present in the whole sequence. Their percentage is less in the lower beds than in the upper ones; in the latter they are dominant. Change of faunal elements can be characterized by increasing dominance of pelagic forms.

Sedimentation

Significant terrigenous influx is characteristic for the lower (Aalenian to Bathonian) part of the sequence. After Bathonian this decreases to zero. Meanwhile carbonate content grows, changing the rocks from silty marl to cherty limestone. Cherts can be found in rocks younger than Bathonian–Callovian. The older beds (Aalenian–to Bajocian) were sedimented in a relatively nearshore, pelagic environment of not greath depth, as indicated by a significant amount of pelagic forms besides benthonic fossils. A conspicuous feature is the relative thickness of the Bathonian sediments: this indicates a low rate of sedimentation. Red and green colour of the rocks indicate frequent changes in oxydation conditions. Bituminous character disappears upwards.

The Oxfordian–Kimmeridgian cherty and siliceous limestones were sedimented in a pelagic environment with low rate of sedimentation, also indicated by thin beds.

The Tithonian limestone is also open marine, pelagic rock with increased thickness, indicating growing rate of sedimentation. This trend continues during the Early Cretaceous as well.

A continuous subsidence with deepening water can be observed in this basin, followed by an open marine, pelagic sedimentation. Significant change of depth during Late Jurassic cannot be proven. More significant changes occurred in the character of sedimentation, shore distance and terrigenous influx.

Acknowledgements

Sincere thanks are due to Cs. Szabó for his extended and continouous help, for A. Galácz for ammonite determinations and advices in Jurassic stratigraphy, for M. Kázmér for his help in microfacies interpretation and for H. Kozur for determinations of radiolarians.

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OPTICAL ANALYSIS OF DISPERS ORGANIC MATTER OF SENONIAN FORMATIONS IN THE HUNGARIAN PLAIN FROM THE POINT OF VIEW OF HYDROCARBON EXPLORATION

by

G. GALICZ

(Abstract of doctoral thesis accepted by Eötvös University, Budapest)

Target of this dissertation is to develop a theory of hydrocarbon-genetical knowledge concerning to Senonian formations with datas of vitrinite reflectance analysis. Genetical conclusions of these parameters and the other organic geochemical parameters contribute to the scientifical grounding of hydrocarbon prognosis of less known formations.

For establishing of evolutional phase of organic matter I have carried out 46 analysis of polished surface rock specimens, but for interpretation I have made comparison with results of analysis (18 pieces) of other institutes too.

Senonian formations of Hungarian Plain consist of pelitic – calcareous (marl and limestone) and detritic (argillite and sandstone) rocks, however they are mostly epicontinentale margin and turbiditic facies. Reflectance averages (R_0 random) of lithostratigraphic units are changable from 0.71 to 1.88%.

The analysed Senonian rocks – due to the coalification gradient (R_0/1000 m) – can be divided in two groups. This difference of maturation between paleo-temperature (after coalification – temperature – time diagram by Karweil) and present strata-temperature is significant. Reason of these are the lifting upwards post-Senonian events – in certain areas – in the other hand, just acting contrary rapid Neogen sedimentation.

Due to measured reflectance value, the Senonian formations of Hungarian Plain are presently in oil and wet gas generating phase or – rather – in dry gas generating genetical zone. The average of organic geochemical parameters are low; so they make likely post-migration phase. Some bituminological analysis have shown mostly huminitic- and mixed type of organic matter.

Regard to organic geochemical datas and reflectance values, Senonian formation as source rock took part in genesis of oil bearing in the southern part of Duna – Tisza Interfluve region, furthermore in Tiszántúl area – with Paleogen formation – in genesis of so called "Middle Plain" gas province.

ROLE OF CARBONATE ROCKS IN THE GENESIS OF BAUXITE

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ABSTRACT

The Al_2O_3 average of Triassic limestones and dolomites are 0.36%. On the basis of results the wethering of 200 m Triassic and Lower Jurasic limestone or/and dolomite may create about 1 metre of bauxite. These rocks may have been the parent rocks and they had to play a very important role in the genesis of Hungarian bauxite.

Many papers have been employed with the genesis of bauxite. Nobody has given a convincing explanation about the genesis of karst bauxite. Those who refuse the theory of terra rossa say that the solution of carbonates was too slight for accumulating of bauxite. Former chemical analysis of limestones were made almost without exception from the acid solution of limestones. Recently decomposition is made directly from dolomites and limestones, and these analysis have given more aluminium.

The programme of my paper is to re-examine the aluminium contents of carbonate rocks. I have examined the aluminium and silicium concentration of older mesozoic limestones and dolomites in Hungary (fig. 1 – 7).

If we dissolve dolomite and limestone in acid the aluminium will also dissolve with carbonate. Examinations were made without shatter by neutron activation analysis in the nuclear reactor of the Technical University in Budapest.

The following nuclear reaction was used at the examination:

^{27}Al isotop (with slow neutron) will turn into ^{28}Al isotop with n, γ reaction

^{28}Si isotop (with fast neutron) will turn into ^{28}Al isotop with n,p reaction

The half life of ^{28}Al isotop is 2,24 s, γ energy photopeaks are 0,84; 1,27; and 1,77 MeV.

When I choose the irradiation time it must be consider:

1. The magnesium and calcium couldn't be transformed
2. The ^{27}Al isotop shouldn't be transformed into ^{24}Na isotop
3. Let ^{28}Al isotop be transformed to measurable quantity.

In this way the samples got irradiation during 30 s. Next the samples stood 180 s, the measuring of them was 100 s living time. After printing I established the bearing of Gamma energy spectrum. The basis of appreciation was the standard and unknown samples composition of identical photopeaks of γ energy spectrum. The peak territory was calculated with the Covell method.

At the neutron activation analysis disturbing nuclear reactions are established. When n, p reaction is produced then ^{28}Al isotop from ^{27}Si. It was problematical, during examinations, because the channel of fast neutrons is near the heating element, and in this channel the radiation is very dissimilar. The proportion of fast neutron to the slow ones is 3 to 1. So the fast neutrons produce ^{28}Al from ^{28}Si isotop, and the slow neutrons produce ^{28}Al from ^{27}Al isotop too. Cadmium tubes defend the samples from slow neutrons. This cadmium defensive tube couldn't sift out the slow neutrons, so corrections were necessary.

Result of measuring

The samples were collected from Transdanubian Central Mountains in Hungary. The age of rocks are Upper Triassic (dolomite and Dachstein limestone) Lower Jurassic (lias limestone) and Lower Eocen (reworked dolomite, the material is Upper Triassic). The marles were not examined.

The aluminiumoxide average of twenty-one Dachstein limestones are 0,31%. The aluminiumoxide average of twenty two Upper Triassic dolomites are 0,42%. The aluminiumoxide average of ten Lias limestones are 0,8%, and reworked dolomites are 0,34%.

The averages of results are lower than the data in the literature. I think the difference arose as I measured only clear carbonate rocks.

On the basis of results the wethering of 200 m Triassic and Lower Jurassic limestone or/and dolomite may create about 1 metre of bauxite (Al_2O_3 concentration is 65%).

Naturally I wouldn't say, that the parent rocks of bauxite resulted only from carbonate rocks. I think these rocks also may have been the parent rocks and on basis of results they had to play a very important role in the genesis of Hungarian bauxite.

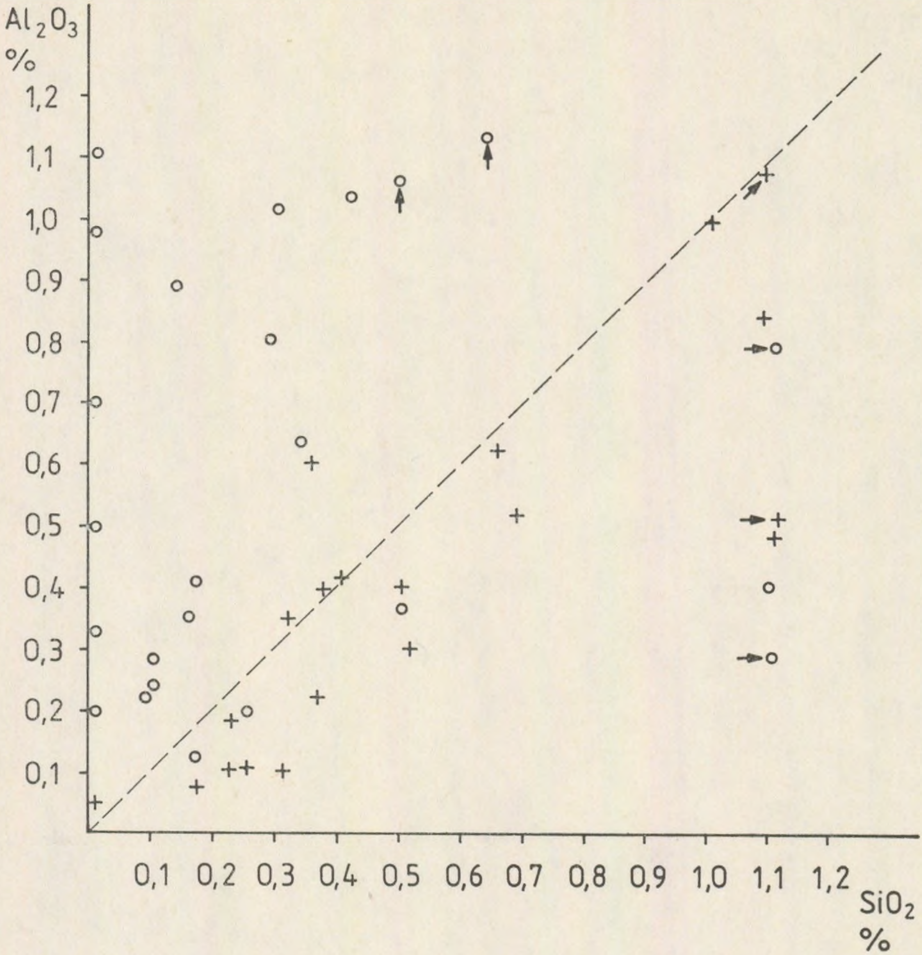

Fig. 1. Al_2O_3 and SiO_2 concentration in Upper Triassic dolomites
\+ on the basis of neutron activation analysis
○ on the basis of literature

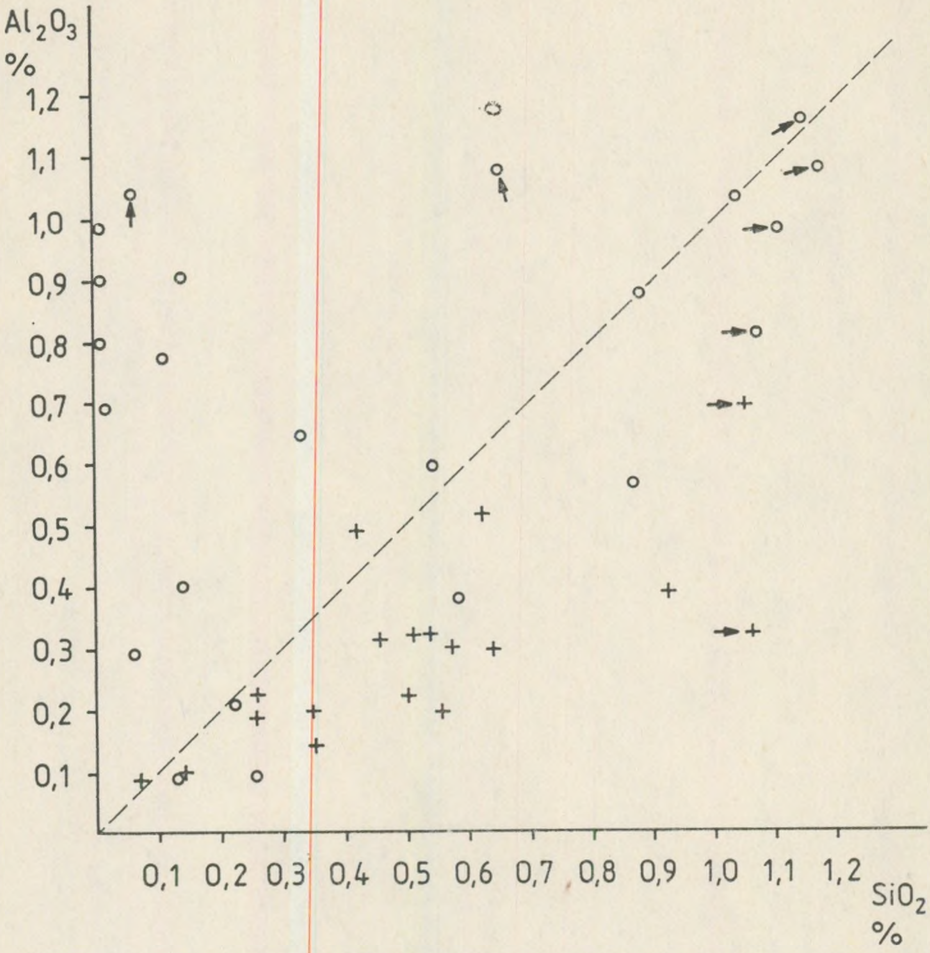

Fig. 2. Al_2O_3 and SiO_2 concentration in Dachstein limestones
+ on the basis of neutron activation analysis
○ on the basis of literature

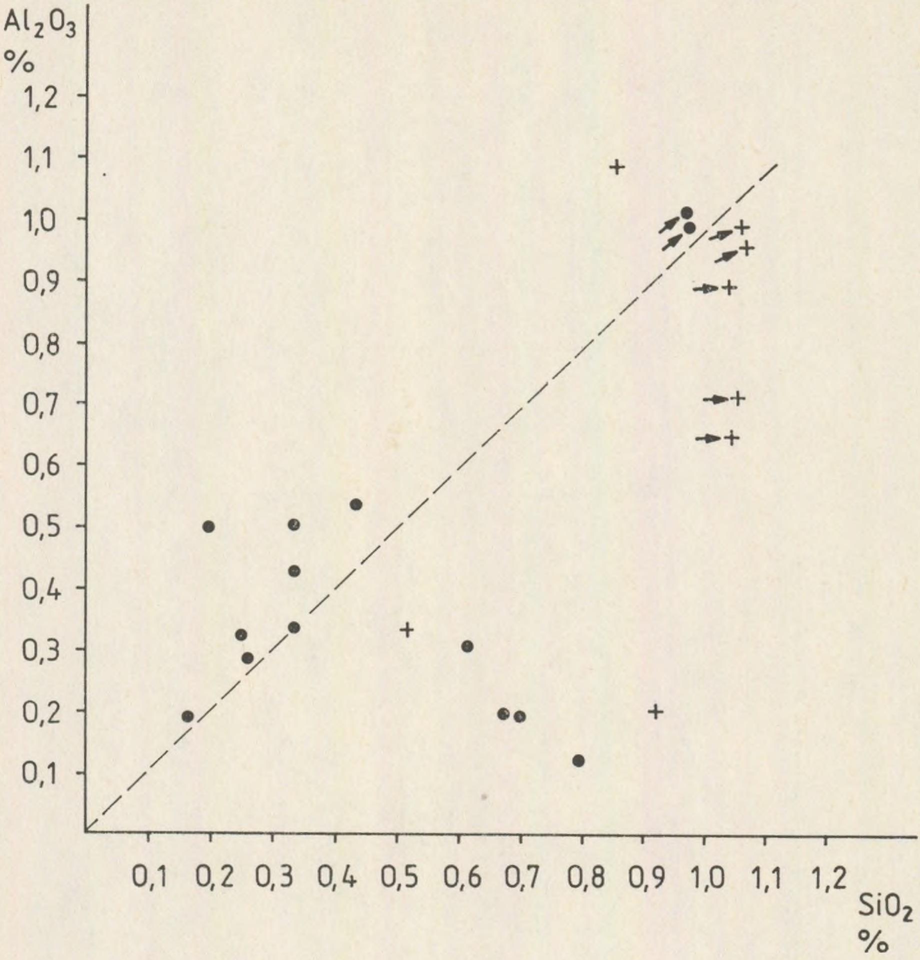

***Fig.** 3.* Al_2O_3 and SiO_2 concentration in Lower Jurassic limestones
+ on the basis of neutron activation analysis
● on the basis of literature

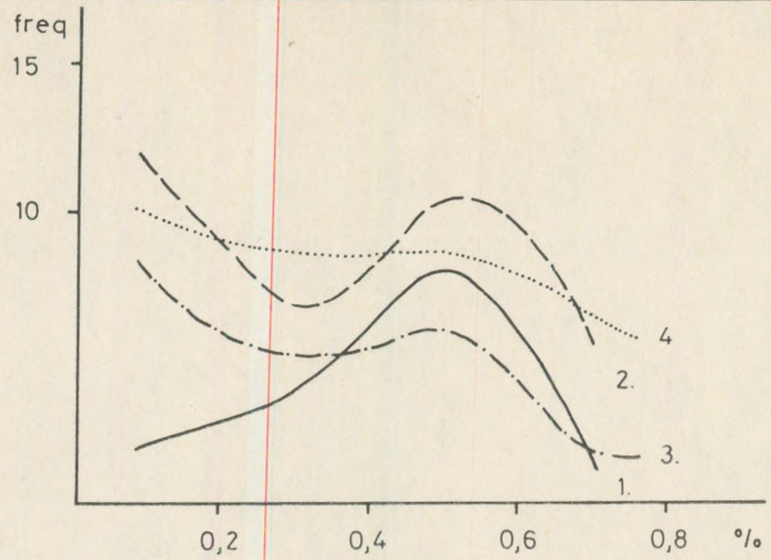

Fig. 4. Concentration frequency curves in Dachstein limestones
1. SiO_2 % on the basis of neutron activation analysis
2. SiO_2 % on the basis total dates
3. Al_2O_3 % on the basis of neutron activation analysis
4. Al_2O_3 % on the basis of total dates

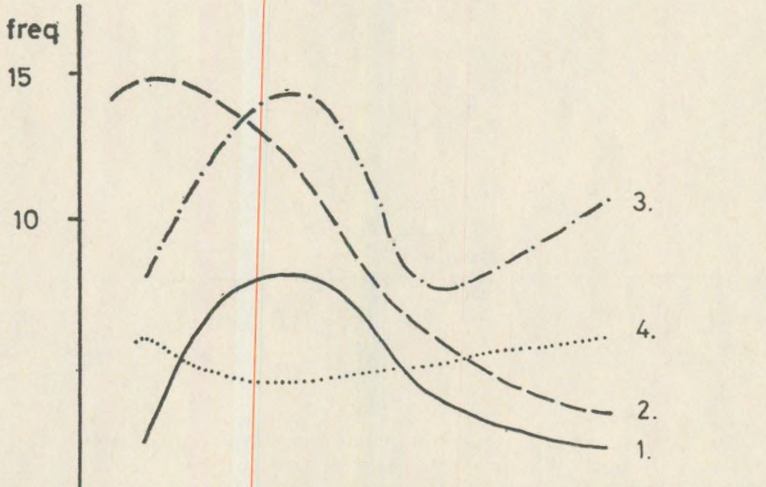

Fig. 5. Concentration frequency curves in Upper Triassic dolomites
1. SiO_2 % on the basis of neutron activation analysis
2. SiO_2 % on the basis total dates
3. Al_2O_3 % on the basis of neutron activation analysis
4. Al_2O_3 % on the basis of total dates

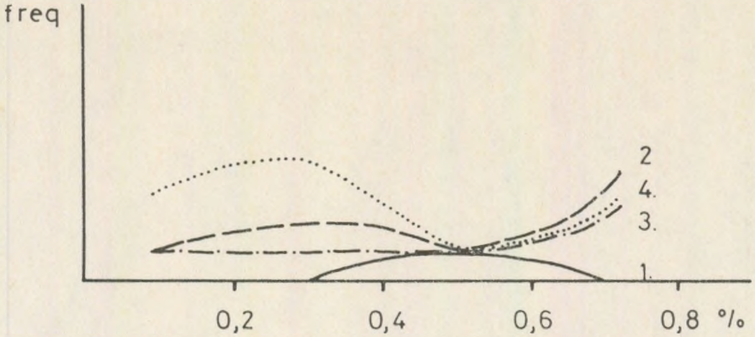

Fig. 6. Concentration frequency curves in Lower Jurasic limestones
1. SiO_2 % on the basis of neutron activation analysis
2. SiO_2 % on the basis total dates
3. Al_2O_3 % on the basis of neutron activation analysis
4. Al_2O_3 % on the basis of total dates

Table 1.

Upper Triassic dolomites (Transdanubian Central Mountains, Hungary)

		Al_2O_3	SiO_2
1	Budapest Sashegy	0.49	1.35
2	Gánt	0.40	0.50
3	Gánt	0.51	3.12
4	Gánt	0.35	0.32
5	Gánt	0.85	1.08
6	Gánt	0.08	0.17
7	Gánt	0.06	
8	Gánt	0.40	0.38
9	Gánt	0.61	0.36
10	Gánt	0.42	0.41
11	Gánt	0.63	0.65
12	Gánt	0.40	0.30
13	Nyirád – Darvastó VI. (bauxite bed rock)	0.11	0.25
14	Nyirád – Darvastó VI. (bauxite bed rock)	0.22	0.35
15	Nyirád – Darvastó VI. (bauxite bed rock)	0.10	0.31
16	Nyirád – Darvastó VI. (bauxite bed rock)	0.30	0.51
17	Nyirád – Darvastó VI. (bauxite bed rock)	1.18	1.20
18	Nyirád – Darvastó VI. (bauxite bed rock)	0.52	0.61
19	Cserszegtomaj	0.18	0.22
20	Cserszegtomaj	0.11	0.32
21	Isztimér	0.76	
22	Halimba (bauxite bed rock)	0.61	
Arithm. average:		0.42	0.62

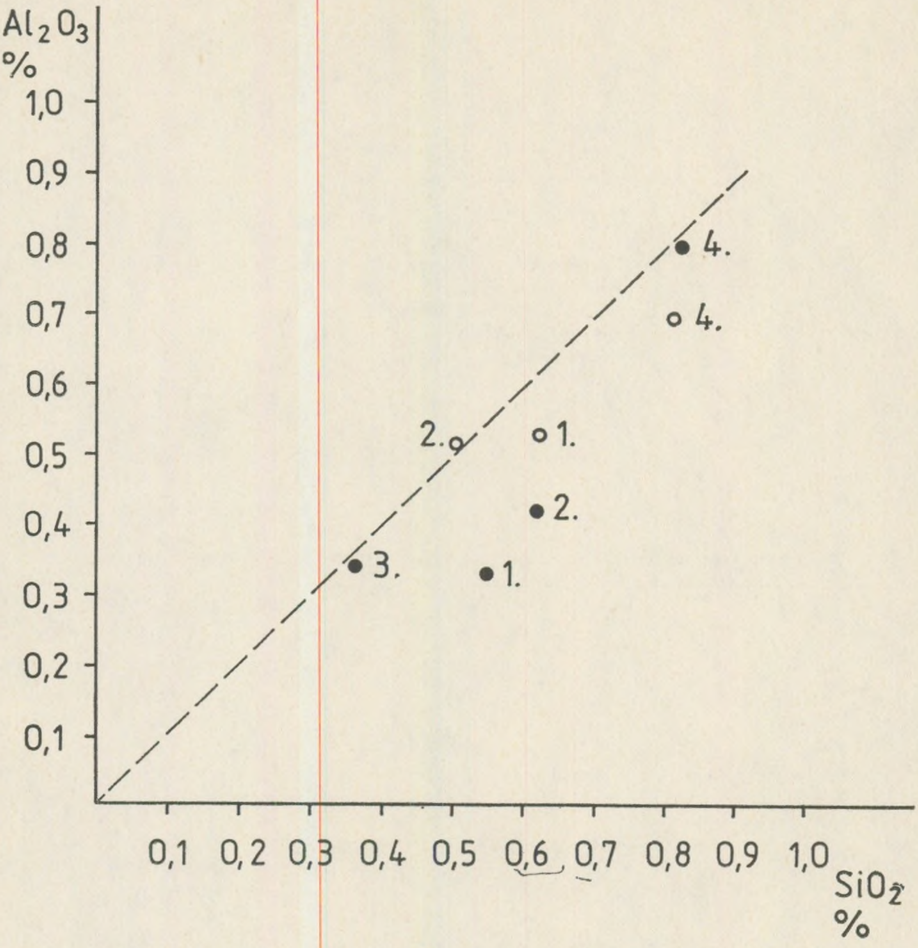

Fig. 7. Average concentration of the measured limestones and dolomites

● on the basis of neutron activation analysis

○ on literature

1. Dachstein limestones
2. Upper Triassic dolomites
3. Reworked dolomites
4. Lower Jurasic limestones

Table 2.

Dachstein limestones (Transdanubian Central Mountains, Hungary)

		Al_2O_3	SiO_2
1	Tata (Kálvária domb)	0.68	1.39
2	Tata (Kálvária domb)	0.38	0.92
3	Tata (Kálvária domb)	0.13	0.35
4	Tata (Kálvária domb)	0.30	1.29
5	Tata (Kálvária domb)	0.19	0.55
6	Tata (Kálvária domb)	0.22	0.50
7	Tata (Kálvária domb)	0.18	0.35
8	Tata (Kálvária domb)	0.29	0.64
9	Tata (Kálvária domb)	0.29	0.57
10	Tata (Kálvária domb)	0.31	0.51
11	Tata (Kálvária domb)	0.51	0.62
12	Tata (Kálvária domb)	0.19	0.34
13	Tata (Kálvária domb)	0.33	0.52
14	Tata (Kálvária domb)	0.49	0.42
15	Tata (Kálvária domb)	0.22	0.25
16	Budapest (Fazekashegy)	0.08	0.07
17	Budapest (Fazekashegy)	0.09	0.14
18	Halimba (bauxite bed rock)	0.48	
19	Halimba (bauxite bed rock)	0.51	
20	Lábatlan	0.13	
21	Lábatlan	0.30	0.46
Arithm. average:		0.31	0.55

Table 3.

Lower Jurasic limestones (Transdanubian Central Mountains, Hungary)

		Al_2O_3	SiO_2
1	Tata (Kálvária domb)	0.19	0.92
2	Lábatlan	0.30	
3	Bakonycsernye	0.72	2.97
4	Bakonycsernye	0.88	4.82
5	Bakonycsernye	1.09	0.84
6	Bakonycsernye	0.33	0.51
7	Bakonycsernye	1.93	3.12
8	Bakonycsernye	0.55	
9	Bakonycsernye	1.48	3.31
10	Bakonycsernye	0.54	2.37
Arithm. average:		0.80	1.89

Table 4.

Reworked dolomites (Lower Eocen)

		Al_2O_3	SiO_2
1	Nagyegyháza	0.49	0.34
2	Nagyegyháza	0.08	0.07
3	Nagyegyháza	0.19	0.68
4	Nagyegyháza	0.32	0.33
5	Nagyegyháza	0.43	0.33
6	Nagyegyháza	0.53	0.49
Arithm. average:		0.34	0.37

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THE GEOCHEMICAL INVESTIGATION OF IRON-MANGANESE PHASE CHANGE IN GROUND WATER MEDIUM

by

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ABSTRACT

The theoretical and in vitro knowledge can be used only as a hypothesis; the coastal filtered aquifer modifies the reaction rates of the processes and the equilibrium constant significantly.

The catalytic effect of bacteria on the precipitation is of greater significante than the pure chemical reaction. This fact caused some further problems as the optimums of the chemical and biochemical processes are not the same; chemical precipitation calls for much O_2 and low CO_2 content and little C_{org} and higher pH; in the case of biochemical process it is just the contrary. In the case of identical circumstances both in chemical processes iron is likely to precipitate with six times more than manganese (but remobilisation of manganese is more difficult). So if both element have to be eliminated parameters should be accorded to that of manganese (pH, redox potential, pCO_2, etc.).

Introduction

The geochemical behaviour of iron and manganese is observed mostly in aquious medium first of all in sea. In ground water medium the most important are the reactions where phase change occurs, but these phenomena are not known in every respect. This paper tries to adapt the followings to real ground water medium:

- *a)* the in vitro and theoretical chemical experiences with the help of equilibrium studies;
- *b)* the in vitro microbiological experiences;
- *c)* the geological analogies looking through other geophase

1. Summary of the reversible equilibriums

1.1. Equilibrium of sulfide compounds

1.1.1. Iron

The starting point is the in situ formed sulfide bond (we do not deal with the sulfide as an intermediate of the decomposition product of the syngenetic melnikovit-hydrotroilit).

Adding $[NH_4]_2S$ to ferro compounds a greyishblack precipitate with bad water solubility is formed, that can't be obtained with H_2S (in acidic media)

$$L = 6\times10^{-18} \qquad Fe^{2+} = 1{,}37\times10^{-4}\ \text{mg/liter} \tag{1}$$

$$S = 2{,}45\times10^{-9}\ \text{mól/1}\ S^{2-} = 7{,}86\times10^{-5}\ \text{mg/liter}$$

(Pataki – Zapp, 1974).

In ground water with small O_2 content both $[NH_4]_2S$ and H_2S exist.

The FeS formed (melnikovit-hydrotroilit amorf or cristalline) is in equilibrium mostly with hydrocarbonate in natural surroundings when active CO_2 is present (Öllős, 1970):

$$FeS + 2\,CO_2 + 2\,H_2O \rightleftharpoons Fe\,[HCO_3]_2 + H_2S \tag{2}$$

The most important role of the iron sulfide that it can adsorb only precipitate colloid or ion and thus influences other chemical reactions.

In the presence of sulfide (but not H_2S/FeS/melnikovit hydrotroilit) and sulphur is formed from $Fe[OH]_3$ but the reaction is not wellcaracterised.

The sulfide equilibrium is significant only in the redox potential range that is seldom observed in a coastal filtered aquifer.

1.2.1. Iron

The manganese sulfide is present in a weak cristalline form in the sublayer impermeable clay beside melnikovit and in situ formation.

A precipitate with bad solubility is formed from mangano compounds for the effect of $[NH_4]_2S$ but it is not possible to precipitate it with H_2S in acidic media (Pataki – Zapp, 1974).

The solubility is very much dependent on the rate of crystallization. (Pataki – Zapp, 1974)

	L	S mol/1	Mn^2 mg/l	S^2 mg/l
MnS (amorphous)	3×10^{-10}	1.73×10^{-5}	9.52×10^{-1}	5.55×10^{-1}
MnS (cryst.)	3×10^{-3}	5.48×10^{-7}	3.01×10^{-2}	1.76×10^{-2}

Reversible equilibrium is formed with hydrocarbonate in $(NCO_3)^-$ coastal filtered circumstances, but similarly to iron it is more significant as an adsorbent.

1.2. Hydrocarbonate-carbonate equilibrium

1.2.1. Iron

The crystalline form of iron carbonate (siderite) $FeCO_3$ does not react in coastal filtered circumstances in aquious solution but in other position e.g. in oxidation ore for the longlasting effect of descendent water with significant O_2 content it is oxidized to limonite. The stability of siderite is important because if it was possible to shift the carbonate-hydrocarbonate equilibrium towards the cristalline form, the process would become irreversible.

The reaction of ferro-compounds and alkaline carbonates gives $FeCO_3$ in the lack of oxygen or if not significant oxygen is present.

$FeCO_3$ (amorphous)
$L = 3{,}5 \times 10^{-11}$ $S = 5{,}9 \times 10^{-6}$ mól/l
$Fe^{2+} = 3{,}3 \times 10^{-1}$ $CO_3^{2-} = 3{,}5 \times 10^{-1}$ (Pataki – Zapp, 1974)
Water containing CO_2 dissolves it to a little extent:

$$FeCO_3 + CO_2 + H_2O \rightleftharpoons Fe[HCO_3]_2 \text{ (Öllős, 1970)} \tag{3}$$

but the H_2CO_3 dissociate in two steps

$$H_2CO_3 \rightleftharpoons HCO_3^- + H^+ \tag{4}$$

$$HCO_3^- \rightleftharpoons CO_3^{2-} + H^+ \tag{5}$$

the first step is more significant therefore:

$$FeCO_3 + H^+ + HCO_3^- \rightleftharpoons Fe^{2+} + 2HCO_3^- \tag{6}$$

the equilibrium constant is 0,46
The O_2 dissolved in water has the following effect:

$$2FeCO_3 + 3H_2O + 1/2\ O_2 \rightarrow 2Fe[OH]_3 + 2CO_2 + 47{,}2 \text{ cal} \tag{7}$$

$Eo' = 0{,}75$ V (Oszkó, 1975)

$$2Fe[HCO_3]_2 + H_2O + 1/2\ O_2 \rightarrow 2Fe[OH]_3 + 4CO_2 \tag{8}$$

It can be seen from the above written equations that the dissolved O_2 content causes the amorphous carbonate precipitate and the hydrocarbonate from ferrihydroxide. Reaction (3) goes to the other direction only when CO_2 is so high that is very seldom observed in coastal filtered circumstances, so it can be stated it to be irreversible.

1.2.2. Manganese

The crystalline $MnCO_3$ (rodokrozit) is insoluble in water. It forms manganite and piroluzite in the oxidation ore of manganese ore bed containing carbonate for the effect of O_2 and descendent water containing O_2. This effect is not significant in coastal filtered circumstances. The manganese carbonate that is formed for the effect of alkaline carbonate is hardly soluble.

$MnCO_3$ (amorphous) $L = 1{,}8 \times 10^{-11}$
$S = 4{,}24 \times 10^{-6}$ mol/l
$Mn^{2+} = 2{,}3 \times 10^{-1}$ mg/l
$CO_3^{2-} = 2{,}54 \times 10^{-1}$ mg/l
(PATAKI – ZAPP, 1974)

The range of solubility of the $MnCO_3$ is identical to that of the $FeCO_3$ and its valve is very near to the manganese content of the coastal filtered aquifers.

It is slightly soluble in water containing CO_2 if O_2 content is low:

$$MnCO_3 + H^+ + HCO^3 \rightleftharpoons Mn^{2+} + 2HCO_3^- \qquad (9)$$

In the presence of O_2:

$$MnCO_3 + H_2O + 1/2\ O_2 \rightarrow MnO[OH]_2 + CO_2 + 54\ \text{cal} \qquad (10)$$

(Oszkó, 1975)

$$Mn[HCO_3]_2 + 1/2\ O_2 \rightarrow MnO[OH]_2 + 2CO_2 \qquad (11)$$

The rate of reversibility is similar to that of the reaction of the iron and goes to the other direction only when CO_2 concentration is high and is low. It is however characteristic that the $MnO[OH]_2$ precipitate formed in the sample wessel can be solved only with acid.

1.3. Reversible equilibrium for the effect of the pH

The solubility of both the $Fe[OH]_2$ and the $Fe[OH]_3$ is dependent on the pH so they can be dissolved if pH is changed.

It can be seen from the diagram that in a ferro and manganohydroxide solution the ferri and manganihydroxide is present as precipitate and the later is not stable. In the coastal filtered aquifers there is not such great change in pH that exceeds this limit. Though pH can be raised to precipitate the $Fe[OH]_2$ and $Mn[OH]_2$ the method is not economical in industrial sizes, and not useful from other points of wiev.

1.4. Reversible equlibrium for the effect of redox potential change

1.4.1. Iron

The most characteristic reversible system is the

$Fe^{2+} \rightleftharpoons Fe^{3+} + e^-$ $Eo = 0{,}77$ V in alkaline and
$Eo = 0{,}56$ V in acidic medium.

$$2Fe[OH]_2 + H_2O + 1/2\ O_2 \rightleftharpoons 2Fe[OH]_3 \qquad (12)$$

As is mentioned earlier both the carbonate and hydrocarbonate can be oxidized. See Eq. 7.

$$2Fe[HCO_3]_2 + 1/2\ O_2 + H_2O \rightleftharpoons 2Fe[OH]_3 + 4\ CO_2$$

The ferrohydroxide that is rare in nature is oxidized in a similar way:

$$2FeO + 1/2\ O_2 + 3H_2O \rightleftharpoons 2Fe[OH]_3 + 253\ \text{cal} \qquad (13)$$

It is quite difficult to deal with this process because the normal potential $E_0 = 0{,}77$ V and the formal potential $E'_0 = 0{,}75$ V is too high comparing to those in natural circumstances.

Both the Hungarian and Finnish experiments of in situ elimination of iron and manganese showed that oxidation of iron took place in the redox potential range of $E'_0 = +0{,}15 - +0{,}45$ V. The ideal $E_0 = +0{,}77$ V is however shifted due to the fact that the oxidated form is mostly in precipitate, so solubility at pH = 7 is about $6{,}5 \times 10^{-12}$ mg/l

Taking into account the above mentioned fact and the avarage iron concentration in a coastal filtered system the modified value of E_0 is about $0{,}5 - 0{,}525$ V, but it is still to high comparing to values observed.

A further explanation of this fact is microbiological explanation that the iron forms a chelate complex. It is wellknown that the ferri-ferro redox potential decreases due chelate formation, but unfortunately microbiology does not give any value of E_0.

Some values can be found in geochemical literature that is near to the values observed but unfortunately it is not mentioned how these values were interpretated, so it could be handled as datum-nudum (SZÁDECZKY – KARDOSS, 1955).

$$Fe^{2+} = Fe^{3+} + e^- \quad E'_0 = +0{,}77 \text{ V for the single ion}$$
$$E'_0 = +0{,}15 \text{ V for the hydroxide}$$

Some results of in situ elimination of iron and manganese is shown that were achieved at waterworks in West-Germany (HASSELBARTH-LÜDEMANN, 1967):

Water-work		Eact mv
Hunxe	6 th well	+69 – +99
	5 th well	+64 – +59
Nordhorn		–81 – –91
Mönchengladbach		+219 – +249

We have tried to investigate how can theory follow the more complicated redox processes.

The coexistence of two redox system can just be followed if formal potentials and concentrations are known. Unfortunately not all formal potentials can be found. Analyses of such systems is therefore quite difficult. Redox systems with there or more participants are very difficult to handle.

On the basis of the above mentioned it can be stated only that higher redox potential helps the formation of precipitate in an oxidative reaction but the equilibrium constant and the redox potential characteristic for the given only approximately. Its value is about $E_0 \approx +0{,}15 - + +0{,}45$ V.

1.4.2. Manganese

Manganese is one of the elements that occurs with different valencies; in coastal filtered aquifers Mn^{2+} and Mn^{4+} occurs. The reactions and redox potentials have to be taken into account with great care as numerous variation of the two ions can form different compounds. In natural circumstances there are more than twenty manganese oxide-hydroxide is known and even more can be made in laboratory circumstances.

Furthermore the change in valency takes place in several steps and chemosorption, adsorption is likely in the surface of the precipitate; autocatalysis can also occur.

On the basis of the above mentioned fact the following few equations are only examples of what happens in fact:

$$2MnO + O_2 + 2H_2O \rightleftharpoons 2MnO[OH]_2 + 40\text{ cal} \tag{14}$$

$$Mn[OH]_2 + 1/2\ O_2 \rightleftharpoons MnO[OH]_2 \tag{15}$$

and for more see Eq. 10., 11.

It has to be stated however that analysis proves to be very difficult because of the processes that are very slow in time; and as result of excitation further oxidation and irreversible formation of crystals occur. Therefore the theoretical characterisation of the real processes are felt to be the most difficult here.

2. Equilibrium of manganese and iron influenced by microbiological effects

The effects of bacteriums were examined in details in connection with the geotechnological recovery (SZOLNOKI-BOGNÁR, et al. 1965). The biochemical processes and the energetical relations are known from this work. The ores containing sulfids are oxidized by *Thiobacillus thiooxidans* and *Thiobacillus ferrooxidans* to form ferrihydroxide and sulfuric acid (SZABÓ, 1982).

Some authors state that the test materials have no connection with the compounds to be oxidized. Their role in the process seems that they help the electron transfer from the sulphur and iron to other electron donors such as oxygen, and the energy of the process helps to form the adenozin-triphosphate the "energy warehouse" of the cell. Other authors state the bacteria act as electron donors (we think that electron acceptor). The bacteria mentioned above exist in acidic medium the growing limit is pH 1,4 – 6,0, the productive maximum is pH 2,5 – 5,8. It can be read in literature that they can form a sulfuric acid surrounding locally in almost neutral medium. It cannot be suspected taking into account the water permeability of the coastal filtered aquifers, but it is common in the Pannonian or Rupelian clay under the aquifer.

Pyrite centered limonite nodules can be observed, the clay mineral of these is caolinite, despite the characteristic illit- montmorillonite clay minerals. The formation of caolinite is due to the sulfuric acid. This latter phenomenon is significant only from the point of view of iron mobilisation, but not interesting in the reversible equilibrium.

In bank filtered circumstances other kind of bacteria are to be found. They cause the formation of $Fe(OH)_3$ The (more or less) anaerob bacteria uses the CO_2 coming from iron compounds or in the case of hydroxide compounds they use the CO_2 dissolved in water or organic acid first of all huminic acid and the energy coming from the oxidation.

They well-known genus are: *Gallionella*, *Siderocapsa*, *Sideromonas*, *Leptothrix* (Szabó, 1982).

The bacterological formation of manganese is a similar process, often with the help of iron bacteria. Specifically genus for manganese oxidation are *Crenothrix*, *Cladothrix*, *Clenothrix*. If circumstances are optimal the formation of crystalline MnO_2 piroluzite occurs. In the case of manganese oxidation the energy that releases is only 1/6 of that in case of the iron so the bacteria that oxidize manganese are likely to use organic carbon as further source of energy (Szabó, 1982).

Bacteria builds in partly the elements of higher oxidation state into their body partly adsorbs them on the surface of their body.

This gelatinous material decreases the permeability of the aquifer.

Bacteria not only oxidized but also reduced the iron and manganese so this process reversible. But far less is known about the reduction of the $Fe[OH]_3$ caused by bacteria. It has been observed in neutral medium, so it is likely to occur in coastal filtered circumstances. Certain kinds of the *Thiobacillus* and the *Sulfolobus* oxidise sulphur so sulphur acts as electron donor in the case of iron reduction (Szabó, 1982).

Furthermore the decomposition of the organic material sets up a reductive surroundings that reduces the precipitated iron and makes it soluble.

3. The process of the phase change of iron and manganese

The iron [III] is insoluble in the neutral pH range forming hydroxide that can be hardly filtered because of the huminic acid protecting colloid. After coagulation dehydratation and mineralisation it is irreversibly precipitated. The ferrihydroxide sol adsorbs mainly anions. In the case of iron the real process can be characterised quite well the only question is the remobilisation and restabilisation.

In case of manganese reactions are far more complicated due to chemosorption and because the different valency combination. The Mn[III] compunds are not stable and they decompose quickly if are formed at all.

The mangano compounds in aquious solution form manganese dioxide-hydrate ($MnO[OH]_2 \cdot \times H_2O$) and metamanganese acid ($MnO[OH]_2 \rightleftharpoons H_2\,Mn[IV]O_3$) for the effect of dissolved oxygen. The metamanganese acid can take up mangano ion in the place of the H_2 to form $Mn[II]Mn[IV]O_3$ but this is not stable in water so it can be stabilised in two ways:

a) with the take up of further mangano ion and oxygen it forms protohausmannite Mn$[II]_2 \times$Mn$[IV]O_4$ that is the most stable crystalline manganese oxide

b) with the help of bacteria protobirnessite (Ca, Na) [Mb (II), Mn (IV)]$_7O_{14} \times 3H_2O$, or δMnO_2 and [(Mn (II), Mn(IV)] (O, OH)$_2$ or γMnO_2 is formed.

The manganese oxide-hydroxides form sols with weak acid character, and on the surface there are adsorbed OH^- ions that ensure favourable conditions to the further oxidation of the iron and manganese (SZÁDECZKY – KARDOSS, 1955) Certainly the oxidation process needs oxygen or other electron acceptor, the active surface only helps the reaction so to say it acts as a catalyzer. It is misreported in literature as autocatalysis.

In chemistry autocatalysis means that in the course of a reaction this phenomenon increases the reaction rate after the induction period. This is not true in our case because with growing size of the precipitate the specific area decreases so does the catalytic effect. According to FLICK (1968) we advise to use the name "adsorptive catalysis" that characterises the process much better.

4. Interpretation of the Fe – Mn reaction in bank filtered systems on the basis of geological analogies

Though it is possible to use geological analogies we are aware of the fact that there are differencies between the coastal filtered aquifer and other geophases, but a very careful interpretation is not worse than data coming from in vitro experiment.

From the point of view of the above mentioned aim only the aquious sediment geophases that are interesting for us.

4.1. Euxin facies

The classical area of sulfide formation is the deeper region of the Black-sea. The anaerob decomposition is characteristic of this area because of the lack of oxygen; the H_2S and the $[NH_4]_2S$ coming from the decomposition of proteins precipitates the iron as sulfide in the range of pH 8,1 – 8,4. The precipitate crystallizes to form hydrotroilite ($FeS \times H_2O$) and melnikovite (FeS_2) in an irreversible process (SZÁDECZKY – KARDOSS, 1955). The decomposition of this is not a reversible process but wearing.

4.2. Manganese precipitation in the bottom of the sea

The precipitation of manganese in some region of the bottom of the sea is a very sorrowly observed phenomenon for some tenth of years. It can be stated that more is known about it than about the processes taking place in coastal filtered systems. As the reaction takes place in the pH range about 8 – 8,5 the results cannot be adopted directly; it may be used perhaps for examining that what happens if the pH of the ground water would be raised to this value.

Adaptation seems to be difficult because of other reasons as well, e.g. comparing the n. 100 – n. 1000 mg/l salt content of the coastal filtered water to that of the sea wich is about 35 000 mg/l; and there are different kinds of bacteria in sea water than in the bank filtered systems. To summerise experiments there are two important fact that are worth mentioning (Crerar et al., 1980):

a) the reacting rate of the catalytic oxidation of manganese:

$Mn^{2+} + O_2 \rightarrow MnO_2$ slow
$Mn^{2+} + MnO_2 \rightarrow Mn[II] \times MnO_2$ fast
$Mn[II] \times MnO_2 + O_2 \rightarrow 2MnO_2$ slow

b) it is proved that the Mn[II] → Mn[IV] oxidation goes in one step to yield MnO_2 sicc.

$$Mn^{2+} + 2H_2O \rightarrow \delta MnO_2 + 4H^+ + 2e^- \quad E'_0 = +1{,}293\ V$$

In ground water systems this reaction goes in several steps, and sometimes does not reach the cristalline state without a general dehydration.

Numerous E – pH diagrams are worked out to different temperature and concentration so they cannot be used for bank filtered aquifer (Grekak et al., 1980).

4.3. Formation of bog ore

In bog circumstances in acidic medium the iron moves in a humin acid bond as colloid. The humate is decomposed by bacteria and limonite is formed goethite αFeO[OH]; lepidokrokite γFeO[OH]. This formation is irreversible and the virtual returning of the process is due to wearing.

In the middle deeper part of the bog where oxygen content is low ferrocarbonate "white ore" is formed. In bog surroundings with extrem low oxygen content even sulfide formation is to be observed, but this is the result of the decrease of redox potential during the epi- and diagenesis (Stefanovits, 1976)

4.4. Formation of noble sand

As a geological analogy for the change of the pH we can mention the getting sterile masse of the noble sand bed towards the sea. The infiltration of the water containing huminic acid from the lagoon behind the beach drifting mobilises (perhaps forming chelate complex) the iron. At the outer side of the beach drifting where the pH reaches the value of 8 – 8,5 characteristic for sea water the $Fe[OH]_3$ is precipitated and after mineralisation it forms limonite.

4.5. The effect of frost

The most similar system comparing to the coastal filtered one is the pleistocene terrace where the following phenomenon can be observed (Budapest, Cinkota, Pestlőrinc).

In the body of a well classified gravel of the biggest size – if it was in level with surface of the ground water – manganese shell MnO_2 could be found, in the case of badly classified gravel iron shell FeO[OH] could be found. The sandy gravel was originally lack of shell. The fact mentioned above is very important from the point of view of bank filtered aquifer of terrace origin, and the individual pore size has great importance.

Similar phenomenon could be observed in the cuttings of the M3 motorway. In the course of the aging of the splay surface and the decrease of the level of water and the drying out of the wet parts manganese precipitated in the places of rough grain size, the iron formed limonite in the places where grain size was smaller and in the clay fraction ferrihydroxide colloid was found. In other approach the general geochemical number that is characterised by the $2Fe_2O_3/FeO$ ratio is 3,26 in clay and 7,1 in sand and > 10 in gravel.

4.6. Ochraceousing of the wells

Investigations in connection with the ochraceousing of the wells are quite near to our aims. Only the sign of the processes has to be changed that means if one thing is useful in a certain case it is unuseful in the other.

On the basis of literature the following summary can be given: chemical processes have not important role in the incrustation blocking of filter, the most important role is played by the iron hydroxide formed biochemically, the effect of what was increased by the cementation effect of the living and already died biomass.

The limits observed experimentally are:

concentration: 0,2 – 0,5 mg/l Fe
redox-potential: $E'o = -10 - \pm 20$ mV
$pH = 6{,}5 - 7{,}6$

$$rH = \frac{E_{H2}}{0{,}0992} + 2pH \geqq 14{,}5\ 1$$

and the streaming speed of the water has to be greater than the natural leaking speed (Hünerberg, 1966).

Summary

1. The theoretical and in vitro knowledge can be used only as a hypothesis; the coastal filtered aquifer modifies the reaction rates of the processes and the equilibrium constant significantly.
2. The catalytic effect of bacteria on the precipitation is of greater significante than the pure chemical reaction. This fact caused some further problems as the optimums of the chemical and biochemical processes

are not the same; chemical precipitation calls for much O_2 and low CO_2 content and little C_{org} and higher pH; in the case of biochemical process it is just the contrary.

3. In the case of identical circumstances both in chemical processes iron is likely to precipitate with six times more than mangan se (but remobilisation of manganese is more difficult). So if both element have to be eliminated parameters should be accorded to that of manganese (pH, redox potential, pCO_2, etc.).

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THE INVESTIGATION OF THE THEORETICAL BASIS OF IN SITU ELIMINATION OF IRON AND MANGANESE WITH THE HELP OF MODEL EXPERIMENTS

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ABSTRACT

The chemical technological aimed experiments proved the reaction processes known from the theories in aqueous media, but quite different results were obtained in the sandy-gravel aquifers that are similar to the real aquifers. It can be stated generally that reaction times has increased, and with decreasing grain size and though permeability the time needed has increased greatly. This qualitative change sometime has ment quantitative change as well, because the cycle time of the in situ elimination of manganese and iron reaction took place partly or not at all.

The results of the processes influenced by numerous natural factors has a certain deviation the rate of deviation changed depending on the reaction types in aqueous or sandy media. Eg. the deviation of results obtained in the $CO_3 - HCO_3$ – system had of greater deviation in aqueous than in sandy media, and with the pH the situation was opposite.

The humin acid bond or protecting colloid could not be oxidised water saturated with O_2, the gasous O_2 or O_3 partially and the latter fully could oxidise.

Introduction

One of the serious problems of the production of the bank filtered water is the high iron and manganese contents. The most economical solution of this is the in situ elimination of iron and manganese. The method has been worked out empirically and application of it to different types of aquifers (moraine sediments, terrace gravel, etc.), and water engineering systems calls for empirical solution. The theoretical knowledge of the process did not play an important role beside the above mentioned things. Publications having delt with the subject theoretically altogether have suspected processes differing from or opposite one another. The experiments introducting here serves as an approach of the real processes.

Model experiments from chemical-technological approach

Adaptation of the law of samples of small numbers.

First we have adopted the ratio multipliers of the above mentioned law for hydraulic experiments. We have used from them that is nessesery for us: taking into account the gravitation and the frictional force (because the capillary force in a coarse sandy-gravelly aquifer is neglible) identical grane distribution yields identical leakage constant, the pressure difference in the sample tub determines the speed of filtration and furthermore the dwelling time at a given steaming length.

The small size of the sample tub is not in accordance with the filtration time and the dwelling speed, therefore this difficulty has been overcome by closed system multicirculation.

The greatest distortion in this system was caused by fact that the 6 – 30 m thickness of the bank filtered aquifer could be contracted to 30 cm. In most of the experiments only one homogenous layer has been built in, and the covering has been solved with a 1 cm polyurethane sheet or puc foil in thickness. The closed system circulation has been solved with an adjustable membrane pump. In certain experiments if the chemical effect of gases was useful the motion of water was achieved by pumping through CO_2, O_2, or N_2.

As both the spontaneous and the exerted biogeochemical process are very complex, the conception of the series of investigation was as follows: starting off from the most simple system, in the experiments following one another only one important factor was changed, so in this way the differences could be measured quantitatively.

Measurements were accepted semi-quantitative due to not so good reproducibility. The first part of the series investigated such systems not occuring in nature (distilled water, elimination of gases with boiling etc.).

Investigation of sulfide equilibrium.

The ferrous-sulfide precipitate is only very oxidised by oxygen solved in water (protomelnikovite, protohidrotoilite). Sulfide precipitate is more easily oxidised if Fe (III) or Mn (IV) compound is present. The Fe (II) and mangane compounds formed in the reaction are exidised by the oxygen solved in water, so it has of no importance from the point of view of the whole process, going under natural circumstances. (Figure I.) But if the oxygen solved were taken out of the system the sulfide precipitate became an important and remobilizing factor.

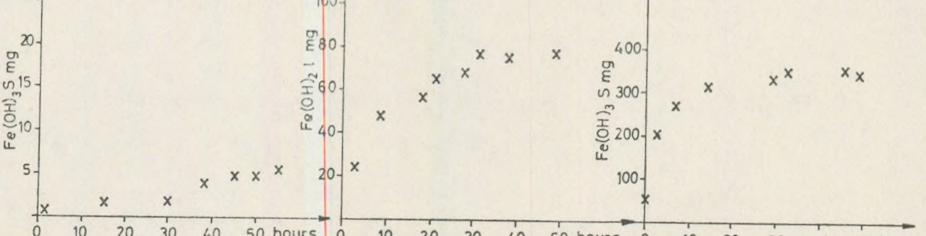


Fig. 1. Pyrite oxidation with help $Fe(OH)_3$

Despite theory that the sulfide precipitation is stable at $E(act) < 0$ mV redox potential, our investigations has showen that it is stable at a higher redox potential valve appr. $E(act) = 120$ mV.

Investigation of carbonate-hydrocarbonate equilibrium

In the first step we have tried to solve crystalline mineral carbonate powder in water previously deoxigenated water with the help of CO_2 bubbling in glass tub into the form of hydrocarbonate. The results of the solving process were not very exact due to the variation of the partial pressure of the CO_2, but in general we have got the results expected, as the solvation was hardly better then the limit of detection (0,1 Mg/l), and there was no difference between the samples treated or not with CO_2. Experiments were repeated in a sandy gravel aquifer, and though the deviation was smaller, the reaction time was $10-15$ times more.

The solvation of the precipitation formed in situ gave considerably different valves. The precipitate partly dissolved as bicarbonate due to the effect of excess CO_2, and the after the removel of CO_2 the iron and manganese precipitated as carbonate. The process was reversible, the solvation was only partial. The quantitative evaluation of CO_2 needed for the $CaCO_3/Ca/HCO_3/_2$ system is well known, so we would have liked to set up a similar value for the iron and manganese carbonate-bicarbonate. This was not possible due to the difficulties of measuring the CO_2.

In the sandy-gravel aquifer similar to the above mentioned the reaction time raised.

Investigation of the effect of the: pH variation

Variation of the pH has an effect mainly on the solvation of the $Fe(OH)_3$ In the pH range measured in the circumstances of coastal filtering ($6{,}5 < pH < 7{,}5$) were made the first experiments. In this range both the solvation and the change in the solvation due to the variation in the pH were neglible, cca. in the 0,01 mg/l range.

It is to be suspected that bacterial activity determines quite a different pH in the local Angström range comparing to the valve mentioned above. As the in alkaline media there is no solvation this effect was not examined only in acidic media in the $2 < pH < 6{,}5$ range. Experiments were repeated in a sandy gravel aquifer and the reaction time became greater (see later) and deviation increased (Figure 2.).

Change of the redox potential

Variation of the actual redox potential has been achieved by bubbling trough O_2 and O_3 or air. The redox potential has been measured by RH – 226 industrial measuring system with the reproducibility of 20 mV.

The oxidation of $Fe(OH)_2$ in a tub filled with water took place on the air-water boundary. This reaction was neglible in a tub filled with sandy-gravel, only 1,5% of the $Fe(OH)_2$ was oxidised beyond the surface.

Bubbling through air yielded complete oxidation the reaction rate depended on how fine carburation was.

The entire homogeneousnes of bubbling in sandy-gravel sample tub could not be enabled, therefore it was made by building up a vertical curtain and a horizontal stream of liquid. Oxidation was measurable only around the bubble curtain befor starting off filtration, but it was not possible to caracterize it because of the uncertainty of the boundary of the curtain. (Figure 3.)

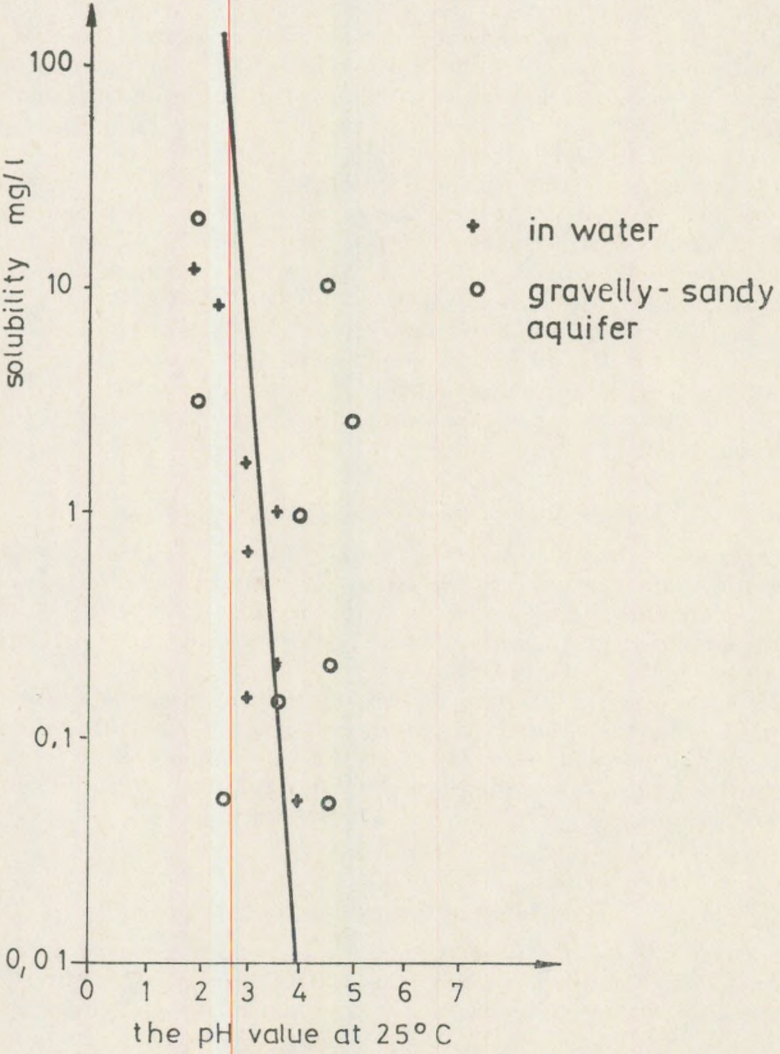


Fig. 2. Relation between the solubility and the pH value

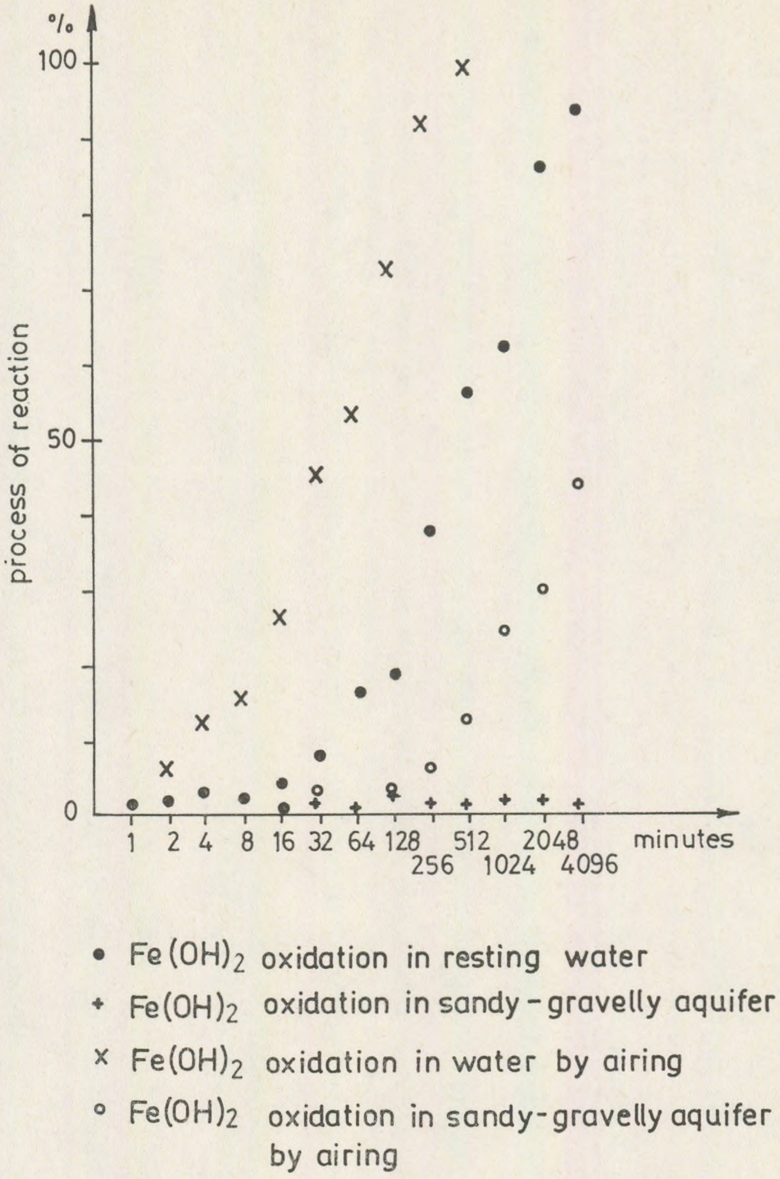


Fig. 3. Relation between the degree of the reaction and the reaction time in varions media [$Fe(OH)_2$]

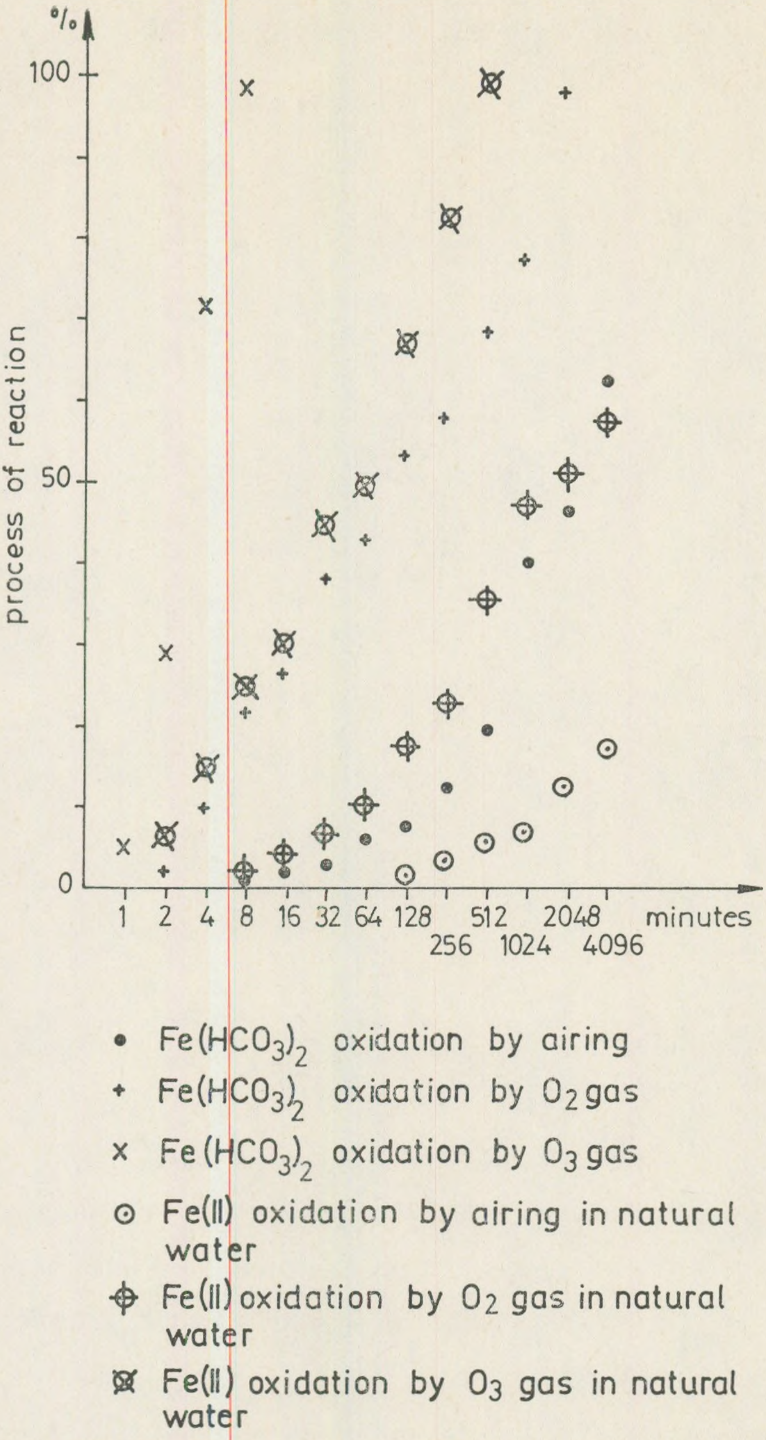


Fig. 4. Relation between the degree of the reaction and the reaction time in varions media [$Fe(HCO_3)_2$]

The effect of the O_2 and O_3 was tested under similar circumstances. With the $Fe(OH)_2$ the significant decrease of reaction time was observed, with $Fe(HCO_3)_2$ displacement of the equilibrium towards the oxidised state was observed.

With the natural bank filtration water from Csepel – island oxidation hardly took place with bubbling air; O_2 gave better result and O_3 oxided completely. The explanation of this phenomenon is that the iron in this kind of water is bounded to humin acid or is in a humin acidic protecting colloid. This can be hardly oxidised by air because of the small partial pressure of O_2, and that is the explanation of the better results with O_2 and O_3. (Figure 4.)

The tendency of phenomena in a sandy-gravel aquifer is similar only the time of reaction increased.

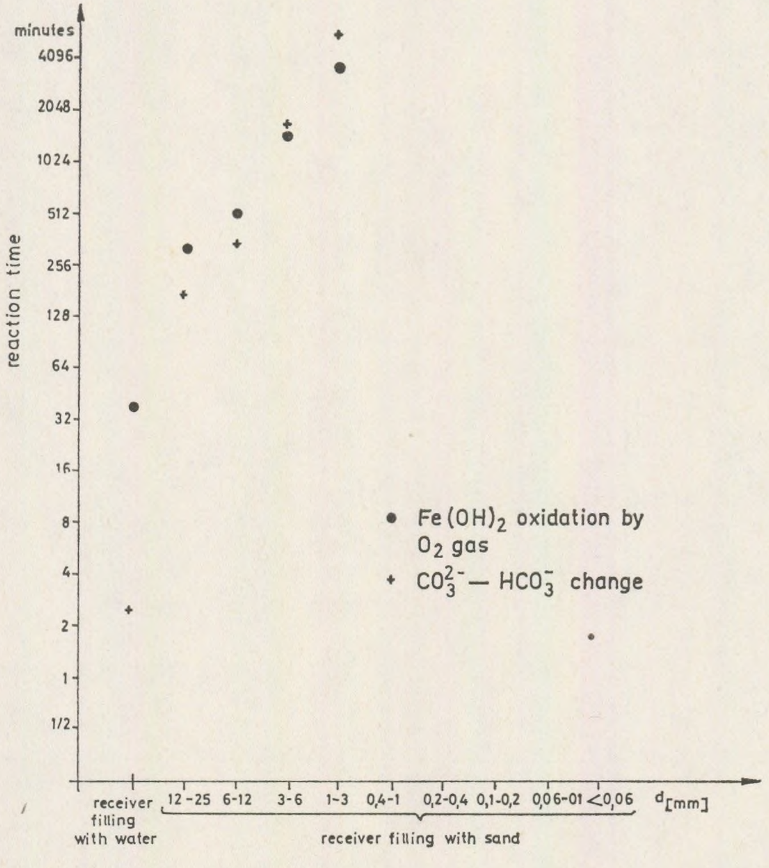


Fig. 5. Relation between the reaction time and the granulometry of medium

Measuring the rate of reaction

Experiments have shown that chemical reaction basically are identical either in water or in a sandy-gravel aquifer.

A great difference was observed in reaction time either. Comparing the sandy-gravel aquifer to the water filled tub it can be stated that reactions took place slower in the previous one and the smaller the size of the grain the longer the reaction time was.

To illustrate it the time of the two reaction is shown in Fig. 5.

The reaction rate is proportional to the liquid transmission of the aquifer, but the exact function is rather complicated and cannot be set up due to the small number of data.

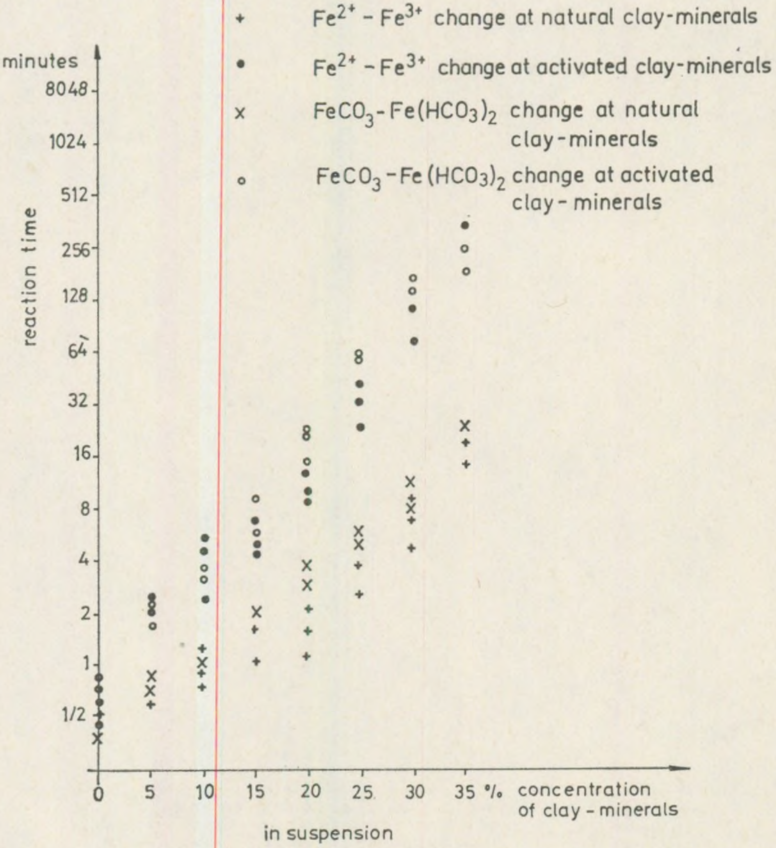


Fig. 6. Relation between the reaction time and the concentration of clay-minerals in suspension

The role of clay minerals

The role of the clay minerals in the water-geochemical processes of ground is rather important because of its surface adsorption.

After boiling with H_2O_2 we have separated the $2-50$ μm fraction from the material of the aquifer. It contained mostly clay mineral.

Its ionic change capacity in natural state is 40 mequiv/100 g, 90 mequiv/100 g after activating with HCl, and $70-80$ mequiv/100 g after activating with Na_2CO_3. The composition counting from the data above is approximately 1:3 illite + kaolinite/montmorillonite; this composition was approved by X-ray diffractogram either.

Mineral clay of natural state and clay activated with Na_2CO_3 were used for technological experiments (A similar state can be achieved comparing to the activation with Na_2CO_3 in the in situ elimination of manganese and iron if the pH is raised with NaOH). The mineral in natural state changes the Ca Mg ions then changes then back with the Fe^{2+} and Mn^{2+} ions influencing indirectly the chemical processes.

Changing the quantity of the Ca-Mg within the limits observed in the bank filtered aquifers, it could be seen that the quantity of the Ca-Mg and Fe-Mn bounded to ion change places changed without any tendency in time.

It can be however stated that the rule that ion potential determines the bond strength is not valid in the case of clay minerals. Ion with smaller ion potantial can bind stronger depending on concentration.

Experiments were made in clay mineral water suspension and in clay sand + water system. Reaction time was measured altering the concentration of clay.

It can be seen from Fig. 6. that the sludge content cca. $3-15\%$ is the most significant effect on the increasing of the reaction time.

It is known that certain kind of clay minerals (Fillis- Molof, 1972) catalyse oxidation (see adsorptive catalysis). We have not met such phenomenon; it likely that the clay minerals not belonging to the smektite group has catalytic effect, but the smektites characterizing the home aquifers (montmorillonite, beidellite) gas ion change effect. (Fig. 7.)

Investigation of the effect of organic substances

The next part of our experiments tried to investigate the role of the organic substances in the costal filterd systems.

It is of no doubt, that the organic substances uses the dissolved oxygen in their decomposition so they decrease the actual redox potential of the system.

Another effect: the solid organic substance has an effect similar to the clay minerals due to it adsorptive effect, but it is difficult measure it. It dissolved organic substance is present in the form of humin acid. It is known from the home in situ elimination experiments of iron and manganese that iron being bounded to humin acid can hardly be oxidised in a simple economical way. (e. g. airing) Our experiments gave similar results to the theories so it would not be explained here.

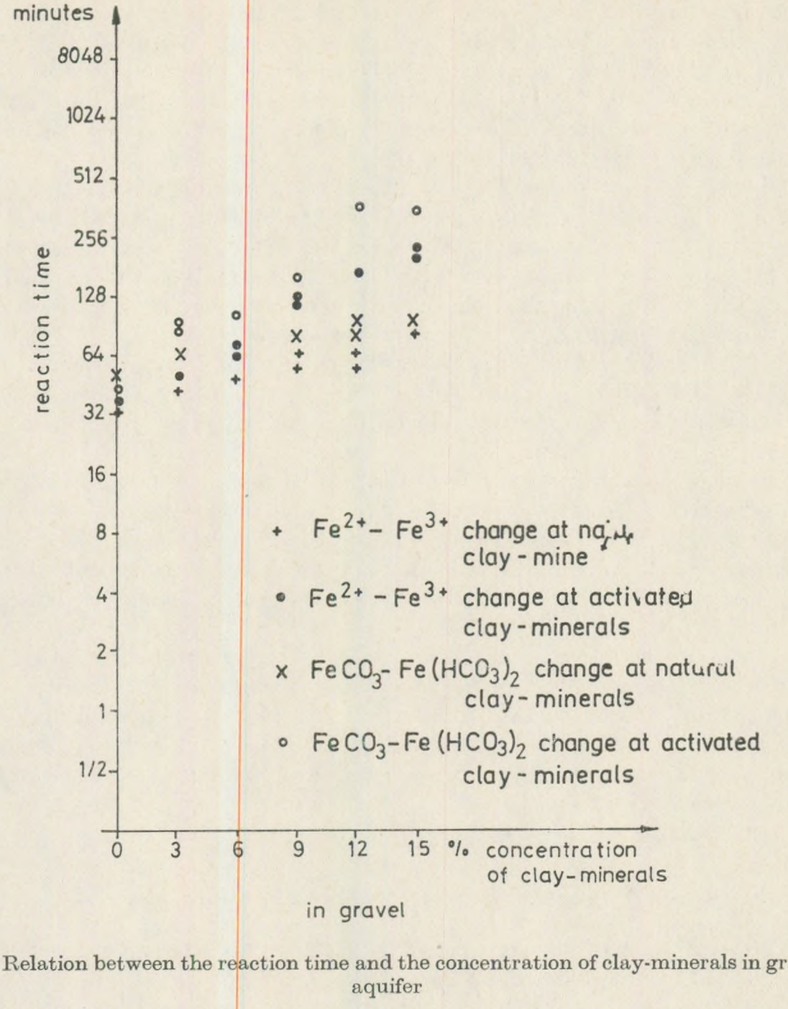


Fig. 7. Relation between the reaction time and the concentration of clay-minerals in gravelly aquifer

Another unuseful effect of the humin acid is that it forms a protecting colloid around the iron precipitate, so it does not allow its coagulation, dehydration, finally its mineralisation.

The disperse iron- manganese precipitate can be filtered badly, so it remains in the aquifer decreasing its water permeability (Figure 8, 9, 10).

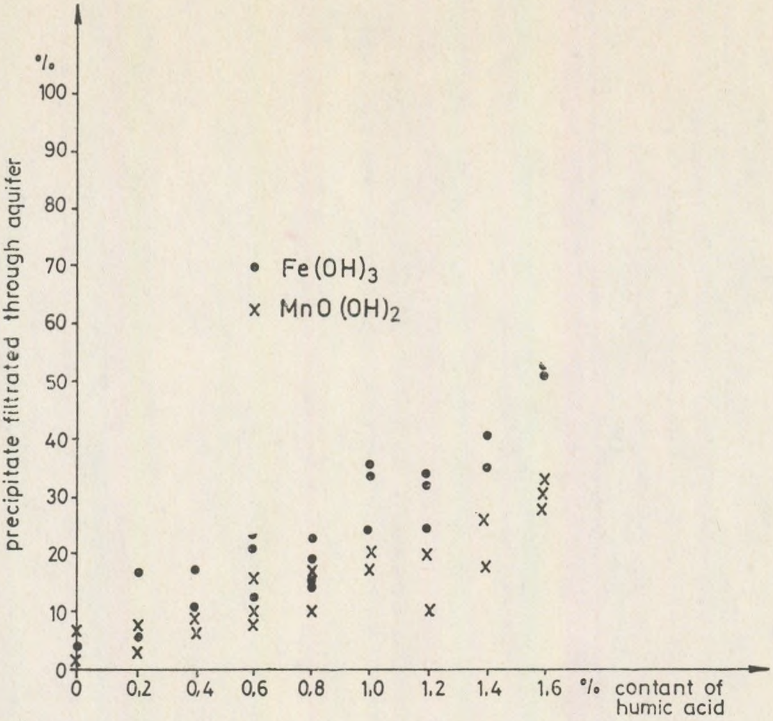


Fig. 8. Relation between the concentration of humic acid and the unfilterable precipitate

Microbiological experiments

The above mentioned experiments were carried out in a sterile media so in the following we deal with the processes going in nature influenced by bacteria. The pH range favourable to chemical processes influenced badly the bacterial activity, at pH 8 we observed only chemical oxidation, going back to pH 7 it took 40 days for the bacterial flora to regenerate. Concerning to literature (Szabó, 1982) the pH optimum of bacteria living in the ground water is around 6 – 7, so we stabilised the pH to 7.

Changing the dissolved $O_2 - CO_2$ concentration that influencies the actual redox potential we have achieved cirumstances optimal for bacteria. It is optimum only from the point of view of the Fe-Mg oxidation and not of the growth of the bacteria. The measuring method responds to this aspect.

It can be seen from Fig. 11. that significantly low concentration of O_2 is enough to optimal bacterial oxidation (cca. 2 mg/l on 10 C) and there is no dependence of results on the anions (OH^-or HCO_3^-). Optimalisation of the CO_2 concentration gave the following: with iron there was a significant difference due to anions; with $Fe(OH)_2$ (Figure 12.) maximums could

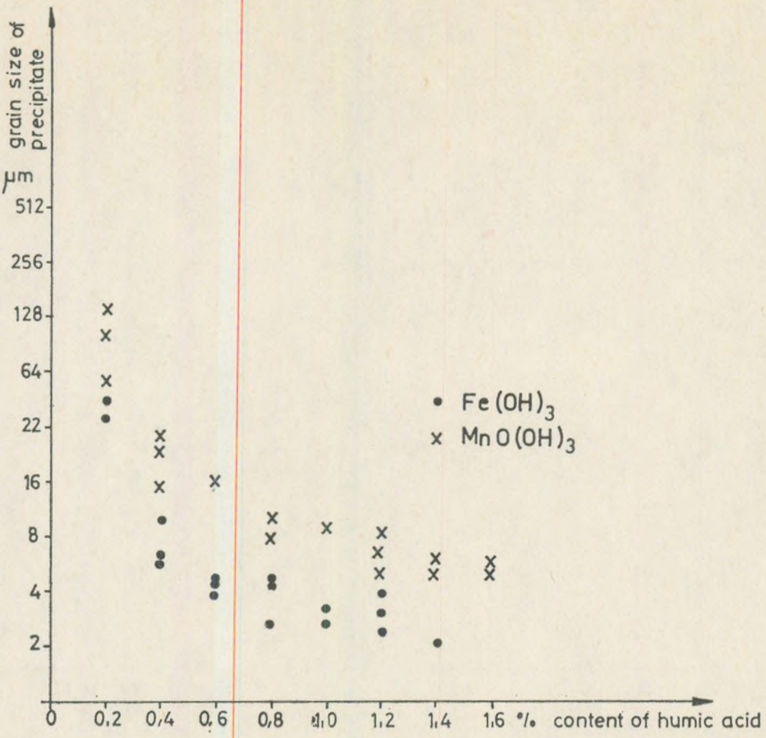


Fig. 9. Relation between the concentration of humic acid and the grain size of precipitate

be observed depending on the CO_2 concentration at different CO_2 contents; with $Fe(HCO_3)_2$ a slight decreasing is only observed (Figure 13.); with $Mn(OH)_2$ there is no dependence (Figure 14.); behaviour of the $Mn(HCO_3)_2$ is similar to the iron (Figure 15.)

The explanation of the phenomenon is as follows: the Gallionella genus is chemolitotrophe, it uses the CO_2 forming from the HCO_3^- and if it cannot get it from HCO_3^- it uses CO_2 of only other origin. This genus does not oxidise the Mn.

The Leptothrix genus that oxidises the Mn is chemoorganotrophe, does not uses CO_2 so such a difference observed with the iron cannot be observed with Mn.

In other relation similar phenomena were observed in water-works in production (Rott, 1976).

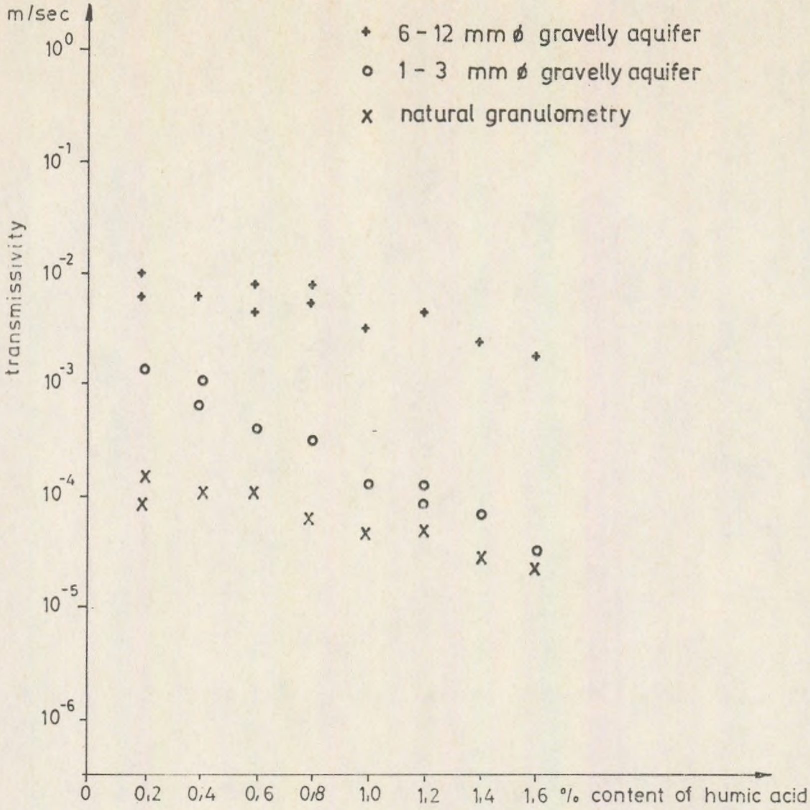


Fig. 10. Relation between the humic acid and the transmissivity

Experiments for mineralisation

One of the aim of the in situ elimination of Fe-Mn is the mineralisation of the Fe-Mn precipitate. It is useful in from two aspects: precipitation becomes irreversible and the volume of the precipitate becomes smaller so the choking of the aquifer is going to be slower.

Mineralisation has been achieved in such circumstances that is not common in bank filtered aquifers of cannot be achieved economically.

Though mineralisation is a cristallisation process its measure has been chosen that practical point of view that the change of the precipitate has reached an irreversible phase or not. Therefore indirect method has chosen to measure so the Fe-Mn going into solution in the remobilisation process has been measured.

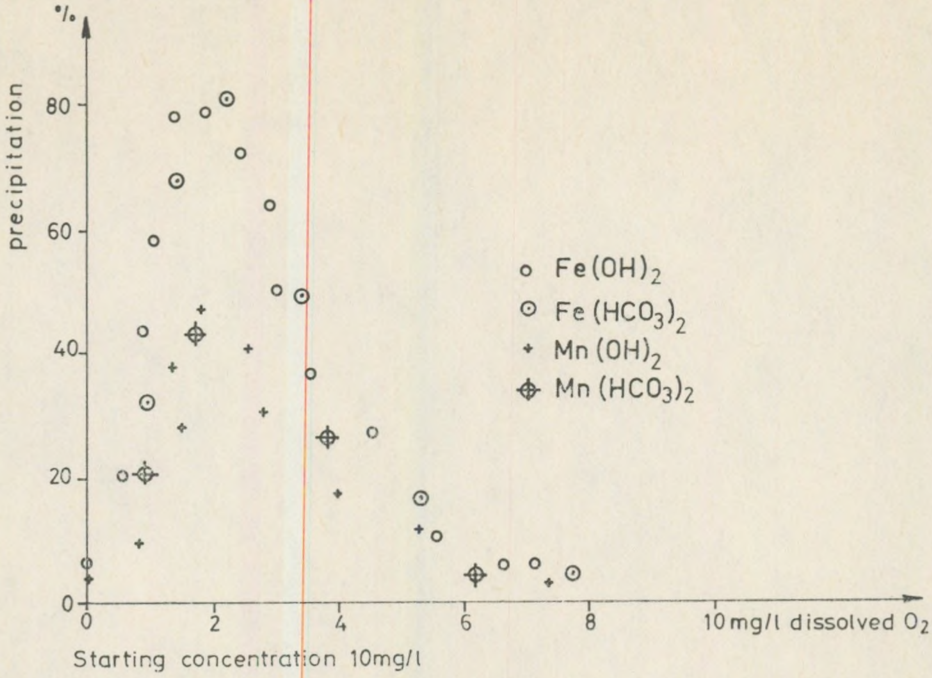


Fig. 11. Relation between the dissolved O_2 and the degree of precipitation by different starting materials

Mineralisation without chemical and biochemical effect

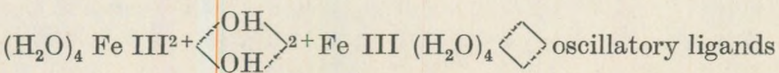
It is often stated in literature that the Fe-Mn precipitate causes only insignificant choking as it is mineralised from time to time.

We have investigated the spontaneous mineralisation. It was observed that significant cristallisation under water has not happened for even 3 years.

In a chemically closed system some mineralisation was observed if the water was circulated by means if a pump. The greater range of cristallisation could be observed in the pipe line directly after the pump, and at the entering point of the gravel body. Precipitation of Mn was not observed at all in the pipe, only the $Fe(OH)_3$ had become in the limonite state.

Carrying on the experiments with different composition of charge the ratio of mineralisation decreased significantly going from the coarse fraction to the fine. Foreign literature (Rott, 1976) puts forward the possibility of the polymerisation of ferrihydroxide as follows:

$$2[\mathrm{Fe\ III}(\mathrm{H_2O})_5 \cdot (\mathrm{OH})]^{2+} = [\mathrm{Fe_2\ III}(\mathrm{H_2O})_8(\mathrm{OH})_2]^{4+} + 2\ \mathrm{H_2O}$$



$$(\mathrm{H_2O})_4\ \mathrm{Fe\ III}^{2+} \left\langle \begin{matrix} \mathrm{OH} \\ \mathrm{OH} \end{matrix} \right\rangle^{2+} \mathrm{Fe\ III}\ (\mathrm{H_2O})_4 \ \diamond \ \text{oscillatory ligands}$$

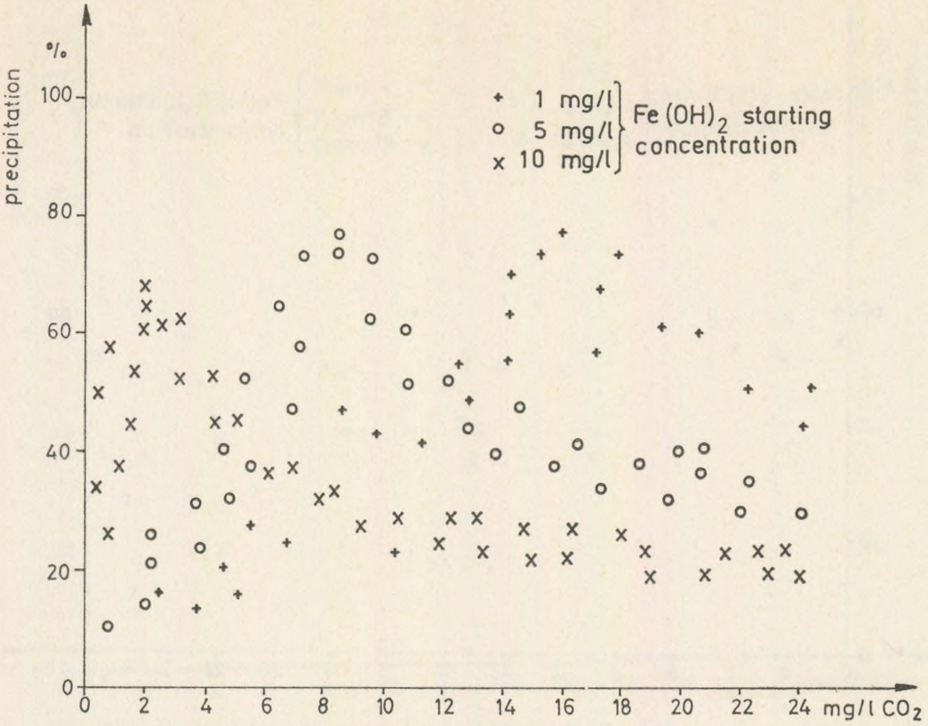


Fig. 12. Relation between the dissolved CO_2 and the degree of precipitation by different concentration of $Fe(OH)_2$

It can be seen that dimerisation and further the polymerisation is followed by water formation that makes situation favourable to dehydrational mineralisation. Rott states at the same time that the polymer is not a bad soluble material practically a colloid.

The phenomenon could not be investigated because of the difficultes of polymer analysis therefore as an analog we used the processes of the alumina production. To summarise it can be said that the different Al oxide – hydroxides influenced the energy of dehydration neglibly.

The conditions of polymerisation stand near to that of the mineralisation therefore we do not deal with it any more.

Mineralisation for air bubbling

The Fe-Mn precipitate mineralised both in the water tub and in the sandy gravel aquifer as well. Bubbling through air the tub or saturating the circulating water made no difference, though direct bubbling was a little more effective because air supply was faster in this way.

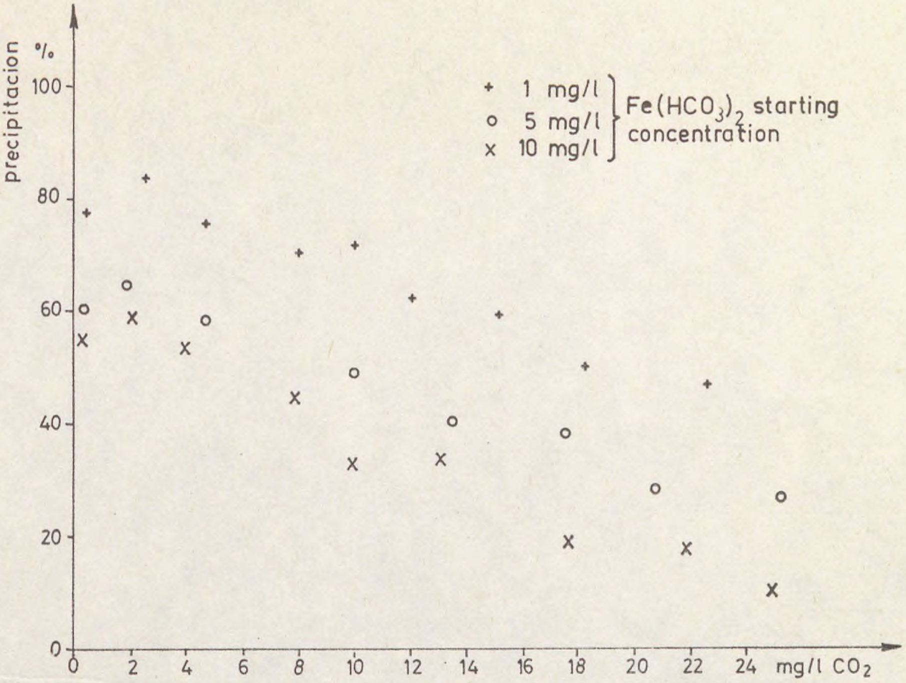


Fig. 13. Relation between the dissolved CO_2 and the degree of precipitation by different concentration of $Fe(HCO_3)_2$

More exact measurements were possible when saturating the circulated water with air. The difference between the oxygen content of the water entering and leaving the tub made it possible to estimate the oxygen needed for the processes. Mineralisation was not observed until oxygen consumption was measured. After stopping oxygen supply, a part of the $Fe(OH)_3$ was reduced. We supsect, that the O_2 present in the system does not allow the reducing substances to reduce the $Fe(OH)_3$ so it makes favorable condition for mineralisation.

Our experience is that the O_2 quantity needed for effective mineralisation of the bank filtered water collected from the Danube between the 1600 – 1800 km part of the river is 10 – 30 times more than is need for the oxidation of the Fe-Mn.

Experiments for mineralisation with O_2 and O_3

Though it is not economical in industry we tried O_2 and O_3 saturating both in supplying water and in the aquifer. The effect was more significant and the increase was proportional to the partial pressure difference.

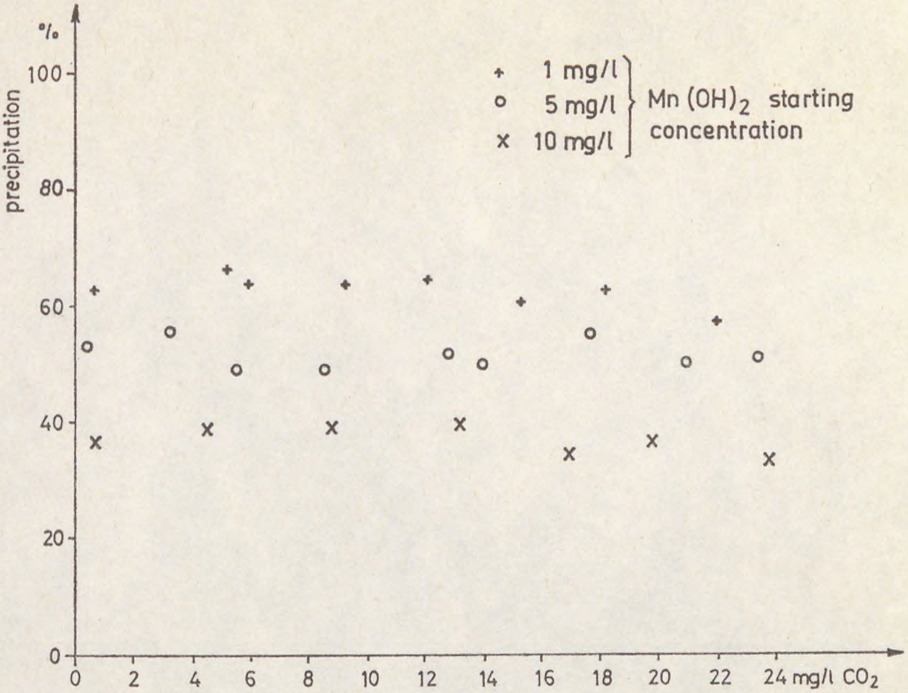


Fig. 14. Relation between the dissolved CO_2 and the degree of precipitation by different concentration of $Mn(OH)_2$

At the same time we observed that the oxidants oxidised the oxidisable substances first and mineralisation occured only after that. It must be stated however that the concentration needed for mineralisation is bactericide.

Mineralisation with the help of $KMnO_4$ and $KClO_4$

The precipitate formation effect of the strong oxidants are well-known, but it is still a question however that adding them in excess the promote mineralisation.

Experiments gave the same results as written in former but some further difficulties arose.

The quality of water was significantly worse if they were added in excess; if less than needed were added to solution the $MnO(OH)_2$ formed from the $KMnO_4$ was reduced by the remained reducing agents, so in certain experiments Mn content was higher at the end than it was at the begining.

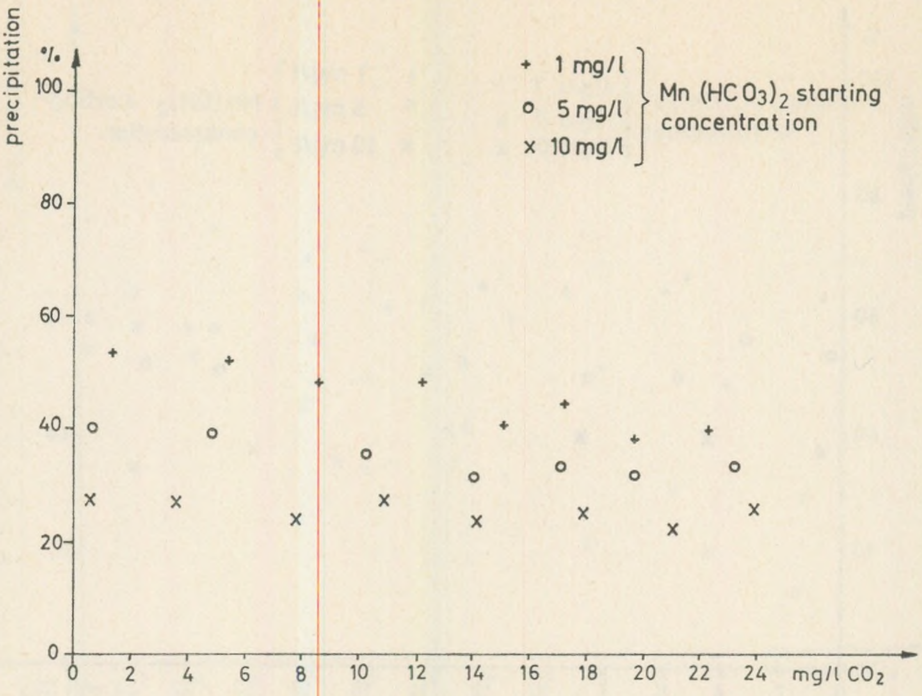


Fig. 15. Relation between the dissolved CO_2 and the degree of precipitation by different concentration of $Mn(HCO_3)_2$

The ion exchange effect of the clay minerals retards and makes uncertain the reactions. Despite the fact written in literature we have not observed any adsorptive catalysis with the sludge fractions obtained from the home aquifers.

Bacterial effect proved to be the most important in the precipitation of the Fe-Mn. In accordance with the theory we observed that the optimal circumstances of bacterial action is not identical to that of the chemical reaction.

Both the redox potential and the pH is optimal for the bacterial action at a lower value than for the chemical reaction. Luckily in the natural conditions these valves stand spontaneously, the pH range is 6,5 – 7,2 and cca. 2 mg/l O_2 at +10 °C. There was a significant difference between the action of the chemolitotrophe and chemoorganotrophe bacteria in their need of CO_2.

The long term result of the in situ elimination of Mn-Fe depends on the mineralisation of the precipitate.

The spontaneous mineralisation was not proved to be significant. The factors helping the oxidative precipitation made the mineralisation process faster. Though mineralisation is not always accompanied by redox process, we think that the role of the oxidation is that it ceases the reductive and though the remobilisation of facts.

Mineralisation for bacterial effect

Looking into the transmission microscope one can often see hexagonal sheets, cristals of hematite with the diameter of 5 – 100 μm in the body of the bacteria. In 100 – 200 times magnification cristals of goethit and lepidokrokite can be identified, so though mineralisation takes places in fact in the body of the bacteria. Minerals of Mn could not be seen. This mineralisation realises only the irreversible precipitation but the decrease of volume does not take places till the bacterium is alive.

Microbiology can hardly answer the question that how dehydration not accompained with the change of redox potential fits into the live functions of the bacteria.

The possibility of remobilisation was investigated for case of decase of bacteria. The bacteria containing limonite and hematite were deceased by heat treatment then anaerob fermenting was made in the same circumstances as were in the investigation of the need of biochemical oxygen. The hematite and limonite was not decomposited after 5 days of treatment, the $Fe(OH)_3$ being on the surface of the body the bacteria was reduced quantitatively and went into solution.

It may suspected that the hematite and limonite cristallised in an inorganic mineralisation process outside the body of the bacterium, and got into the body after that process. We tried to decide the question experimentally, but this was not succesfull.

The motion of the bacteria is realised only in layer circumstances but the process cannot be investigated in this way. In the circumstances of our investigations bacteria decreased or suspended their biochemical actions and often deceased. Because of the above mentioned the question cannot be decided and there is no data for it in the literature either.

Mineralising chemically the cristals growing are not idiomorf comparing to those in the body of the bacteria, so the effect of mineralisation can be assigned to bacteria.

Investigation of the choking the aquifer

The precipitate at the in situ elimination of the Mn-Fe decreases the water permeability of the layer.

That is a question of practice and economy that how fast this decrease is and how fast it exceeds the decrease of water output due to colmatation and any other not very well-known factors.

Significant output of water was not observed at water works having been working for a long time (cca. 10 – 15 years), therefore literature does not deal with this problem.

On conferences dealing with the subject quite different data are mentioned, the relative decrease of pore size is between 0,1 – 5%.

The decrease of pore size has only an indirect effect on the water production, so we have not dealt with problem. The decrease of water permeability is considered to be more important, so further experiments were made on this subject.

Periodic draining producting mode (subterra-system)

The so-called oxidation court where the water saturated with air fills the pore space in the draining period is a more or less well defined space. The Fe-Mn precipitate is formed in this space.

It can be assumed from our experiments that choking is mostly occured the cylinder jacket of the oxidation coat, but this space is quite large so significant choking cannot be occured in their space. In our model tub 40% of the precipitate can be found in the outer 10% of the oxidation court. The other 60% is of equal distribution of weight, and decreasing by volume towards the centrum of the well, because the mineralisation effect of the O_2 filled water is stronger around the well. The specific volume of the partially mineralised precipitate is 1/6 of that in the outer side of the oxidation coart.

Continous production in the production well and continous draining in the distinct draining wells (Vyredox method)

It is difficult to define the oxidation coat in a series of draining wells being in a circle because of the depression effect of the central production well. This was observed concerning the position of the Fe-Mn precipitate.

Out of the zone of the draining wells (3 – 4 wells in a line) there was no formation of precipitate in normal industrial production.

Most of the precipitate (70%) was formed at the contact surface of the drained water and the water streaming from the aquifer to the well. The form of this surface depended on the number of the draining wells. In the case of 3 – 4 wells the sheaves met only at the producting well, in the case of 8 or more the shape of the surface was nearer to a cylinder shape. Mineralisation is only significance in the neighbourhood of the draining wells.

According to this the autocolmatation destructs the water permeability at the most important place, and though the pouring of the drained water and the streaming ground water. Our experience was that the pouring zone became more and more nearer to the production well.

Vertical probes taken with a narrow glass tube were used for our experiments and using the glass tube as a permeabymeter permeability were measured at a constant water pressure. In the following washing the material through a 0,125 mm sieve the precipitate were separated and specific gravity and Mn content measurements were made.

The time of measurements were decreased by increasing the values of some experimental factors, eg. the hydraulic unity gradient was raised from the industrial value of 0,01 – 0,1 to 1. As a consequence of this the results could not be extrapolated to industrial sizes and gave only a tendency.

Investigation of choking in aquifers of different grain size.

In our experiments out lined there was a great importance of grain size therefore the speed of choking was also investigated. As it could be suspected the permeability decreased greaty paralell to the grain size. In industrial processes with the decelerating of chemicals of streaming and of other processes the choking process also declerates so the total effects are equalised. As mineralisation hardly takes in an aquifer filled with fine grain substances a long-lasting inpermeability most be taken into account.

Summary

The chemical technological aimed experiments proved the reaction processes known from the theories in aqueous media, but quite different results were obtained in the sandy-gravel equifers that are similar to the real aquifers. It can be stated generally that reaction times has increased, and with decreasing grain size and though permeability the time needed has increased greatly. This qualitative change sometime has ment quantitative change as well, because the cycle time of the in situ elimination of manganese and iron reaction took place partly or not at all.

The results of the processes influenced by numerous natural factors has a certain deviation the rate of deviation changed depending on the reaction types in aqueous or sandy media. Eg. the deviation of results obtained in the CO_3-HCO_3-system had of greater deviation in aqueous than in sandy media, and with the pH the situation was opposite.

The humin acid bond or protecting colloid could not be oxidised water saturated with O_2, the gasous O_2 or O_3 partially and the latter fully could oxidise.

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ENGINEERING-GEOLOGICAL CONDITION OF GÖDÖLLŐ HILLS

by

P. SCHAREK

(Absract of doctoral thesis accepted by Eötvös University, Budapest)

The Gödöllő Hills are situated on the northern margin of the Great Hungarian Plain, about 20 km east of Budapest. There are two loess covered ranges of NW-SE direction with 250 – 300 m altitude. The ranges are divided by steep valleys of young brooks (Szilas, Rákos, Tápió) and separated by fluviatile sediments of Galga river (NE) and the Danube (SW). The old Pleistocene Danube terrasses can be found in the south-western range.

This thesis is the first summary of the engineering geological conditions of the said territory based on the method of regional mapping of scale 1 : 200 000 developed in the Hungarian Geological Survey.

413 boreholes were drilled with depths ranging from 10 to 40 m in the W – E and N – S sections sampled the typical superficial formations of our vast map of about 1500 sq kms. These samples of Upper Oligocene-Holocene age were analysed to know their sedimentological, paleontological and physical characteristics.

The results are summarized on 15 map-sheets of the above scale. These are as follows:

- Boring grid
- Surface geology
- Thickness and structural sketch of the Quaternary formations
- Lithological columns of the 10 m-deep boreholes
- Lithology at 2 m below the surface
- Lithology at 5 m below the surface
- Lithology at 10 m below the surface
- Hydrostatic level of the ground-water table
- Position of the ground-water table above the sea level
- Mineralization of ground-water
- Engineering-geological rayons
- $CaCO_3$ content in the subsoil (0,4 – 0,5 m depth)
- Permeability of the surface layer at 0, – 0,5 m depth
- Depth of the best aquifer within the uppermost 300 m
- Mineral resources and important artesian wells

Continouos fluviatile sedimentation of NW–SE extension is traceable from the Upper Pliocene. Weathering starting at the beginning of the Pleistocene – a process controlling the contraction of the original pre-Pleistocene formations – exposed Upper Oligocene sediments in the NW part of Gödöllő Hills. The uplifting has taken place in step-like belts of SW–NE while the two ranges developed under the influence of revived NW–SE faults and the erosion of the two rivers and the Tápió creek in the middle. The process of the erosion can be traced in their sediments and micromineralogical content.

The engineering-geological map-sheets show the lithology of the uppermost 10 m layer and the locaton or mineralogical content of the groundwater as well. The engineering geological areas (rayons) were formed by similar lithology and soil-mechanical conditions.

We could find quantitative relation between the main soil-mechanical parameters (plasticity, consistency, porosity, impregnation, frictional degree, compressibility, cohesion and compressive strength) for the characterization of the most frequent layers on the surface (Upper Pliocene silts and clays, Pleistocene loess and fluviatile sands).

We demonstrated the alteration of plasticity due to the diagenesis, influenced by the clay-mineral-varieties, structure and quantity of $CaCO_3$.

Finally we could explain the annual quantitative alteration of the ground-water level by the variation of three climatic factors:

Annual precipitation (collected every hydrological year – lst November 31st October)

Precipitation in winter (November–March)

Mean temperature in summer (May–September) (in inverse proportion).

INDEX

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