*Acta Mineralogica-Petrographica, Szeged, XXVIII, 75—93, 1986*

# K/AR DATING OF POST-SARMATIAN ALKALI BASALTIC ROCKS IN HUNGARY

KADOSA BALOGH[1], E. ÁRVA-SÓS and Z. PÉCSKAY
Institute of Nuclear Research, Hungarian Academy of Sciences

L. RAVASZ-BARANYAI[2]
Hungarian Geological Institute

## ABSTRACT

The systematic K/Ar chronologic study of post-Sarmatian alkali basaltic rocks in Hungary started in 1978. Since then about 250 determinations were carried out on samples representing the majority of occurrences. This work enabled us to establish a numerical time scale for the evolution of basaltic volcanic activity and to estimate the absolute ages of biostratigraphic units.

In order to discover the possible disagreement of radiometric and geologic ages, which are caused by incomplete degassing, presence of xenolites and radiogenic argon loss, the isochron methods were used on cogenetic rocks and/or on fractions of different magnetic susceptibility and/or density of a single piece of basalt.

The oldest basalts erupted in the Lower Pannonian* in the Danube—Tisza Interfluve Region. Their ages fall in the range of 8.1—10.4 Ma. The indicated age for the Lower-Upper Pannonian boundary is a bit younger than 8 Ma but due to the absence of basalts in the lower part of Upper Pannonian, this age estimation is uncertain.

In Transdanubia, in the Balaton Highland, Bakony Mts. and Little Plain the oldest basaltic rocks are tuffs in the $Pa_2^1$ *(Congeria ungulacaprae)* level, these are unsuitable for dating. The oldest eruptive basalts are 5.5—6.0 Ma old, these are in a stratigraphically undefined position. Most of the basalts are younger than 5 Ma and volcanism terminated about 3 Ma ago. The age of boundary between the $Pa_2^2$ *(Congeria balatonica)* and $Pa_2^3$ *(Unio wetzleri)* levels changes in space. The deposition of $Pa_2^3$ sediments started 4.5 Ma ago (or even earlier) in certain areas and in other places the end of the $Pa_2^2$ level is younger than 4 Ma.

At the village of Bár (southeastern part of Transdanubia) jumillite overlies early Pleistocene red clay. Its age is 2.17±0.17 Ma. This shows that deposition of sediments, classed traditionally as Pleistocene in Hungary, started prior to 1.8 Ma.

In North-Hungary, around town Salgótarján, basalts are 2.0—2.5 Ma old. Since they lie on eroded Oligocene and Miocene surfaces, their K/Ar data can not be related to the age of Pliocene-Pleistocene boundary.

* *The term Pannonian is used in this paper in sensu lato.*

## INTRODUCTION

In the Carpathian-basin intermediate and acid volcanic activity of calc-alkalic type started in the Lower Miocene and continued until the Lower Pannonian. This was followed in the Lower Pannonians, due to the change of structural environment, by an alkali basic volcanism producing volcanic material both of Atlantic and Mediterranean types. The basic volcanic process lasted till the Pleistocene.

In the Danube — Tisza Interfluve Region Lower Pannonian basalts are known from deep drillings; jumillite occurs on the right bank of Danube, south of town Mohács, near village Bár, which according to the traditional stratigraphy is classed

[1] H—4026 Debrecen, Bem tér 18/C, Hungary
[2] H—1442 Budapest, Népstadion út 14, Hungary

as Early Pleistocene. Basaltic rocks in the Balaton Highland, southern part of Bakony Mountains and Little Plain are among the layers or on the eroded surface of Upper Pannonian sediments. Around the town of Salgótarján on Hungarian territory basaltic rocks lay discordantly on eroded Oligocene and Miocene surfaces. Thus, their radiometric ages lack chronostratigraphic importance and indicate merely the time of volcanic activity.

This paper treats first of all the chronologic interpretation of K/Ar data measured in the Institute of Nuclear Research of the Hungarian Academy of Sciences. As for the stratigraphic and partly petrologic and geochemical data used in this work, the corresponding geological literature is cited. Results of accomplished petrographic investigations indispensable for the evaluation and interpretation of radiometric ages are briefly summarized, too.

Chronologic relations of the Lower Pannonian basalt reached by borehole Sárospatak — 10 (K/Ar age: 9.4 ± 0.5 Ma) have been discussed elsewhere (Balogh, Kadosa, *et al.*, 1983b). In the Little Plain Lower Pannonian basaltic rocks were reached by boreholes Pásztori—1 and 4 and described by Balázs and Nusszer (1982). The scarcity of available datable material and the extremely high gas content of this rocks prevented a reliable K/Ar study up to now.

Experimental methods, instruments and treatment of measured data are published elsewhere (Balogh, K., Mórik, Gy., 1978, 1979; Molnár, J. *et. al.*, 1980; Balogh, K., 1985). Atomic constants suggested by the Subcommission on Geochronology of IUGS have been used for calculating K/Ar ages (Steiger, R. H., Jäger, E., 1977).

## CHARACTERISTICS AND ORIGIN OF YOUNG BASALTIC MAGMAS

Parallel to the radiometric age determinations, petrographic examinations were made minimum on two thin sections per samples of the dated rock types. Essential mineralogical-petrographical characteristics are summarized in Table 1. Based on the results of earlier researches published by numerous authors as well as on recent observations, conclusions mentioned below can be drawn.

It appears that the young basaltic magmas have been originated from a depth of the spinel-lherzolite pressure regime or from a source, below it. This basic volcanic series comprises rock types of alkali basalts, differentiation products as trachyte and trachybasalt, nepheline basanites and leucite — rich varieties. The two latter highly alkaline as well as youngest members of the series represent two different magma provinces: atlantic and mediterranean.

The spinel-lherzolitic relation from a source below the subcontinental crust of 40—80 km depth is demonstrated by the common xenoliths of the basaltic tuffs (Embey-Isztin, A., 1984) and by xenoliths and xenocrysts of the analysed rock samples (Table 1 and 2). It seems, that the K/Ar ages of the samples have not been influenced significantly by the xenoliths present in varying amount in the basaltic rocks.

According to our up-to-date knowledge, alkali basalts and trachytic derivatives outpoured over voluminous tuffaceous accumulations during the Lower Pannonian are found in the region of Little Plain, at Sárospatak and in the area of the Danube — Tisza Interfluve Region, covered by thick, younger Pannonian basin deposits. In the area of the Little Plain the trachyte and trachytic agglomerates are underlying the trachybasalt flows and are crossed by trachybasalt dikes of younger eruptions (Balázs, E., Nusszer, A., 1982).

| Locality | Rock name | Texture | Phenocrysts | | | | Groundmass | | | | | | | | | Cavity-filling minerals | | Secondary minerals | | | | | Remarks | Xenoliths |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | olivine | pyroxene | plagioclase | kaersutite | olivine | pyroxene | katophorite? | plagioclase | pot. feldspar | nepheline | zeolite | glass | opaque min. | zeolite | calcite | chlorite | iddingsite | serpentine | chlorite montmor. | carbonates | | |
| NE-Hungary | | | | | | | | | | | | | | | | | | | | | | | | |
| Sárospatak—10 | b | int | x | o | s | | x | x | | x | m | | o | | □ | | | | | | o | | 2. 3. 4 | ch. |
| Duna—Tisza Interfluve | | | | | | | | | | | | | | | | | | | | | | | | |
| Kiskunhalas-Ny-3. 1162. 0—1167.0 | b | int | | | | | | x | | x | | | o | x | ★ | o | o | | | | x | x | 1 | |
| Ruzsa—4 2657.0—2666. Om | b | hya-int | (o) | | | | ? | ? | | x | | | x | x | ★ | x | | o | | | x | | | |
| Kecel—1 1432.0—1434.0 | b | hya-int | (o) | o | x | | (o) | o | | x | | | | x | ★ | | | | | | x | o | 2 | |
| Balaton Highland Bakony Mts., Little Plain | | | | | | | | | | | | | | | | | | | | | | | | |
| Mencshely, Ragonya börc | b | int | x | x | | s | x | x | | x | | | o | | ● | | | | x | | | | 1. 2 | di, co, sp, ka, qu |
| Barnag, Kőhegy | b | int | x | s | | s | x | x | | x | | | o | | ● | | | | x | | | | 1. 2 | di, ch, sk, li |
| Zánka, Hegyestő | b | int | x | s | | | o | x | | x | | | o | | ● | | | | | | | | 1. 2 | di, qu |
| Tihany, monk's caves | tr | sub | x | x | | | | x | x | x | m | o | | | ★ | | | o | o | | | x | 1 | di, qu, ph, sa |
| Várkesző—1. 71.5—76.5 | b | hya | x | s | | | o | x | | x | | | | x | ● | | | | | | | | 2 | |
| Monostorapáti—1 120.8—122.4 m | b | int | x | o | | | o | x | | x | | | o | | ● | | | o | | | | o | 1 | sp, co, en, di, sk |
| Malomsok—1. 40.0—46.5 m | b | sub | x | | | | x | x | | x | | | | | □ | | | o | o | | | | 1 | |
| Malomsok—2. 54.7—58.1 m | b | sub | | | | | x | x | | x | m | | | | □ | | | | x | | | | 1 | |
| Kab-hill | b | sub | x | | | | x | x | | x | m | | | | □ | | | | x | | | | 2. 3 | |
| Kab-hill II | b | sub | x | | | | x | x | | x | | | | | □ | | | | x | | | | 2 | |
| Kab-hill III | b | sub | x | | | | x | x | | x | | | | | □ | | | | x | | o | | 2 | |
| Kab-hill, toward Öcs village | b | intg | x | | | | x | x | | x | | | | | □ | | | | x | | | | 2 | |
| Kab-hill, TV-transmitter | b | intg | x | | | | x | x | | x | | | | | ★ | | | | o | | | | 2 | |
| Tálod | b | sub | x | | | | o | x | | x | m | | | | □ | | | | o | | | | 2. 3 | |
| Ság-hill | b | intg | x | | | | o | x | | x | m | | | | □ | | | | o | | | | 1. 3 | |
| Ság-hill, basalt underlain by tuff | b | int | x | | | | (o) | x | | x | | | | | □ | | | | | o | o | | 1. 3 | |
| Ság-hill | b | sub | x | | | | o | x | | x | | | | | □ | | | | o | | | | 1. 3 | |
| Vigándpetend—1. 7.5 m | b | intg | x | | | | x | x | | x | m | | | | □ | | | | o | | | | 1 | |
| Rábaszentandrás—1. 56.4—58.5 m | b | sub | | | | | x | x | | x | m | | | | □ | | | | x | | | | 1 | |
| Marcaltő—1. 51.8—60.5 m | b | sub | | | | | x | x | | x | m | | | | □ | | | | x | | | | 1 | |
| Pula—1. 144.0—147.0 m | b | int | x | s | | | o | x | | x | | | | x | ● | o | o | | | | | | 2 | sa |
| Pula—8. 51.5—55.0 m | b | int | x | s | | | o | x | | x | | | | x | ● | | o | | | | | | 2 | di, ch |
| Pula—14. 30.3—34.0 m | b | int | x | s | | | o | x | | x | | | | x | ● | | o | | | | | | 1. 2 | |
| Kapolcs—1. 0.3—9.0 m | b | hya | x | o | | | o | x | | x | | | | x | □ | | o | | | | | | 1 | qu |
| Kapolcs—1. 45.0—50.0 m | b | int | x | s | | | o | x | | x | m | | | | ● | | | | | | | | 1 | co |
| 70.0—75.0 m | b | int | x | s | | | s | x | | x | | | | | ● | | | | | | | | 1 | |
| 85.0—91.0 m | b | int | x | s | | | o | x | | x | | | | | ● | | | | | | | | 1 | sp+ch+en ka+sp |
| Kissomlyó | b | int | o | x | | | o | x | | x | | | o | | ★ | o | | | | | | | 1 | di |
| Várkesző—4. 94.5 m | b | int | x | s | | | | x | | x | | | | x | ● | | x | | | | o | | 1 | |
| Sátorma | b | int | x | | | | o | x | | x | | | | | ● | | | | | | | | 1 | ch+sp, qu |
| Diszel, Délkő | b | int | x | s | | | o | x | | x | | | o | x | ● | | o | | | | | | 1 | |

| Locality | Rock name | Texture | Phenocrysts: olivine | Phenocrysts: pyroxene | Phenocrysts: plagioclase | Phenocrysts: kaersutite | Groundmass: olivine | Groundmass: pyroxene | Groundmass: katophorite? | Groundmass: plagioclase | Groundmass: pot. feldspar | Groundmass: nepheline | Groundmass: zeolite | Groundmass: glass | opaque min. | Cavity-filling minerals: zeolite | Cavity-filling minerals: calcite | Cavity-filling minerals: chlorite | Secondary minerals: iddingsite | Secondary minerals: serpentine | Secondary minerals: chlorite montmor. | Secondary minerals: carbonates | Remarks | Xenoliths |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Badacsony | b | intg | x | | | | x | x | | x | m | m | o | | ★ | | | | o | | | | 1 | |
| Uzsa-quarry, lower part | b | int | x | s | | | x | x | | x | | | o | | ★ | | | | | | | | 1 | di |
| Uzsa-quarry, upper part | b | int | x | s | | | x | x | | x | m | | x | m | ★ | x | | | | | o | | 1. 3 | |
| Doba—3. 47.0—48.9 m | b | int | x | s | | | o | x | | x | m | | o | | □ | | | | o | | o | | 1 | |
| Doba—3. 71.0—72.0 m | b | int | x | s | | | x | x | | x | m | | o | | □ | | | | o | | o | | 1 | |
| Doba—3. 115.0—116.0 m | b | int | x | s | | | o | x | | x | | | | o | □ | | o | | o | | | | 1. 2 | |
| Somló | b | int | x | s | | | x | x | s | x | | | o | | ★ | | | | | | x | | 1 | |
| Bazsi, quarry | b | sub | | | | | x | x | | x | m | | o | | ★ | | | | x | o | | | 1 | ba |
| Sümegprága | b | int | x | | s | | x | x | | x | | | o | x | □ | | | | | | | | 1 | sa |
| Felsődörgicse, Sárkút | b | int | x | x | | | o | x | | x | | | o | | ● | | | | | | | | 2 | |
| Mencshely, Halomhegy | b | int | x | o | | | o | x | s | x | | | o | | ● | | | | | | | | 1 | di |
| Zalaszántó Kovácsi hills | b | sub | x | s | | | o | x | s | x | m | | o | | □ | | | | | | | | 1. 3 | |
| Várkesző—3. 26.5—33.0 m | b | int | x | o | | | o | x | | x | | | | x | ● | | o | | | | o | | 1 | |
| Monostorapáti—1 39.7—41.0 m | b | int | x | s | | | x | x | | x | | | | | ● | | | | o | | | | 2 | sp+ch, sk sp+en+di |
| Hegyesd | b | hya | x | x | | | o | x | | x | | | | x | ● | | | | | | | | 1. 2 | |
| Fekete-hill | b | int | x | | | | o | x | s | x | | | o | | ★ | | | | | | o | | 1. 3 | di+ch |
| Szt. György hill | b | intg | x | s | | | x | x | | x | m | | o | | □ | | | | | | o | | 1 | |
| Zalahaláp | b | intg | x | s | | | o | x | | x | | | | | ● | | | | | | | | 2 | co, di |
| Agártető | b | intg | x | o | | | o | x | | x | | | | | □ | | | | x | | | | 2 | |
| Mindszentkálla, Kopasz hill | b | int | (x) | o | | | (o) | x | | x | | | o | | ● | o | o | | | | | | 2 | sp, di, qu |
| Salgótarján area | | | | | | | | | | | | | | | | | | | | | | | | |
| Somoskőújfalu | bas. | int | x | o | | (o) | o | x | | x | | x | o | | ● | | | | | | o | | 1. 2 | ol+di-au+ +ka+sp |
| Somoskőújfalu | bas. | int | x | x | | (o) | x | x | | x | | o | x | | ● | | | | | | | | 1. 2 | |
| Somoskőújfalu, quarry | bas. | int. | o | x | | (o) | o | x | | x | | x | x | | ● | | | | | | o | | 1. 2 | |
| Somoskőújfalu, Eresztvény | bas. | int | o | x | | (o) | o | x | | x | | x | o | | ● | o | | | | | o | | 1. 2 | ch+co, di+ +sp, di+ +ol+ch+sp |
| Medves, Magyarbánya | bas. | int | x | x | | | o | x | s | x | | x | o | | ● | | | | | | | | 1. 2 | ch+co |
| Medves, Középbánya | bas. | int. | o | x | | (o) | o | x | | x | | o | o | | ● | | | | | | | | 1. 2 | ch, sp |

x main constituents
o constituents 10%
m minor constituents
s sporadic
(o) pseudomorphs
□ ilmenite
★ titanomagnetite
● magnetite-titano-magnetite
∗ titanohematite

Rock names
b basalt
tr trachybasalt bomb in tuff
bas basanite

Spinel: mostly picotite
Basalt: uniformly alkali basalt
remarks 1. titanoaugite
2. augite, diopsidic augite
3. minor amount of biotite in the groundmass
4. accessory picotite

texture
int intersertal
hya hyalopilitic
sub subophitic
intg intergranular

Xenoliths
ch chromite
sp spinel
di diopside
co corundum
ka kaersutite
sk skarn
li limestone
pk phyllite
sa sandstone
en enstatite
ba basalt
ol olivine
qu quartz

TABLE 2

*Texture and mineral constituents of jumillite at Bár*

| Locality | Texture | Olivine | Pyroxene | Kaersutite | Katophorite | Biotite | Sanidine-anorthoclase | Leucite | Analcime | Opaque minerals | Cavity filling -zeolites | Secondary minerals | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | Iddingsite | Serpentine |
| Bár—4. 18.0 m | porphyritic-poikilitic | x | x | (o) | | s | x | x | o | ★ | | o | |
| 26.0 m | porphyritic-poikilitic | x | x | (o) | o | s | x | x | x | * | | o | |
| Bár—6. 62.0 m | poikilitic | x | x | (o) | | o | x | x | o | ★ | | o | |
| 67.0 m | poikilitic | x | x | o | | o | x | x | x | ★ | s | | o |

Based on petrographic examinations it can be supposed that the common bombs of trachybasaltic dike rocks found in the Upper Pannonian basaltic tuff at Tihany represent wallrock material of the trachybasalts of earlier volcanic episode. Thus the Lower Pannonian basaltic volcanism seems to be detected in an area of greater expansion in Transdanubia.

Upper Pannonian alkali basalts (some of them are near to the basanites in composition) are outcropping in NW Transdanubia, basanites are occurring in the area of Salgótarján (N-Hungary) while early Pleistocene peralkaline rock type (jumillite) was discovered by drillings at a shallow depth, at Bár (S-Hungary).

The Upper Pannonian alkali basalts of the Transdanubian area (Balaton Highland, Bakony Mts., Little Plain) partly are outcropping overlying Pannonian basin deposits as remnant hills, partly are covered by Pleistocene loess (locally by Upper Pannonian sedimentary rocks) and one part was eroded. Volcanism is supposed to be represented probably by three repeated episodes, each of which can be characterized by a period of higher activity producing pyroclastics in the beginning while during the period of decaying shields, flows, dikes were formed. As a result of gravitational differentiation, lavas of lower setting are enriched in olivine.

The area, characterized by unnumbered young as well as renewed faults and representing a series of sediments with high number of local varieties, makes difficulties regarding determination of relative age of the members of repeated volcanic episodes on stratigraphic base. Petrographic examinations are also proved inadequate for the clear isolation of the roughly contemporaneous basalts due likely to differentiation and fractionation of the magma. Products of the same volcanic episode are represented by members rich in volatiles and poor in olivine followed later by olivin rich lavas poorer in volatiles and free of xenoliths and xenocrysts due to slow upward transit and fusion during the ascent. The latter magma type has been crystallized also undersurface, intruding into the beds of the Upper Pannonian sedimentary rocks.

The youngest volcanic products of Hungary erupted near the Pannonian-Pleistocene boundary are highly alkaline varieties. In the area of Salgótarján nepheline bearing basanites are outcropping enclosing numerous xenoliths and xenocrysts, the same, found in the alkali basalts in Transdanubia. On the contrary, in the southern part of Hungary at Bár, the undersurface basaltic rocks represent a type of high

K-content, product of a Mediterranean magma type. These rocks can hardly be classified (T. SZEDERKÉNYI, 1980), it seems best to be related to the rare jumillite of Spain. Xenoliths of spinel-lherzolitic origine are not observable.

Summarizing, products of the Lower Pannonian volcanic action are widespread within the Hungarian basin while basaltic rocks of the Upper Pannonian volcanic episodes are not yet discovered in the SE part of the country, probably this area devoids of younger Pannonian volcanic phenomenon. Regarding the activity of the volcanic episodes, it can be stated that it seems to be much more explosive during the Lower Pannonian represented by vast pyroclastic accumulations comparing to the Upper Pannonian, the latter can be marked by the growing importance of basaltic flows. Most of the authors publishing data of the Lower Pannonian volcanic rocks agree with the supposition of a clear genetic relation to the magma type of the Upper Pannonian volcanic action. BALÁZS (BALÁZS, E., NUSSZER, A., 1982) regards the trachytic rocks as derivatives of the basaltic magma.

In general, basaltic magmas tend to be more undersaturated with passage of time and also the continental character of the rock types becomes more pronounced by the end of the Pannonian. A chemical diversity can be observed, too, regarding the youngest products as it is well shown in *Fig. 1*. $Na_2O/K_2O$ versus $Na_2O+K_2O$ values available from the literature (GYARMATI, P., 1977, BALÁZS, E., NUSSZER, A., 1982, JUGOVICS, L., 1976) are plotted in MIYASHIRO's (1975) diagramm *(Fig. 1)*.

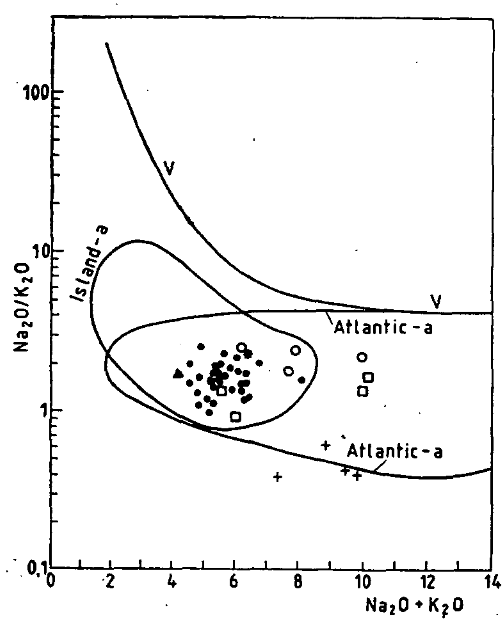



*Fig. 1.* V—V: upper limit of $Na_2O/K_2O$ for all fresh volcanic rocks; Island-a: field of relatively common volcanic rocks in island arcs
Atlantic-a: alkalic rocks on Atlantic islands (except for Island)

▲ Sárospatak
✱ Danube—Tisza Interfluve Region — alkali basalts
● Balaton Highland, Bakony Mts., Little Plain
□ Little Plain, trachyte and trachybasalt dikes
○ Salgótarján area, basanites
\+ Bár, Jumillite

Comparing the basaltic rock types to the ocean-island alkali magma types of similar composition, it can be noticed that against the alignment, basaltic rocks under consideration have a distinct continental character with $K_2O/Na_2O$ between 0,4—0,8 included also the trachytic varieties but excepted the jumillite at Bár, the latter characterized by a value about 2.2. It is also worth to notice that the Ba content of the jumillite is unusually high: 2000 ppm (L. RAVASZ-BARANYAI, 1979). Rock types in the area of the Danube — Tisza Interfluve Region and at Sárospatak are represented by the lower values, between 0.4—0.6

Based on the above data, the basanites in the Salgótarján area can be drawn directly from the alkali basaltic source material while the peralkaline jumillite may represent a source of petrochemically different composition. Considering also the trachytic varieties limited to the NW zone of the country, it appears that the subcontinental crust has not been uniformed within the Hungarian basin during the Pannonian This heterogeneity of the subcontinental crust, or probably of the mantle, could yield to the diversed evolution of magma types in the NE and in the SW zones of Hungary, i. e. the country can be divided into two main structural units from a point of view of volcano-tectonism, regarding the past 10 Ma.

## LOWER PANNONIAN BASALTS IN THE DANUBE—TISZA INTERFLUVE REGION

Lower Pannonian basaltic rocks have been found by hydrocarbon exploratory boreholes in the Danube — Tisza Interfluve Region *(Fig. 2)* and were described first by B. CSEREPES-MESZÉNA (1978). Their petrographic investigation and stratigraphic classification were accomplished by A. NUSSZER (BALÁZS, E., NUSSZER, A., 1982) and M. SZÉLES (In: CSEREPES-MESZÉNA, B., 1978), respectively. A greater number of basalt occurrences have been described by S. PAP (1983).

The basalts are syngenetically altered and rocks penetrated by boreholes Kecel — 1 and Kiskunhalas — Ny — 3 are among sediments belonging to the middle-upper part of the Lower Pannonian. The position of basalts in boreholes Kecel—2 and Ruzsa —4 can not be specified within the Lower Pannonian.

K/Ar ages are summarized in Table 3. The data contribute to the age estimation of Lower Pannonian, since only a limited number of radiometric ages are available from this substage on the territory of the Paratethys.

Out of the dated rocks, the sample coming from borehole Ruzsa — 4 is the most altered. Its relatively old age supports the syngenetic character of alteration and shows that this rock did not lose a considerable amount of excess argon after its cooling down. K/Ar ages on basalts from boreholes Kecel — 1-2 agree within the limits of experimental arrors indicating the similarity of their real ages within the Lower Pannonian. This age is more reliable since it is obtained on samples of different K content; tus, the time given by the K/Ar data falls in the Lower Pannonian substage.

The age of $9.61 \pm 0.38$ Ma on basalt from borehole Kiskunhalas — Ny — 3 is the most reliable since it is measured on different sample franctions. In the light of this datum and the stratigraphic position an age younger than 11.0 Ma for the Sarmatian/Pannonian boundary is highly unlikely. For the age estimation of Lower-Upper Pannonian boundary the $9.61 \pm 0.38$ Ma datum, being older, is less suitable than the ages measured on samples from boreholes at Kecel. In borehole Kiskunhalas-Ny-3, basalt is covered by Lower Pannonian sediments in the depth of 523—1120 m, thus its age does not conflict with the younger data measured for basalts at Kecel which are covered with Lower Pannonian sediments with thicknesses of about 200 m.

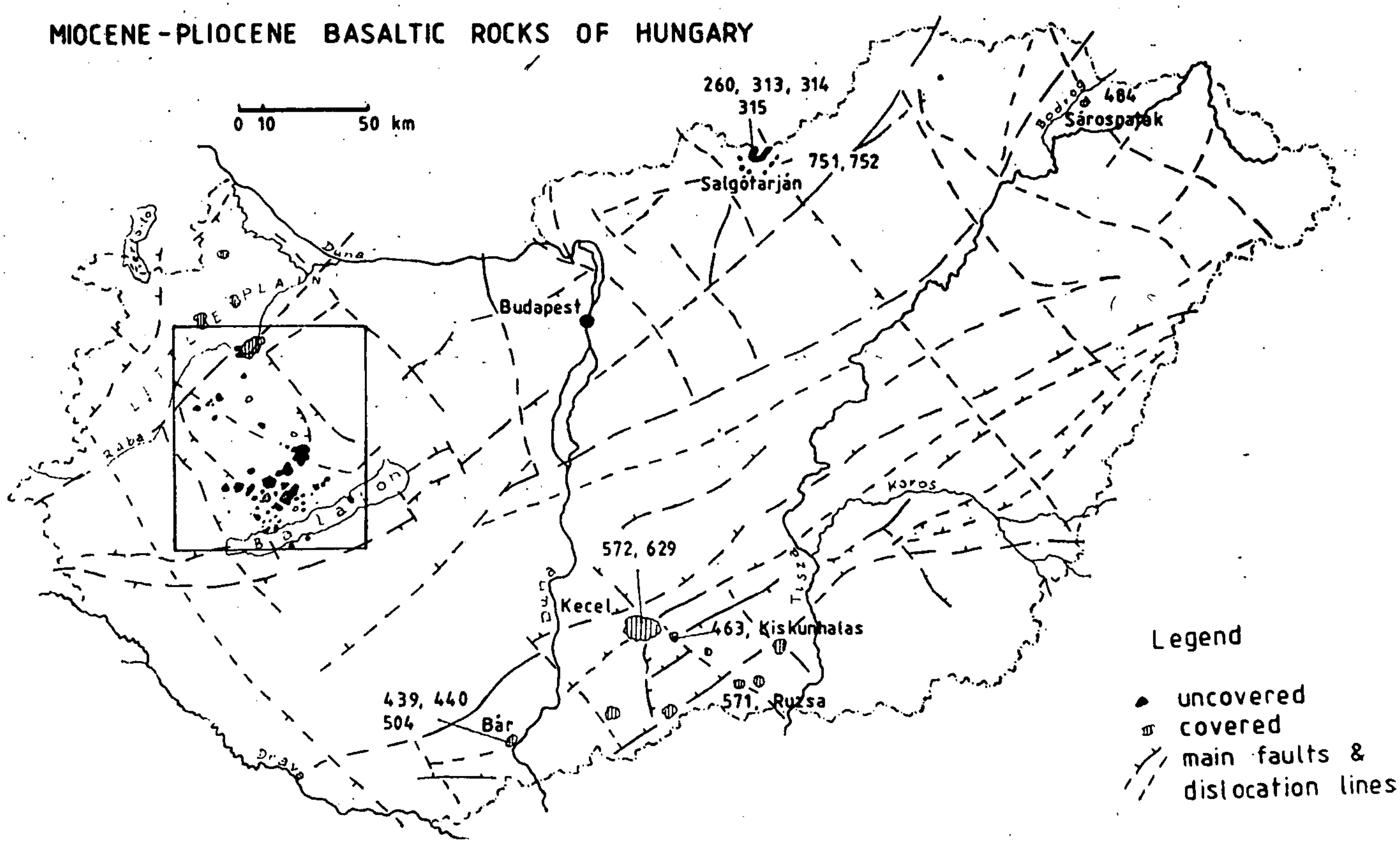



*Fig. 2.* Locality of post-Sarmatian alkali basaltic rocks in Hungary

TABLE 3.

*K/Ar age of Lower Pannonian basaltic rocks from deep-drillings, Danube-Tisza Interfluve area, Hungary*

| No. | Locality<br>Dated fraction | K<br>% | $^{40}Ar_{rad}$<br>% | $10^{-7} \cdot \frac{ccSTP}{g}$ | Age<br>Ma | Stratigraphy |
|---|---|---|---|---|---|---|
| 572 | Bh: Kecel—1. 1432—1434 m | | | | | |
| | 1. w. r. | 0.77 | 13 | 2.548 | 8.50±0.94 | Lower |
| | | | 13 | 2.533 | 8.47±0.77 | Pannonian |
| | | | | | 8.34±0.94 | |
| 629 | Bh: Kecel—2. 1426—1426,5 m | | | | | |
| | 1. w. r. | 1.22 | 13 | 3.863 | 8.13±0.71 | Uncertain |
| 463 | Bh: Kiskunhalas-Ny—3<br>1162—1167 m | | | | | |
| | 1. w. r. | 1.98 | 24 | 7.205 | 9.35±0.68 | Middle-Upper part |
| | 2. dnI | 2.12 | 22 | 8.065 | 9.77±0.71 | of Lower Pannonia |
| | | | | | 9.61±0.38 | |
| | 3. dnII | 1.71 | 25 | 6.447 | 9.68±0.58 | |
| 571 | Bh: Ruzsa—4. 2657—2666 m | | | | | |
| | 1. w. r. | 0.68 | 7.8 | 2.753 | 10.4±1.8 | Uncertain |

w. r.: whole rock

dnI, dnII: fraction separated by heavy liquid, numbered in the order of increasing density

The basaltic remnant hills in the Balaton Highland, the southern part of the Bakony Mountains and the Little Plain attracted the attention of geologists in the first part of the last century. The first works synthetizing the knowledge on the basalts had been prepared in the frame of a project organized by L. Lóczy, having as its aim the scientific study of Lake Balaton and its envidonments (Vitális, I., 1908, Lóczy, L., 1913). Locations of the dated rocks are shown in *Fig. 3.*

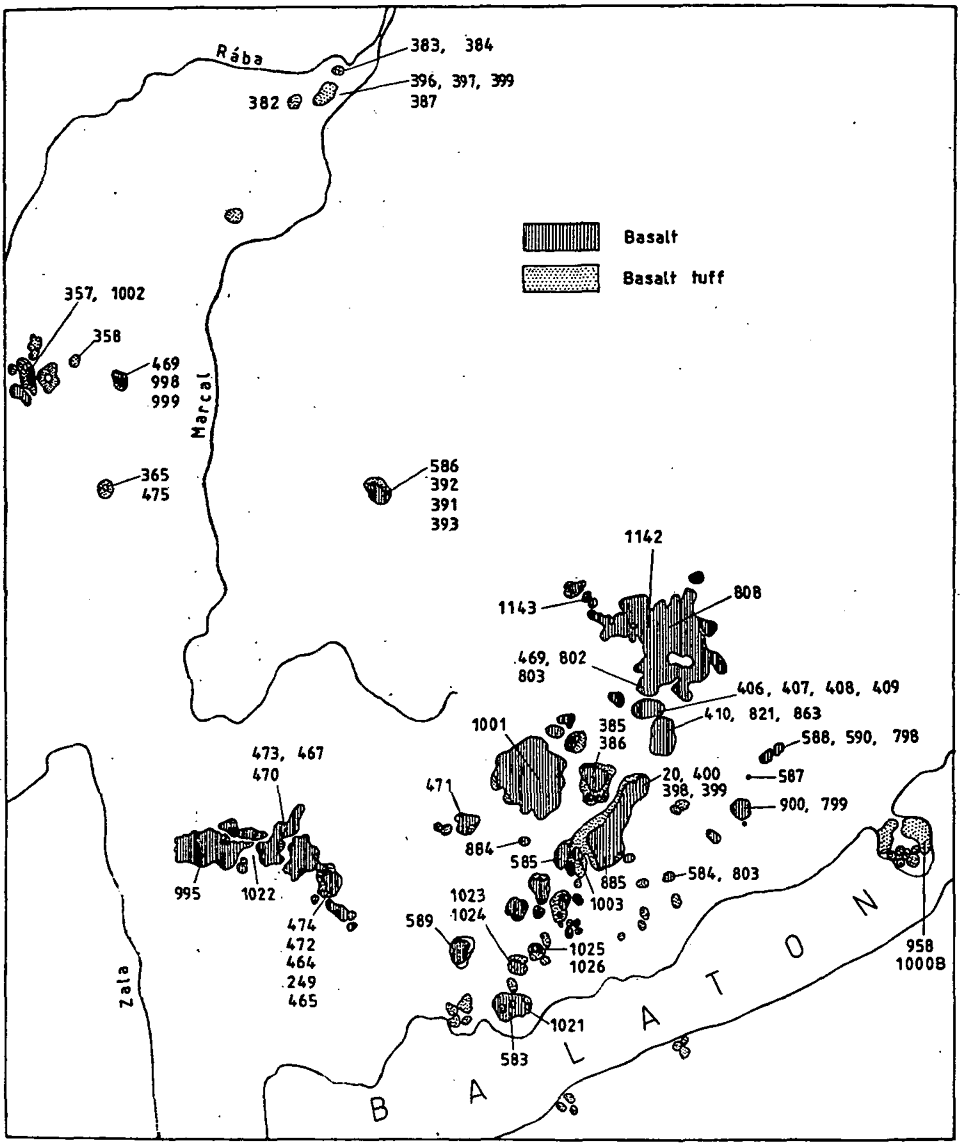



*Fig. 3.* Locality of post-Sarmatian alkali basaltic rocks in the Balaton Highland, Bakony Mts. and Little Plain. (After Jugovics, L., 1969)

In the last decades a great number of papers have been published dealing with petrologic and geochemical features (VOGL, M., 1979, 1980; PANTÓ, GY., 1981; NAGY, G. 1983; RAVASZ, CS., 1976; KULCSÁR, L., GUZY-SOMOGYI, A., 1962; JUGOVICS, L. 1976; SZÁDECZKY-KARDOSS, E., ERDÉLYI, J., 1957; VICZIÁN, I., 1965; SZEDERKÉNYI, T., 1980) stratigraphic and tectonic position (EMBEY-ISZTIN, A., 1981; JUGOVICS, L., 1969, 1971a, 1971b, 1972; JÁMBOR, Á., SOLTI, G., 1976; JÁMBOR, Á., *et. al.*, 1981; VÖRÖS, I., 1966; BARTHA, F., 1959.) paleomagnetism (MÁRTON, P., SZALAY, E., 1968) and the economic importance (BENCE, G., *et. al.*, 1979) of basaltic rocks in this region. These papers were relying on more modern methods of research which were applied also to cores of deep drillings. Instead of reviewing the present knowledge on the basalts, the summarizing work by A. JÁMBOR (1980) is recommended.

This paper discusses first of all the reliability and geologic meaning of radiometric data. Chronostratigraphic consequences of K/Ar dating are also described and still existing problems, where geologic and K/Ar results disagree, are emphasized.

The systematic radiometric dating of Transdanubian basalts started in 1977, but only a minor part of results has been published up to now (JÁMBOR, Á., *et. al.*, 1980; BALOGH, K., *et. al.*, 1983.). This work comprises all the data measured in cooperation between the Hungarian Geological Institute and Hungarian Hydrocarbon Institute before 1985. Results obtained on basaltic rocks in the Tapolca-basin in the frame of a joint project with the Department of Geography, Lajos Kossuth University, Debrecen, will be published elsewhere and are only shortly reviewed here.

K/Ar ages are shown in Table 4. $^{40}Ar/^{36}Ar$-$K/^{36}Ar$ and $^{40}Ar_{rad}$-K isochron ages are marked with $I_1$ and $I_2$, respectively. The number of samples and/or fractions used for fitting the straight line is indicated in brackets; a number alone denotes all the measured fractions of the relevant sample. Fractions are numbered in the order of increasing magnetic susceptibility and density. Isochron diagrams are shown in the Appendix.

In the territory of the Balaton Highland, the South—Bakony and the Little Plain, neglecting pyroclastics, the basalt hills Kőhegy near the village of Barnag and Hegyestő between Zánka and Monoszló are the oldest. 4 fractions of sample No. 798 and additionally 2 whole rock samples were used for defining isochron ages for Kőhegy. There is a good agreement between the $I_1$ and $I_2$ ages ($5.69 \pm 0.31$ Ma and $5.67 \pm 1.5$ Ma, respectively). K content of fraction 798/2 greatly differs from that of the other fractions; this increases the reliablility of isochron ages. The intercept with y axis indicates complete degassing during solidification. The lack of excess. argon is an additional argument for the geological acceptability of measured ages

Excess argon has been found in the basalt of Hegyestő, therefore isochron ages ($I_1 = 5.97 \pm 0.41$ Ma and $I_2 = 5.49 \pm 1.5$ Ma) are less convincing than those of Kőhegy, in spite of the considerably different K content in fraction No. 803/2. The similarity of isochron ages of Kőhegy and Hegyestő is an additional reason to accept them as geologic ages. Positive magnetic polarity has been measured on the basalt of Hegyestő (MÁRTON, P., SZALAY, E., 1968) thus the $5.57 \pm 5.77$ magnetic polarity zone (MANKINEN, E. A., DALRYMPLE, G. B., 1979) is the most likely time of basalt eruption.

An anomalously old age has been obtained in the basalt neck "Ragonya" at the village of Mencshely ($I_1 = 7.92 \pm 0.33$ Ma). Incomplete degassing is frequent in case of a neck and the K content is nearly the same in its fractions. Therefore, the fitted line is regarded as "mixing line" and the defined age is only a maximum value. On the basis of its strongly eroded character and occurrence along a common line with Kőhegy and Hegyestő, this rock is believed to belong to the oldest basalts in the Balaton Highland.

All these oldest basalts are volcanic necks, the lava flown originally in the surface is fully eroded by now. Their petrographic similarity supports the assumption of a common age.

In Transdanubia, basaltic volcanic activity started with tuff eruptions (unfortunately, tuffs are mostly unsuitable for dating), thus the ages measured on Kőhegy and Hegyestő have to be regarded younger than the commencement of volcanic activity.

Ages of rock samples and their fractions collected from Halomhegy between the villages of Mencshely and Dörgicse (No. 900, 799) are in a good agreement. The $I_1$ age of 3.26±0.16 Ma shows likely the real time of basalt eruption and excludes the possibility of older volcanic activity.

A small basalt outcrop is known at Sárkút, south of Halomhegy. The $I_1$ age of 3.61±9.52 Ma should be regarded as maximum age, since the K content of the fractions is very similar. It is clear, however, that this rock is likely coeval with Halomhegy, thus the $I_1$ value is a real geologic age. We can not decide whether the outcrop is a remnant of an eroded neck or one that slided down from Halomhegy.

The basalt tuff at Tihany is among the layers of the *Congeria balatonica* level (JÁMBOR, Á., 1980). Thus, its absolute age would have a great chronostratigraphic importance. Dating has been attempted on basalt bombs and blocks with very modest results. Part of the fractions contains excess argon and the K contents are very similar. The fitted line is probably a mixing line, thus the formal $I_1$ age of 7.56±0.50 M is an older limit of the geological age. Since considerable amount of excess argon has been detected in a lherzolite bomb of mantle origin, a fraction of smaller density has been separated from sample No. 1000B in which less contaminating material of mantle origin has been expected. This fraction appeared to be a little younger (7.35±0.65 Ma) but its age did not differ significantly from the ages of fractions No. 958/2—3. Thin section investigations of these samples offered an alternative possibility for the explanation of too old ages. According to their textures the trachybasalt samples are of dike origin, similar to those cut by boreholes at Pásztori, and were torn off and transported to the surface by the basalt tuff eruption. In this case the closure age of dated basalt may be significantly older than the tuff eruption.

The basalt at Tálod-forest is represented by samples from boreholes Vigántpetend — 1 and Put — 2 (No. 410, 821) and by No. 863 collected from the surface. This rock is coeval with the youngest basalt of Kabhegy, and according to Á. JÁMBOR (1980) it is a detached part of it. Both are underlain by the Kabhegy red clay, which covers the Nagyvázsony fresh water limestone under the Tálod-forest. The youngest basalt of Kabhegy has been dated on samples collected from the surface at the television tower and on the slope of the hill toward the village of Öcs. Regarding the stratigraphic importance, repeated, detailed age determination were carried out on these samples. Out of 25 dated fractions, excess argon has been detected in N. 813/2 and 821/2 and argon loss can be supposed from No. 802/2. All these are the least magnetic fractions in which xenolites may accumulate and argon loss may have been caused, too, by weathering. More reasons support the reality of K/Ar ages obtained on these occurrences. A great number of samples, collected from different locations yielded the same age, there is a great difference in the K content of the dated fractions and, according to the intercepts, the basalt degassed completely during its cooling down. A small density fraction (No. 863/4) has been dated, too, and its age is in accordance with that of the other fractions. The K/Ar dating supports the opinion that these basalts are of the same age (JÁMBOR, Á., 1980), but conflicts with the view which regards them as the youngest products of basaltic volcanic activity in the Balaton Highland and Bakony Mountains (JÁMBOR, Á., *et. al.,* 1981). No K/Ar da-

| No. | Sample locality | Dated fraction | K % | $^{40}Ar_{rad}$ % | $10^{-7}\cdot\frac{ccSTP}{g}$ | $\frac{^{40}Ar}{^{36}Ar}$ | $\frac{K/^{36}Ar\ \%}{\left(\frac{ccSTP}{g}\right)}\times10^{-9}$ | K/Ar Age Ma | |
|---|---|---|---|---|---|---|---|---|---|
| 587a | Mencshely, Ragonya | 1. w. r. | 1.15 | 53 | 3.470 | | | 7.75±0.50 | |
| 587b | Mencshely, Ragonya | 1. w. r. | 1.12 | 21 | 3.06 | 374.1 | 0.284 | 7.02±0.60 | $I_1$(587): |
| | | 2. mgI | 1.12 | 51 | 3.383 | 603.1 | 1.018 | 7.36±0.50 | 7.92±0.33 |
| | | 3. mgII | 1.18 | 44 | 3.375 | 527.1 | 0.811 | 7.76±0.50 | |
| 588 | Barnag, Kőhegy, Northern slope | 1. w. r. | 0.79 | 14 | 1.789 | 343.6 | 0.212 | 5.82±0.63 | $I_1$(588+590+798): 5.69±0.31 |
| 590 | Barnag, W of Kőhegy little outcrop | 1. w. r. | 0.91 | 12 | 2.283 | 335.8 | 0.161 | 6.45±0.53 | |
| 798 | Barnag, Kőhegy | 1. w. r. | 0.828 | 33 | 1.933 | 441.0 | 0.623 | 6.00±0.39 | $I_2$(588+590+798): |
| | | 2. mgI | 0.377 | 6.6 | 0.919 | 316.4 | 0.086 | 6.27±1.30 | 5.67±1.50 |
| | | 3. mgII | 0.750 | 18 | 1.842 | 360.4 | 0.246 | 6.31±0.57 | |
| | | 4. mgIII | 0.894 | 41 | 1.955 | 500.8 | 0.939 | 5.62±0.35 | |
| 584 | Hegyestő, between Zánka and Monoszló | 1. w. r. | 2.05 | 67 | 6.310 | 895.5 | 1.949 | 7.91±0.51 | |
| 803 | Hegyestő, between Zánka and Monoszló | 1. w. r. | 2.09 | 61 | 5.475 | 757.7 | 1.764 | 6.74±0.35 | $I_1$(803): |
| | | 2. mgI | 0.613 | 27 | 2.427 | 404.8 | 0.276 | 10.20±0.60 | 5.97±0.41 |
| | | 3. mgII | 2.01 | 53 | 4.869 | 628.7 | 1.376 | 6.23±0.35 | $I_2$(803): |
| | | 4. mgIII | 2.26 | 65 | 5.891 | 844.3 | 2.105 | 6.70±0.30 | 5.49±1.59 |
| 900 | Mencshely, Halomhegy | 1. w. r. | 1.89 | 48 | 2.384 | 568.3 | 2.163 | 3.25±0.15 | |
| | | 2. mgI | 1.48 | 50 | 1.873 | 591.0 | 2.335 | 3.26±0.15 | |
| | | 3. mgII | 1.57 | 45 | 2.115 | 537.3 | 1.795 | 3.47±0.16 | |
| 799 | Mencshely, Halomhegy | 1. w. r. | 1.89 | 26 | 2.535 | 399.3 | 0.775 | 3.45±0.22 | $I_1$(799+800): |
| | | 2. mgI | 1.31 | 13 | 1.805 | 339.7 | 0.320 | 3.55±0.39 | 3.26±0.13 |
| | | 3. mgII | 1.96 | 19 | 2.713 | 364.8 | 0.501 | 3.56±0.27 | |
| 1004 | Felső Dörgicse, Sárkút | 1. w. r. | 0.98 | 37 | 1.367 | 469.0 | 1.244 | 3.59±0.18 | $I_1$(1004): |
| | | 2. mgI | 0.796 | 13 | 1.109 | 339.7 | 0.317 | 3.58±0.24 | 3.61±0.52 |
| | | 3. mgII | 0.99 | 23 | 1.555 | 383.7 | 0.562 | 4.04±0.27 | |
| 958 | Tihany, hermits' caves basalt bomb | 1. w. r. | 1.79 | 52 | 5.852 | 615.6 | 0.979 | 8.40±0.36 | |
| | | 2. mgI | 1.84 | 36 | 5.524 | 461.7 | 0.554 | 7.72±0.38 | |
| | | 3. mgII | 1.87 | 65 | 5.428 | 844.3 | 1.891 | 7.46±0.30 | |
| 1000B | Tihany, hermits' caves basalt block | 1. w. r. | 1.75 | 25 | 5.796 | 395.0 | 0.297 | 8.51±0.45 | $I_1$(958+1000B/1—3) |
| | | 2. mgI | 1.53 | 19 | 5.797 | 364.8 | 0.183 | 9.73±0.75 | 7.56±0.50 |
| | | 3. mgII | 1.76 | 20 | 5.686 | 369.4 | 0.229 | 8.30±0.61 | |
| | | 4. dnI | 1.79 | 17 | 5.120 | 356.0 | 0.211 | 7.35±0.65 | |
| 410a | Bh: Vigántpetend—1. 7.5 m | 1. w. r. | 1.33 | 70 | 2.594 | 385.0 | 3.535 | 5.02±0.30 | $I_1$(410a): |
| | | 2. mgI | 1.16 | 67 | 2.204 | 895.5 | 3.158 | 4.88±0.25 | 4.68±0.87 |
| | | 3. mgII | 1.81 | 74 | 3.395 | 1136.5 | 4.484 | 4.82±0.20 | $I_2$(410a): 4.69±0.60 |
| 410b | Bh: Vigántpetend—1. 7.5 m | 1. w. r. | 1.48 | 35 | 2.838 | 454.6 | 0.830 | 4.93±0.24 | $I_1$(410b): |
| | | 2. w. r. | 1.48 | 38 | 2.766 | 476.6 | 0.969 | 4.81±0.23 | 4.89±0.20 |
| | | 3. mgI | 1.12 | 34 | 2.082 | 447.7 | 0.819 | 4.78±0.24 | $I_2$(410b): |
| | | 4. mgII | 1.53 | 84 | 2.909 | 1846.9 | 8.160 | 4.89±0.20 | 5.05±0.64 |
| | | 5. mgIII | 1.79 | 49 | 3.386 | 579.4 | 1.501 | 4.87±0.20 | |
| 821 | Bh: Put — 2. 3.0 —7.3 m | 1. w. r. | 1.39 | 19 | 2.717 | 364.8 | 0.355 | 5.03±0.39 | $I_1$(821):5.01±0.68 |
| | | 2. mgI | 0.67 | 29 | 1.485 | 416.2 | 0.544 | 5.70±0.31 | $I_2$(821):4.52±0.39 |
| | | 3. mgII | 1.69 | 53 | 3.286 | 628.7 | 1.714 | 5.00±0.23 | $I_1$(821+863/1—3): 4.84±0.28 |
| 863 | Forest at Tálod, II | 1. w. r. | 1.43 | 51 | 2.816 | 603.1 | 1.562 | 5.06±0.22 | $I_2$(821+863/1—3): |
| | | 2. mgI | 1.03 | 51 | 1.854 | 603.1 | 1.709 | 4.97±0.20 | 4.65±0.72 |
| | | 3. mgII | 1.53 | 66 | 2.959 | 869.1 | 2.966 | 4.63±0.20 | $I_1$(863/1—3): 5.09±1.07 |
| | | 4. dnI | 1.63 | 29 | 2.901 | 416.2 | 0.679 | 4.58±0.30 | $I_2$(863/1—3): 5.87±0.78 |
| 469 | Kabhegy, slope at village Öcs | 1. w. r. | 1.43 | 49 | 2.584 | 579.4 | 1.569 | 4.65±0.23 | $I_1$(469+802+803): 5.07±0.81 $I_2$(469+802+803): 4.43±0.56 |
| 802 | Kabhegy II., slope at village Öcs | 1. w. r. | 1.35 | 21 | 2.513 | 374.1 | 0.442 | 4.79±0.39 | |
| | | 2. mgI | 0,839 | 40 | 1.557 | 492.5 | 1.135 | 4.46±0.21 | $I_1$(802).4.39±0.49 |
| | | 3. mgII | 1.58 | 28 | 2.957 | 410.4 | 0.614 | 4.82±0.23 | $I_2$(802):5.23±0.58 |
| 803 | Kabhegy III., slope at village Öcs | 1. w. r. | 1.39 | 38 | 2.567 | 476.6 | 0.981 | 4.75±0.23 | $I_1$(803):4.92±1.53 |
| | | 2. mgI | 0.425 | 46 | 1.037 | 547.2 | 1.032 | 6.27±0.43 | $I_2$(803):4.38±0.31 |
| | | 3. mgII | 1.81 | 75 | 3.458 | 1182.0 | 4.640 | 4.91±0.19 | $I_1$(469+802+ +803/1,3): 4.82±0.22 $I_2$(469+802+ +803/1.3): 5.23±0.35 |
| 808 | Kabhegy, at the television tower | 1. w. r. | 1.60 | 55 | 2.961 | 656.7 | 1.952 | 4.76±0.20 | $I_1$(808):4.73±0.46 |
| | | 2. mgI | 1.10 | 36 | 2.050 | 461.7 | 0.892 | 4.79±0.27 | $I_2$(808):4.79±0.64 |
| | | 3. mgII | 1.81 | 43 | 3.385 | 518.4 | 1.192 | 4.81±0.22 | |
| 1142 | Kabhegy, lowest lava flow | 1. w. r. | 1.36 | 18 | 2.647 | | | 5.01±0.40 | |
| 1143 | Ajka-Padragkut basalt ring | 1. w. r. | 0.96 | 15 | 1.923 | | | 5.14±0.50 | |
| 408 | Bh: Pula—1. 40.0—40.5 m | 1. w. r. | 1.88 | 34 | 3·093 | 447.7 | 0.925 | 4.23±0.32 | $I_1$(408+406+409+ +407):4.25±0.17 |
| 406 | Bh: Pula—1. 144.5—147.0 m | 1. w. r. | 1.86 | 8 | 2.831 | 321.2 | 0.169 | 3.92±0.96 | |
| 409 | Bh: Pula—8. 51.5—55.0 m | 1. w. r. | 2.03 | 46 | 3.379 | 547.2 | 1.512 | 4.28±0.26 | |
| 407 | Bh: Pula—14. 30.3—34.0 m | 1. w. r. | 1.61 | 50 | 2.599 | 591.0 | 1.831 | 4.16±0.27 | |
| 20 | Bh: Kapolcs—1. 0.3—9.0 m | 1. w. r. | 2.11 | 52 | 3.137 | | | 3.82±0.17 | |
| | | 2. mgI | 1.95 | 37 | 3.116 | | | 4.11±0.20 | |
| | | 3. mgII | 2.05 | 34 | 3.257 | | | 4.09±0.21 | |
| 400a | Bh: Kapolcs—1. 45.0—50.0 m | 1. w. r. | 1.23 | 32 | 1.833 | | | 3.94±0.35 | |
| 400b | Bh: Kapolcs—1. 45.0—50.0 m | 1. w. r. | 1.16 | 21 | 1.934 | 374.1 | 0.471 | 4.29±0.30 | |
| | | 2. w. r. | 1.16 | 31 | 2.014 | 428.3 | 0.765 | 4.47±0.24 | |
| | | 3. mgI | 0.96 | 25 | 2.212 | 394.0 | 0.427 | 5.92±0.36 | |
| | | 4. mgII | 1.25 | 32 | 1.858 | 434.6 | 0.936 | 3.82±0.20 | |
| 398 | Bh: Kapolcs—1. 70.0—75.0 m | 1. w. r. | 0.75 | 34 | 1.263 | 447.7 | 0.904 | 4.33±0.44 | |
| 399a | Bh: Kapolcs—1. 85.0—91.0 m | 1. w. r. | 0.98 | 56 | 1.758 | | | 4.62±0.34 | |
| 399b | Bh: Kapolcs—1. 85.0—91.0 m | 1. w. r. | 1.00 | 11 | 1.351 | 332.0 | 0.270 | 3.48±0.44 | $I_1$(399a, b): |
| | | 2. mgI | 0.99 | 21 | 1.716 | 374.1 | 0.453 | 4.46±0.31 | 4.66±0.36 |
| | | 3. mgII | 0.99 | 37 | 1.670 | 469.0 | 1.070 | 4.17±0.20 | |
| 385 | Bh: Monostorapáti—1. 39.7—41.0 m | 1. w. r. | 0.60 | 20 | 0.674 | | | 2.90±0.62 | |
| 386a | Bh: Monostorapáti—1. 120.8—122.4 m | 1. w. r. | 0.92 | 61 | 1.970 | | | 5.54±0.40 | |
| 386b | Bh: Monostorapáti—1. 120.8—122.4 m | 1. w. r. | 0.914 | 37 | 1.925 | 469.0 | 0.827 | 5.42±0.26 | |
| | | 2. mgI | 0.244 | 43 | 1.603 | 518.4 | 0.339 | 16.80±0.75 | |
| | | 3. mgII | 1.16 | 52 | 1.740 | 615.6 | 2.134 | 3.86±0.20 | |

| No. | Sample locality | Dated fraction | K % | $^{40}Ar_{rad}$ % | $10^{-7}\cdot\frac{ccSTP}{g}$ | $\frac{^{40}Ar}{^{36}Ar}$ | $\frac{K/^{36}Ar\ \%}{\left(\frac{ccSTP}{g}\right)}\times10^{-9}$ | K/Ar age Ma | |
|---|---|---|---|---|---|---|---|---|---|
| 1003 | Sátorma | 1. w. r. | 1.95 | 53 | 3.103 | | | 4.09±0.18 | |
| | | 2. mgI | 1.80 | 53 | 3.170 | | | 4.53±0.20 | |
| | | 3. mgII | 1·87 | 51 | 3.112 | | | 4.27±0.18 | |
| 585a | Diszel, Hajagos Délkő quarry | 1. w. r. | 1.85 | 35 | 2.837 | 454.5 | 1.038 | 3.95±0.20 | |
| 585b | Diszel, Hajagos Délkő quarry | 1. w. r. | 1.79 | 47 | 2.837 | 557.5 | 1.653 | 4.08±0.18 | $I_1$(585b): |
| | | 2. mgI | 1.63 | 59 | 2.522 | 720.7 | 2.748 | 3.98±0.17 | 3.94±0.25 |
| | | 3. mgII | 1.96 | 57 | 2.956 | 687.2 | 2.597 | 3.88±0.18 | |
| 1001 | Agártető | 1. w. r. | 1.60 | 27 | 1.855 | | | 2.98±0.18 | |
| | | 2. mgI | 1.47 | 29 | 1.966 | | | 3.44±0.19 | |
| | | 3. mgII | 1.58 | 26 | 1.783 | | | 2.90±0.18 | |
| 471 | Haláp | 1. w. r. | 1.77 | 18 | 1.845 | | | 2.70±0.36 | $T_a$(471): |
| | | 2. w. r. | 1.77 | 12 | 2.170 | | | 3.16±0.37 | 2.94±0.34 |
| 884 | Hegyesd | 1. w. r. | 2.04 | 23 | 2.650 | 383.8 | 0.679 | 3.43±0.22 | $I_1$(884):2.92±0.40 |
| | | 2. mgI | 0.55 | 9.6 | 1.020 | 326.9 | 0.169 | 4.77±0.72 | $I_2$(884):3.08±0.58 |
| | | 3. mgII | 2.38 | 19 | 3.417 | 364.8 | 0.482 | 3.70±0.28 | |
| 885 | Feketehegy Kővágóörs basin | 1. w.r. | 1.51 | 18 | 1.715 | 360.4 | 0.571 | 2.92±0.24 | |
| | | 2. mgI | 1.31 | 23 | 1.342 | 383.8 | 0.862 | 2.64±0.18 | |
| | | 3. mgII | 1.39 | 18 | 1.473 | 360.4 | 0.604 | 2.77±0.23 | |
| 1023 | Gulács, NW of the top, 50 m H: 370 m | 1. w. r. | 1.88 | 45 | 2.535 | | | 3.47±0.18 | |
| 1024 | Gulács, Northern quarry trapp basalt, H: 220 m | 1. w. r. | 1.96 | 40 | 2.800 | | | 3.68±0.20 | |
| 1025 | Tóti-hegy, southern end of the southern peak | 1. w. r. | 0.94 | 35 | 2.184 | 454.6 | 0.685 | 5.71±0.29 | |
| | | 2. mgI | 0.96 | 19 | 1.681 | 364.8 | 0.396 | 4.51±0.35 | |
| | | 3. mgII | 1.01 | 17 | 1·644 | 356.0 | 0.372 | 4.19±0.36 | |
| 1026 | Tóti-hegy, northern peak | 1. w. r. | 1.67 | 6.9 | 3.296 | 317.4 | 0.111 | 5.07±1.10 | |
| | | 2. mgI | 1.55 | 6 | 2.610 | 314.4 | 0.112 | 4.33±1.12 | |
| | | 3. mgII | 1.59 | 7.3 | 2.981 | 318.8 | 0.124 | 4.82±0.82 | |
| 583 | Badacsony, block field at Rózsakő | 1. w. r. | 2.12 | 46 | 2.817 | 347.2 | 1.894 | 3.42±0.20 | $I_1$(583):3.45±0.23 |
| | | 2. mgI | 1.60 | 22 | 2.229 | 378.8 | 0.598 | 3.58±0.24 | |
| | | 3. mgII | 1.94 | 39 | 2.738 | 484.4 | 1.338 | 3.63±0.20 | |
| 1021 | Badacsony, quarry at Tördemic, southern court, lower level, H: 315 m | 1. w. r. | 1.91 | 30 | 2.663 | | | 3.59±0.20 | |
| 474 | Uzsa-quarry | 1. w. r. | 2.03 | 18 | 2.986 | 360.4 | 0.441 | 4.06±0.34 | |
| 472 | Uzsa-quarry | 1. w. r. | 2.05 | 24 | 2.725 | 388.8 | 0.702 | 3.42±0.25 | $I_1$(474+472+464+ +249+465a): |
| 464 | Uzsa-quarry | 1. w. r. | 1.15 | 3.4 | 1.916 | 305.9 | 0.062 | 4.29±2.56 | 3.41±0.84 |
| 249 | Uzsa-quarry | 1. w. r. | 1.87 | 15 | 3.508 | 356.0 | 0.346 | 4.82±0.66 | |
| 465a | Uzsa-quarry | 1. w. r. | 2.07 | 17 | 3.622 | 356.0 | 0.346 | 4.50±0.64 | $I_2$(465a, b): 4.25±0.59 |
| 465b | Uzsa-quarry | 2. mgI | 1.43 | 13 | 2.284 | 339.7 | 0.276 | 4.11±0.45 | |
| | | 3. mgII | 1.92 | 27 | 3.165 | 404.8 | 0.663 | 4.24±0.25 | |
| 473 | Sümegprága, quarry | 1. w. r. | 2.38 | 33 | 2.869 | 441.0 | 1.207 | 3.10±0.20 | $I_1$(473+467+470a): 2.79±0.29 |
| 467 | Sümegprága, quarry | 1. w. r. | 2.82 | 19 | 3.853 | 364.8 | 0.507 | 3.52±0.41 | |
| 470a | Bazsi, quarry | 1. w. r. | 1.63 | 15 | 2.463 | 347.6 | 0.345 | 3.39±0.63 | |
| 470b | Bazsi, quarry | 2. mgI | 1.17 | 13 | 1.877 | 339.4 | 0.275 | 4.12±0.45 | $I_2$(470a, b): |
| | | 3. mgII | 1.42 | 11 | 2.174 | 332.0 | 0.239 | 3.94±0.50 | 3.27±1.70 |
| 995 | Kovácsi-hegy, quarry | 1. w. r. | 1.67 | 17 | 2.007 | | | 3.10±0.26 | |
| | | 2. mgI | 1.73 | 18 | 1.948 | | | 2.90±0.24 | |
| | | 3. mgII | 1.63 | 16 | 2.024 | | | 3.20±0.29 | |
| 1022 | Bh: Zalaszántó—2. 56.3 m | 1. w. r. | 1.90 | 25 | 2.244 | 394.0 | 0.834 | 3.04±0.20 | |
| | | 2. mgI | 2.00 | 34 | 2.594 | 447.7 | 1.174 | 3.34±0.18 | |
| | | 3. mgII | 1.37 | 13 | 1.630 | 339.7 | 0.371 | 3.06±0.33 | |
| 586 | Somló | 1. w. r. | 1.26 | 5 | 1.720 | 316.1 | 0.114 | 3.51±0.97 | $I_1$(586+392+391): |
| 392 | Bh: Doba—3. 47.0—48.9 m | 1. w. r. | 2.35 | 37 | 2.709 | 469.0 | 1.505 | 2.97±0.20 | 2.98±0.19 |
| 391 | Bh: Doba—3. 71.0—72.2 m | 1. w. r. | 1.49 | 25 | 1.871 | 394.0 | 0.784 | 3.23±0.36 | |
| 393a | Bh: Doba—3. 115.4—115.2 m | 1. w. r. | 1.91 | 69 | 3.098 | 953.2 | 4.055 | 4.18±0.20 | |
| 393b | Bh: Doba—3. 115.4—116.2 m | 1. w. r. | 2.09 | 50 | 3.210 | 591.0 | 1.924 | 3.95±0.20 | |
| | | 2. mgI | 1.85 | 52 | 3.178 | 615.6 | 1.864 | 4.42±0.20 | |
| | | 3. mgII | 2.33 | 62 | 2.528 | 777.6 | 4.444 | 2.79±0.20 | |
| 469 | Sághegy | 1. w. r. | 1.55 | 41 | 3.099 | 500.8 | 1.027 | 45.14±0.25 | |
| 998 | Sághegy, base of the level above the lowest court | 1. w. r. | 1.46 | 21 | 3.383 | 374.1 | 0.339 | 5.96±0.42 | $I_1$(468+998+999): |
| | | 3. mgII | 1.32 | 20 | 2.768 | 369.4 | 0.352 | 5.39±0.40 | 6.27±0.58 |
| 999 | Sághegy, upper basalt | 1. w. r. | 1.43 | 60 | 3.268 | 738.8 | 1.940 | 5.87±0.24 | |
| | | 2. mgI | 1.24 | 49 | 2.754 | 579.4 | 1.278 | 5.71±0.24 | |
| | | 3. mgII | 1.24 | 63 | 3.203 | 798.6 | 1.948 | 6.64±0.28 | |
| | | 4. mgIII | 1.01 | 62 | 2.576 | 777.6 | 1.890 | 6.56±0.27 | |
| 365 | Kissomlyó, quarry | 1. w. r. | 1.78 | 54 | 3.437 | | | 4.97±0.31 | |
| 475a | Kissomlyó, quarry | 1. w. r. | 2.15 | 59 | 3.375 | 720.7 | 2.709 | 4.04±0.17 | |
| 475b | Kissomlyó, quarry | 2. mgI | 1.69 | 48 | 3.561 | 568.3 | 1.295 | 5.42±0.24 | |
| | | 3. mgII | 1.98 | 21 | 3.162 | 374.1 | 0.492 | 4.11±0.29 | |
| 358 | Névtelen-hegy, basalt bomb | 1. w. r. | 1.08 | 32 | 1.696 | | | 4.04±0.44 | |
| 357 | Sitke, Herczeghegy | 1. w. r. | 0.80 | 21 | 1.416 | 374.1 | 0.444 | 4.55±0.31 | |
| 1002 | Sitke, quarry | 1. w. r. | 1.63 | 23 | 3.554 | 383.8 | 0.405 | 5.60±0.37 | $I_1$(1002): |
| | | 2. mgI | 1.70 | 33 | 3.636 | 441.0 | 0.680 | 5.50±0.29 | 4.77±1.8 |
| | | 3. mgII | 1.74 | 25 | 4.367 | 394.0 | 0.392 | 6.45±0.40 | |
| 396 | Bh: Várkesző—3. 26.5—33.0 m | 1. w. r. | 2.09 | 63 | 2.435 | 798.6 | 4.319 | 3.00±0.17 | |
| 397 | Bh: Várkesző—1. 71.5—76.5 m | 1. w. r. | 1.79 | 61 | 3.861 | 757.7 | 2.168 | 5.55±0.26 | |
| 399 | Bh: Várkesző—4. 94.5 m | 1. w. r. | 1.00 | 51 | 1.679 | 603.7 | 1.832 | 4.32±0.31 | |
| 382 | Bh: Rábaszentandrás—1. | 1. w. r. | 1.08 | 52 | 1.956 | 615.6 | 1.768 | 4.66±0.30 | $I_1$(399+382+383+ +384+387/1): |
| 383 | Bh: Malomsok—2. 54.7—58.1 m | 1. w. r. | 1.20 | 28 | 2.502 | 410.4 | 0.551 | 5.36±0.28 | 4.25±0.32 |
| 384 | Bh: Malomsok—1. 40.0—46.5 m | 1. w. r. | 1.52 | 24 | 2.913 | 388.8 | 0.487 | 4.93±0.24 | |
| 387 | Bh: Marcaltő—1. 51.8—60.5 m | 1. w. r. | 1.44 | 43 | 2.584 | 518.4 | 1.242 | 4.63±0.33 | $I_1$(387): |
| | | 2. mgI | 0.78 | 39 | 1.555 | 447.4 | 0.764 | 5.13±0.25 | 4.15±0.32 |
| | | 3. mgII | 1.78 | 56 | 3.124 | 671.6 | 2.143 | 4.52±0.20 | |
| 439 | Bh: Bár—6. 67.0 m | 1. w. r. | 4.32 | 14 | 3.603 | 343.6 | 0.577 | 2.15±0.30 | $I_1$(439+440+504): |
| 440 | Bh: Bár—4. 18.0 m | 1. w. r. | 4.20 | 23 | 3.181 | 383.8 | 1.165 | 1.95±0.20 | 2.17±0.17 |
| 504 | Bh: Bár—6. 62.0 m | 1. w. r. | 5.17 | 42 | 4.370 | 509.5 | 2.532 | 2.18±0.20 | |
| | | 2. pot. fp. | 10.07 | 8 | 7.386 | 321.2 | 0.350 | 1.89±0.35 | |

w. r.: whole rock
mgI, mgII, mgIII: magnetically separated fraction, numbered in the order of increasing magnetic susceptibility
dnI, dnII: fraction separated by heavy liquid, numbered in the order of increasing density
pot. fp.: potash feldspar

tum indicating a younger age has been measured during this study. On the basis of arguments described above it is felt that radiometric dating is more convincing than stratigraphic classification. Therefore, the deposition of the Nagyvázsony fresh water limestone must have started earlier, at least below the basalt at the Tálod-forest, than the K/Ar age of the basalt. The magnetic polarity of basalt is reversed (MÁRTON, P., SZALAY, E., 1968), thus it can be ascribed to the 4.71—5.26 Ma paleomagnetic zone. (MANKINEN, E. A., DALRYMPLE, G. B., 1979.)

The lowest lava flow of Kabhegy has been dated on a single whole rock sample (No. 1142) and the age of $5.01 \pm 0.40$ Ma correlates well with the radiometric data measured on the youngest lava flow. The small age difference between the oldest and youngest basalts shows that volcanic activity at Kabhegy lasted for a shorter period, in spite of the red clay layer between the older and younger lava flows. According to the K/Ar dating, the basalt ring at localities Ajka and Padragkút (No. 1143) is similar in age to the oldest lava flow of Kabhegy.

The basalt near the village of Pula is in a stratigraphically well defined position (JÁMBOR, Á., 1980; JÁMBOR, Á. *et. al.*, 1981.). The solidified basalt lava pond is underlain by sediments belonging to the middle part of the Upper Pannonian substage (*Congeria balatonica* level, $Pa_2^2$) and the covering layers are characterized by *Unio wetzleri* ($Pa_2^3$). The dated samples (No. 406, 407, 408, 409) are collected from distant point of the basalt body and in the $I_1$ diagram fit a straight line well. The intercept indicates neither excess argon nor argon loss, and therefore, in spite of the relative uniformity of K contents, the $I_1$ age of $4.25 \pm 0.17$ Ma is accepted as a datum marking the end of the $Pa_2^2$ level in this area.

Borehole Kapolcs — 1, sited at Királykő hill, cut through three basalt lava flows (JÁMBOR, 1980). The sedimentary layers among them are assigned to the $Pa_2^2$ and $Pa_2^3$ levels. Two samples (No. 398, 399) have been dated from the first, oldest lava flow. $4.66 \pm 0.36$ Ma $I_1$ age has been obtained on fractions of sample No. 399 and the representative point of sample No. 398 fits this isochron, too. The intercept indicates a little argon loss which can be accepted as a consequence of repeated volcanic activity. The second lava flow (sampled by No. 400) is considered, for stratigraphic reasons (JÁMBOR, Á., 1980), to be coeval with the basalt at Pula. Unfortunately, no reliable dating could be accomplished on this rock due to the xenolites accumulating in the least magnetic fraction (No. 400b/3). In this case, the isochron methods are inapplicable since at the time of the rock formation the argon isotopic composition and the amount of excess argon in the fractions were different. When the number of dated samples is small, the representative points may fit a straight line accidentally, and this may lead to erroneous conclusions. This can be observed on fractions 400b/2—4 which defince an errorchron age of $2.19 \pm 0.58$ Ma. This "age" is caused by the excess argon content of fraction 400b/3 and it has been rejected because the intercept indicates a too high ($>350$) initial $^{40}Ar/^{36}Ar$ ratio, which is inacceptable for a lava rock. It can be observed, however, that ages measured on whole rock and on the more magnetic fractions well approximate the age of the basalt at Pula. Thus, K/Ar ages do not disprove the geological correlation.

The youngest basalt lava cut by borehole Kapolcs — 1 is represnted by sample No. 20. The unformity of K content of the fractions frustrates the application of isochron methods, but radiometric ages are in accordance with the stratigraphic position. The real age of this basalt may be younger than their K/Ar data, but this is unlikely since rocks from hills Sátorma (No. 1003) and Hajagos (No. 585) resulted in similar values. It has to be noted, however, that the youngest basalt of Királykő appears to be definitely younger than the basalts of Kabhegy and Tálod-forest.

Borehole Monostorapáti — 1 penetrated the younger (No. 385) and older (No. 386) basalts of Bondoró hill (JÁMBOR, Á., 1980). The older is unsuitable for dating. The extremely old age of fraction 386/b/2 is a joint effect of the high excess argon and low K contents. The representative points are disorderly arranged in both coordinate systems. For stratigraphical reasons this rock is also coeval with the basalt at Pula. It can be noted that geological age is best approximated by the K/Ar age of the most magnetic (No. 386b/3) fraction. The limited sample quantity allowed only one measurement on whole rock for the younger basalt. The analytical error of this datum is great ($2.90 \pm 0.62$ Ma) but the obtained age does not conflict with stratigraphic observations. As it will be seen later, the possibility of argon loss and, consequently, rejuvenation of radiometric ages, has to be frequently considered for basalts yielding K/Ar ages around 3 Ma. Since postvolcanic activity as a reason for age decrease can not be ruled out, further investigations are desirable on the basalts of Bondoró hill.

The dating of basalts at Pula, Királykő, and Bondoró hills shows that only a part of these rocks is suitable for reliable K/Ar dating. The accepted radiometric ages are in accordance with the geological model elaborated for this area (JÁMBOR, Á. 1980), but there is a disagreement between the geologic and radiometric correlation, of these basalts with the ones of Kabhegy and Tálod-forest. The basalts of the latter area are correlated according to the K/Ar ages with the oldest and on stratigraphic reasons with the youngest basalt of Királykő hill. Radiometric ages for Kabhegy and Tálod-forest are considered to be highly reliable, therefore the settling of this problem might started with the reassessment of stratigraphic arguments.

The basalts forming the hills Sátorma (No. 1003) and Hajagos (No. 585) are similar in age and K content to the youngest lava of Királykő. No fractions of different K contents could be separated from these samples. A small amount of excess argon may be present in fraction 1003/2, but in spite of this the similar K/Ar ages may be regarded as the time of basalt eruption.

Sample No. 884 was collected from the pointed basalt hill west of Hegyesd village. The age of fraction 842/2 is too old but the arrangement of representative points approximate a straight line in both isochron diagrams. The intercept indicate excess argon. There is a good agreement between the two isochron ages and on this ground this basalt is ranged among the products of the youngest (about 3 Ma old) phase of basaltic volcanic activity.

It is likely that the basalt of Haláp hill (No. 471) was also produced during this volcanic phase. This hill has been dated by only 2 whole rock samples. It has to be noted, however, that the magnetic polarity of the basalt is reversed (MÁRTON, P., SZALAY, E., 1968), which is less likely in the time interval defined by the K/Ar age and its error. It has to be admitted that K/Ar system might have been modified by postvolcanic effects and the real time of basalt eruption is similar to that of Badacsony hill, and can be in the paleomagnetic zone ending at 3.40 Ma B. P.

No isochron age can be assiganed to the fractions of basalt from Agártető (No. 1001). It is likely that this hill also belongs to the youngest volcanic rocks of the Balaton Highland.

From the Kővágóörs-basin, the hill Fekete-hegy has been dated (No. 885). Similar ages were obtained on the fractions. The distribution of K contents allowed the calculation only of the $I_1$ age. The too young value and too great error show that the fitted line is an errorchron. The arrangement of representative points makes it likely that argon was lost from fraction No. 885/2; thus, geologic age is better approximated by the ages of fractions 1 and 3. This rock is ranged among the youngest basalts of the area, too.

Two samples collected from different heights represent the basalt of Gulács hill (No. 1023, 1024). Measured ages correspond to the stratigraphic position and in view of unpublished data by BORSY *et al.* may be accepted as geological ages. The magnetic polarity of basalt is reversed (MÁRTON, P., SZALAY, E., 1968), therefore it is assigned to the 3.40—3.80 Ma zone.

Samples No. 583 and 1021 come from different points of Badacsony hill. Reliable $I_1$ age has been determined for the first sample, which is confirmed by the whole rock age of sample No. 1021. Radiometric age is in accordance with the reversed magnetic polarity (MÁRTON, P., SZALAY, E., 1968) and fixes the time of basalt eruption in the 3.40—3.80 Ma paleomagnetic zone.

Numerous, still unpublished datings were performed on the basalt hills in and around the Tapolca-basin by BORSY *et al.* The main chronologic results of this work will be only shortly reviewed here.

The oldest reliable ages are a little older than 4 Ma and these were measured on bombs from tuffs forming the hills at Szigliget. Upper Pannonian sand belonging to the *Congeria balatonica* level ($Pa_2^2$) is among the tuff layers, indicating that the deposition of this level in this area did not end prior to about 4 Ma B. P. but likely later. The Csobánc, Gulács and Várhegy hill at Fonyód have been proved to be coeval with Badacsony. The basalt dike of Várhegy at Szigliget intruded 3.3—3.4 Ma ago, so it can be a little younger than Badacsony. According to its reversed paleomagnetic polarity (MÁRTON, P., SZALAY, E., 1968) Szt. György-hill is likely also similar in age to Badacsony; several younger K/Ar ages measured on it may be brought about by postvolcanic effects which can also be detected at Szigliget and Badacsony. Due to the presence of excess argon and radiogenic argon loss, no reliable age could be determined up to now on the basalt of Tóti-hill.

The basaltic rocks of Tátika-group are mostly sills intruding among the sediments of $Pa_2^2$ level (JÁMBOR, Á., *et al.*, 1981.). The similarity of their geological ages is supported by their uniformly normal magnetic polarity (MÁRTON, P., SZALAY, E. 1968). Samples were collected from Uzsa quarry (Láz-hill), from quarries of villages Bazsi and Sümegprága, from borehole Zalaszántó — 2 and Kovácsi hill.

Unfortunately, although several samples have been measured from Láz-hill, the small radiogenic argon enrichment in the only sample of more differing K content (No. 464) frustrated the determination of $I_2$ and greater uncertainty characterizes the $I_1$ age of the 5 whole rock samples, too. ($3.41 \pm 0.84$ Ma). According to the intercept with the $^{40}Ar/^{36}Ar$ axis, the rock did not degass completely during its emplacement. The older $I_1$ age of sample No. 465 is also inaccurate. The irregular pattern of ages shows that samples contain variable amounts of excess argon and their initial $^{40}Ar/^{36}Ar$ rations were also different. Therefore, in spite of older K/Ar ages, there is no sufficient cause to regard Láz-hill as older than other members of Tátika-group. $I_1$ age defined on whole rock samples from the Uzsa quarry is accepted as best approximation of geological age. This agrees with other data obtained for the Tátika group within the limits of experimental error.

Representative points of rocks collected from the quarries at Sümegprága and Bazsi (No. 467, 470, 473) fit a straight line well and the $I_1$ age assigned to it approximates the youngest ages measured in the Balaton Highland. This age is not substantiated by the older $I_2$ age determined on the fractions of sample No. 470. The error of this last datum is likely overestimated; it arises from the too great analytical errors of the radiogenic argon contents. (The error calculated on the basis of residuals is only 0.18 Ma). Considering K/Ar data obtained on samples No. 995 and 1022, the reality of geological ages younger than 3 Ma is unconvincing. Apart from fraction 1022/2, which likely contains excess argon, the ages of samples No. 995 and 1022 agree within the limits of experimental errors and may be regarded as geological ages.

Due to the subsurface solidification, excess argon is frequent in the basalts of Tátika-group. Considering the uniformly normal magnetic polarity (MÁRTON, P., SZALAY, E., 1968) the most likely time of emplacement may be fixed in the 3.15—3.40 Ma paleomagnetic zone. (MANKINON, E. A., DALRYMPLE, G. B., 1979.).

Basalt of Somló-hill in the Little Plain has been dated with samples collected from the surface (No. 586) and taken from three different depths of borehole Doba — 3. The scatter of K/Ar data is great, but 3 whole rock samples define an $I_1$ age of $2.98 \pm \pm 0.19$ Ma. The older K/Ar age of sample No. 393 may be explained either by supposing a greater amount of excess argon in it or by accepting the geological reality of older age, though the second assumption is disfavoured for volcanologic reasons (JÁMBOR, Á., 1980). Ages measured on fractions of sample No. 393 do not fit a straight line, but the K/Ar age of fraction 3 is close to the $I_1$ age of the other three samples of Somló-hill. Older ages may be partly accounted for by the excess argon present at least in sample 393/b/2. On the other hand, radiogenic argon loss from fraction 393b/3, as a consequence of renewed volcanic activity, can not be excluded. Considering radiometric age pattern and volcanologic arguments, the $I_1$ age of $2.98 \pm 0.19$ Ma or a little older time interval may be assigned to the basalt eruption.

Seven samples selected from deep-drilling cores have been dated from the Várkesző—Malomsok basalt area. Five whole rock samples define an $I_1$ isochron of $4.25 \pm 0.32$ Ma, the reality of which is supported by the $4.15 \pm 0.34$ Ma $I_1$ age determined on fractions of greatly different K content of sample No. 387. In both cases little excess argon is indicated by the intercepts of isochrons. The basalt overlies sedimentary layers characterized by *Unio wetzleri* ($Pa_2^3$) (JÁMBOR *et al.*, 1981), thus deposition of this level, at least in this area, started prior to 4.15—4.25 Ma. In the case of samples No. 396 and 397, dating could not be extended to rock fractions due to the insufficient sample quantity available, therefore the too young and too old ages are still unexplained.

A single age has been determined on a basalt bomb from the tuff of Névtelen hill near town Celldömölk. The tuff lies on sediments belonging to the $Pa_2^3$ level (JÁMBOR, Á., *et al.*, 1981) and the age ($4.04 \pm 0.44$ Ma) is near the datum determined for the Várkesző—Malomsok area. This shows that a basalt bomb may be completely degassed, too; its K/Ar age does not necessarily surpass the geological one.

Results of repeated efforts to date Ság-hill are still unsatisfactory. The scatter of K/Ar ages convincingly points to the geological error and due to the similarity of K contents $I_1$ age may be treated only as maximum. The basalt tuff is interlayered with Upper Pannonian sediments and, therefore, the exact knowledge of its age would be of great chronostratigraphic importance. This gives incentive for further investigations.

From ages obtained for Herczeghegy on samples collected from the quarry at Sitke (No. 357, 1002), the geological age can be inferred only with limited certainty. Excess argon in present in sample No. 1002 and the error of the $I_1$ age is great. The K contents of samples No. 357 and 1002 are highly different, and therefore, the similarity of whole rock and $I_1$ ages of these samples is remarkable, but their agreement with geological age still has to be confirmed.

Two samples have been dated from the quarry of Kissomlyó. K/Ar ages indicate excess argon in fraction 475/b/2 and it is likely in sample No. 365, too. Therefore, ages of fractions 475a and 475b/3 may be tentatively related to the geological age.

South of Mohács on the right bank of the Danube at the village of Bár basaltic rock lies on Early Pleistocene red clay (HŐNIG, GY., 1971.). According to the investigations of RAVASZ-BARANYAI (JÁMBOR, Á., *et al.*, 1980), the rock is jumillite. K/Ar ages on 3 whole rock and 1 potash feldspar samples agree well with the $I_1$ age (2.17 ± ± 0.17 Ma) attributed to them and are in accordance with the stratigraphic position. Due to the high atmospheric argon content in fraction 504/2 the accuracy of the $I_2$ age is unsatisfactory.

## BASALT AREA AROUND TOWN SALGÓTARJÁN

In the vicinity of Salgótarján, basalts discordantly lie on Miocene and Oligocene surfaces. Therefore, K/Ar ages may be used to study the time relations of volcanic activity and can not be applied for deriving ages of chronostratigraphic units.

K/Ar results are summarized in Table 5. Due to the high atmospheric argon content the measurement error of 4 samples collected from the vicinity of village Somoskőújfalu (No. 260, 313, 314, 315) is great, but ages agree well within the limits of experimental errors. Representative points fit a straight line well, especially in the $I_2$ diagram. The great error of $I_2$ age (2.30 ± 0.94 Ma) arises from the errors assigned to the radiogenic argon contents. This is likely overestimated since, according to the residuals, the error of age is only 0.16 Ma.

Basalt of Medves is represented by samples No. 751 and 752. In the first of them a greater amount of excess argon has been detected. The agreement of $I_2$ ages (2.25 ± ± 0.30 Ma and 2.30 ± 0.65 Ma) with the value derived for basalts at Somoskőújfalu is remarkable.

It can be observed that representative points fit a straight line better in the $I_2$ diagram. This shows that excess argon is probably incorporated by the ground mass in a more or less uniform concentration. Paleomagnetic polarity of the basalt is reversed (MÁRTON, P., SZALAY, E., 1968) and thus the time of basalt volcanic activity can be fixed at the end of Pliocene in the 2.14—2.48 Ma paleomagnetic zone (MANKINEN, E. A., DALRYMPLE, G. B., 1979.).

In neighbouring Slovakian territory eruption of basalts started earlier and continued until the Early Pleistocene (BALOGH, K., *et al.*, 1981).

## CHRONOSTRATIGRAPHIC CONCLUSIONS

The 9.61 ± 0.38 Ma age determined on 3 fractions of sample No. 463 is accepted as geological age. Since the basalt ranges in the middle-upper part of the Lower Pannonian an age for the Sarmatian-Pannonian boundary younger than about 11.0 Ma is highly unlikely.

The average age of the youngest Lower Pannonian basalts from boreholes at Kecel (No. 572, 629) is about 8.3 ± 0.5 Ma. Supposing similar rates for the sedimentation and using the age difference between the basalts at Kiskunhalas and Kecel, an age of about 7.5—8.0 Ma might be tentatively assigned to the Lower-Upper Pannonian boundary. This conflicts with unpublished paleomagnetic results indicating ages a bit older than 8 Ma for this event. Considering experimental errors, the possible geological error of samples from Kecel, the uncertainty of rate of sedi-

TABLE 5

*K/Ar age of basaltic rocks near town Salgótarján, Hungary*

| No. | Sample locality | Dated fraction | K % | $^{40}Ar_{rad}$ % | $10^{-7} \cdot \frac{ccSTP}{g}$ | $\frac{^{40}Ar}{^{36}Ar}$ | $\frac{K/^{36}Ar\ \%}{\left(\frac{ccSTP}{g}\right)} \times 10^{-9}$ | K/Ar age Ma | |
|---|---|---|---|---|---|---|---|---|---|
| 260 | Somoskőújfalu, quarry | 1. w. r. | 1.09 | 6.1 | 1.181 | 314.7 | 0.177 | $2.79 \pm 0.64$ | |
| 313 | Somoskőújfalu, quarry lower level | 1. w. r. | 1.54 | 7.9 | 1.522 | 320.8 | 0.256 | $2.54 \pm 0.45$ | $I_1(260+313+314++315)$:$2.49 \pm 0.93$ |
| 314 | Somoskőújfalu, quarry | 1. w. r. | 0.836 | 7.8 | 0.909 | 320.5 | 0.230 | $2.80 \pm 0.50$ | $I_2(260+313+314++315)$:$2.30 \pm \pm 0.94 (\pm 0.16)$ |
| 315 | Somoskőújfalu, Eresztvény | 1. w. r. | 1.70 | 5.5 | 1.709 | 312.7 | 0.171 | $2.59 \pm 0.65$ | |
| 751 | Medves, Magyarbánya 5/d | 1. w. r. | 1.96 | 29 | 2.304 | 416.2 | 1.027 | $3.03 \pm 0.20$ | $I_1(751)$:$2.76 \pm 0.34$ |
| | | 2. mgI | 1.06 | 21 | 1.569 | 374.1 | 0.531 | $3.81 \pm 0.27$ | $I_2(751)$:$2.25 \pm 0.31$ |
| | | 3. mgII | 2.18 | 49 | 2.565 | 579.4 | 2.413 | $3.03 \pm 0.20$ | |
| 752 | Medves, Középbánya 7/a | 1. w. r. | 1.47 | 19 | 1.295 | 364.8 | 0.787 | $2.27 \pm 0.20$ | $I_1(752)$:$2.01 \pm 0.96$ |
| | | 2. dnI | 2.01 | 21 | 1.925 | 374.1 | 0.820 | $2.47 \pm 0.20$ | $I_2(752)$:$2.30 \pm 0.65$ |
| | | 3. dnII | 1.02 | 16 | 1.017 | 351.8 | 0.565 | $2.57 \pm 0.23$ | |

w. r.: whole rock
mgI, mgII: magnetically separated fraction, numbered in the order of increasing magnetic susceptibility
dnI, dnII: fraction separated by heavy liquid, numbered in the order of increasing density

mentation and the variation in time of the Lower-Upper Pannonian boundary, the deviation of radiometric and paleomagnetic results is not too serious.

In several previous papers (JÁMBOR, Á., *et al.*, 1980, BALOGH, L., *et al.*, 1983a) the age value of the Lower-Upper Pannonian boundary has been estimated using the youngest ages from the Lower Pannonian and the oldest age from the Pa$_2^2$ level measured on sample No. 399 coming from borehole Kapolcs—1 ($I_1 = 4.66 \pm 0.36$ Ma). These data allowed the correlation of the Lower-Upper Pannonian and the Miocene-Pliocene boundaries at 5.5 Ma ago (BERGGREN, W. W. 1979). However, basaltic volcanic activity in the Balaton Highland started with tuff production in the Pa$_2^1$ lever (*Congeria ungulacaprae,* JÁMBOR, Á., 1980), therefore the oldest tuffs have to be older than the basalts of Hegyestő and Kőhegy and the commencement of the Upper Pannonian must have preceded the time of the first tuff eruption. This is an additional argument to fix the Miocene-Pliocene boundary (according to newer investigations its age is 5.2 Ma (MCDOUGALL, J., *et al.*, 1977) within the Upper Pannonian.

$4.25 \pm 0.32$ Ma and $4.15 \pm 0.34$ Ma $I_1$ ages were determined on whole rock samples for the basalts of the Little Plain and on fractions of sample No. 387, respectively. The basalts overlie sediments of the *Unio wetzleri* (Pa$_2^2$) level (JÁMBOR, Á., *et al.*, 1981), thus an older age, at least 4.5 Ma has to be assigned to the beginning of Pa$_2^3$ level in the Little Plain. On the other hand, at Pula the $I_1$ age of $4.25 \pm 0.17$ Ma marks the end of the Pa$_2^2$ level. According to the dating of hills at Szigliget, the tuff eruptions did not start much before 4 Ma but the deposition of Pa$_2^3$ sediments continued during the tuff accumulation. It has been described earlier that the boundary of Pa$_2^2$ and Pa$_2^3$ levels is not an isochron surface (BARTHA, F., 1959). This picture is confirmed by the K/Ar datations which yield for this boundary a time span starting at least 4.5 Ma ago and ending after 4 My or possibly 3.5 Ma before present.

The jumillite at Bár lying on Early Pleistocene red clay is a little older than 2 Ma. Accepting 1.8 Ma for the Pliocene-Pleistocene boundary, part of the sediments classified as Early Pleistocene in Hungary has to be transferred to the Uppermost Pliocene. This has been confirmed by paleomagnetic investigations resulting in ages in excess of 2 Ma for Early Pleistocene sediments (RÓNAI, A., SZEMETHY, A., 1979).


## ACKNOWLEDGEMENTS

The authors express their gratitude to GÉZA HÁMOR and ÁRON JÁMBOR for initiating and supporting this work and for their continuous interest. The majority of the dated rocks was collected with the help of G. SOLTI and additional samples were supplied by B. CSEREPES-MESZÉNA and A. NUSSZER (No. 463, 571, 572, 629), P. MERZICH (No. 1021—1026), Z. BORSY (No. 884, 885), E. SZALAY (No. 1142, 1143) and A. EMBEY — ISZTIN (No. 995); their valuable help is gratefully acknowledged. This research was sponsored primarily by the Central Geological Office, Budapest.


## REFERENCES


BALÁZS, E., NUSSZER, A. (1982): Magyarország medenceterületeinek alsópannóniai vulkanizmusa. Manuscript. Hung. Geol. Inst., Archives.

BALOGH, KADOSA (1985): K/Ar dating of Neogene volcanic activity in Hungary: Experimental technique, experiences and methods of chronogical studies. ATOMKI Rep. (In press)

BALOGH, KADOSA, MÓRIK, GY. (1978): Magnetic mass spectrometer for K-Ar dating (In Hungarian). ATOMKI Közl., **20,** 215—228.

BALOGH, KADOSA, MÓRIK, GY. (1979): High capacity argon extraction and purification system (In Hungarian). ATOMKI Közl., **21**, 363—375.

BALOGH, KADOSA, MIHALIKOVA, A., VASS, D. (1981): Radiometric dating of basalts in Southern and Central Slovakia. Západné Karpaty, Séria geol. **7**, Geol. Ust. D. Stura, 113—126.

BALOGH, KADOSA, JÁMBOR, Á., PARTÉNYI, Z., RAVASZ-BARANYAI, L., SOLTI, G., NUSSZER, A. (1983a): Petrography and K/Ar dating of Tertiary and Quaternary basaltic rocks in Hungary. An. Inst. Geol. Geof. Bucharest, **LXI**, 365—373.

BALOGH, KADOSA, PÉCSKAY, Z., SZÉKY-FUX, V., GYARMATI, P. (1983b): Chronology of Miocene volcanism in North-East Hungary. An. Inst. Geol. Geofiz., Bucharest, **LXI**, 149—158.

BARTHA, F. (1959): Geologische Ergebnisse von feinstratigraphischen Untersuchungen an oberpannonischen Bildungen von der Umgebung des Balatonsees. (In Hungarian). Földt. Közl., **89**, 23—26.

BENCZE, G., JÁMBOR, Á., PARTÉNYI, Z. (1979): Exploration of alginite (oil-shale) and bentonite deposits between Várkesző and Malomsok. (In Hungarian) Ann. Rep. of the Hung. Geol. Inst. of 1977. 257—267. Műszaki Kiadó, Budapest.

BERGGREN, W. A. (1969): Cenozoic chronostratigraphy, foraminiferal zonation and the radiometric time scale. Nature **224**, 1072—1074.

CSEREPES-MESZÉNA, B. (1978): On the Lower Pannonian basalts and Proterozoic migmatites uncovered by the hydrocarbon-exploratory borehole Kiskunhalas — Ny — 3. (In Hungarian). Földt. Közl., **108**, 53—64.

EMBEY-ISZTIN, A. (1981): Statistical analysis of major element pattern in basic rocks of Hungary: An approach to determine their tectonic setting. (In Hungarian). Földt. Közl., **111**, 43—58.

EMBEY-ISZTIN, A. (1984): Texture types and their relative frequencies in ultramafic and mafic xenolites from Hungarian alkali basaltic rocks. Annales Historico-Naturales Musei Nationalis Hungarici **LXXVI**, 43—58.

GYARMATI, P. (1977): Intermediate volcanism in the Tokaj Mountains. Ann. Hung. Geol. Inst., **LVIII**.

HŐNIG, GY. (1971): A bári B—4, B—5 és B—6 számú fúrások rétegsora. Manuscript. Hung. Geol. Inst. Archives.

JÁMBOR, A. (1980): Pannonian in the Transdanubian Central Mountains. Ann. Hung. Geol. Inst., **LXII**, Műszaki Kiadó, Budapest.

JÁMBOR, Á., SOLTI, G. (1976): Geological conditions of the Upper Pannonian oil shale deposit recovered in the Balaton Highland and at Kemeneshát. (In Hungarian). Ann. Rep. of the Hung. Geol. Inst. of 1974, 193—219. Műszaki Kiadó, Budapest.

JÁMBOR, A., PARTÉNYI, Z., RAVASZ-BARANYAI, L., SOLTI, G., BALOGH, K. (1980): K/Ar dating of basaltic rocks in Transdanubia, Hungary. ATOMKI Közl., **22**, 172—190.

JÁMBOR, Á., PARTÉNYI, Z., SOLTI, G. (1981): Geological features of basalt volcanics in Transdanubia. (In Hungarian). Ann. Rep. of the Hung. Geol. Inst. of 1979, 225—239. Műszaki Kiadó, Budapest.

JUGOVICS, L. (1969): Basalt und Basalttuffgebiete Transdanubiens. (In Hungarian). Ann. Rep. of the Hung. Geol. Inst. of 1967, 75—82. Műszaki Kiadó, Budapest.

JUGOVICS, L. (1971a). Über die Basaltgebiete von Nordungarn (Umgebung von Salgótarján). (In Hungarian). Ann. Rep. of the Hung. Geol. Inst. of 1968, 145—165. Műszaki Kiadó, Budapest.

JUGOVICS, L. (1971b). Über den Bau der Basaltgebiete des Balatonhochlandes und des Tapolcaer Beckens. (In Hungarian). Ann. Rep. of the Hung. Geol. Inst. of 1968, 223—244. Műszaki Kiadó, Budapest.

JUGOVICS, L. (1972): Die Basalt und Basalttuffvorkormmen der Kleinen Ungarischen Tiefebene. (In Hungarian). Ann. Rep. of the Hung. Geol. Inst. of 1970, 29—101. Műszaki Kiadó, Budapest.

JUGOVICS, L. (1976): Chemical features of the basalts in Hungary (In Hungarian). Ann. Rep. of the Hung. Geol. Inst. of 1974, 431—470. Műszaki Kiadó, Budapest.

KULCSÁR, L., GUZY-SOMOGYI, A. (1962): Le volcan de Sághegy de Celldömölk. (In Hungarian). Acta Geogr. Debr., **VIII/1**, No. 27, 33—83.

LÓCZY, L. (1913): A Balaton környékének geológiai képződményei és ezek vidékek szerinti telepedése. A Balaton tudományos tanulmányozásának eredményei. I. I. 1., 1—581, Budapest.

MANKINEN, E. A., DALRYMPLE, G. B. (1979): Revised Geomagnetic Polarity Time Scale for the Interval 0—5 m. y. B. P. J. Geophys. Res., **84**, 615—626.

MÁRTON, P., SZALAY, E. (1968): Paläomagnetische Untersuchungen an Basaltlaven von Ungarn. Acta Geol. Hung., **12**, 291—305.

MCDOUGALL, I., SAEMUNDSON, K., JOHANNESSON, H., WATKINS, N. D., KRISTJANSSON, L. (1977): Extension of the geomagnetic polarity time scale to 6.5 m. y.: K-Ar dating, geologic and paleomagnetic study of a 3,500 m lava succession in western Iceland. Geol. Soc. Am. Bull., **88**, 1—13.

MIYASHIRO, A. (1975): Classification, characteristics, and origin of ophiolites. Jour. Geol., 85 249—276.

MOLNÁR, J., PAÁL, A., SEPSY, K. (1980): Microprocessor based system for control, data aquisition, and processing. (In Hungarian). ATOMKI Közl., **22,** 369—373.

NAGY, G. (1983): Cooling history of young Hungarian basalts based on zoning of olivine phenocrysts Acta Geol. Hung., **26,** 321—339.

PANTÓ, GY. (1981): Rare earth element geochemical pattern of Cenozoic volcanism in Hungary Earth Evol. Sci., **3—4,** 249—256.

PAP, S. (1983): Lower Pannonian basalt volcanism in the Balástya and Üllés—Ruzsa—Zákányszék areas. (In Hungarian). Földt. Közl., **113,** 163—170.

RAVASZ, Cs. (1976): Petrographic examinations of oil-shale at Pula and Gérce. (In Hungarian). Ann. Rep. of the Hung. Geol. Inst. of 1974. 221—245. Műszaki Kiadó, Budapest.

RAVASZNÉ BARANYAI, L. (1979): Bár, alkáli magmás vulkanitok ásvány-kőzettani vizsgálata. Manuscript. Hung. Geol. Inst. Archives.

RÓNAI, A., SZEMETHY, A. (1979): Latest result of lowland research in Hungary. Palaeomagnetic measurements on unconsolidated sediments. (In Hungarian). Ann. Rep. of the Hung. Geol. Inst. of 1977. 67—83. Műszaki Kiadó, Budapest.

STEIGER, R. H., JÄGER, E. (1977): Subcommission on Geochronology: Convention on the use of decay constants in geo- and cosmochronology. Earth and Plan. Sci. Letters **36,** 359—362.

SZÁDECZKY-KARDOSS, E., ERDÉLYI, J. (1957): Über die Zeolithbildungen der Basalte der Balatongegend (In Hungarian). Földt. Közl., **87,** 302—308.

SZEDERKÉNYI, T. (1980): Petrological and geochemical character of the Bár basalt, Baranya county, South Hungary. Acta Miner.-Petr., Szeged, **XXIV/2,** 235—244.

VICZIÁN, I. (1965): Basalt aus dem Komitat Baranya. (In Hungarian). Földt. Közl., **95,** 448—452.

VITÁLIS, I. (1908): A balatonfelvidéki bazaltok. A Balaton tudományos tanulmányozásának eredményei I. I. 2., 1—169, Budapest.

VOGL, M. (1979): Geochemical examination of basalts in Hungary. 1. Little Hungarian Plain. 2. Southern Bakony Mountains. (In Hungarian). Ann. Rep. of the Hung. Geol. Inst. of 1977, 343—361. Műszaki Kiadó, Budapest.

VOGL, M. (1980): Geochemical examination of basalts in Hungary. 3. Tátika group. (In Hungarian). Ann. Rep. of the Hung. Geol. Inst. of 1978, 333—341. Műszaki Kiadó, Budapest.

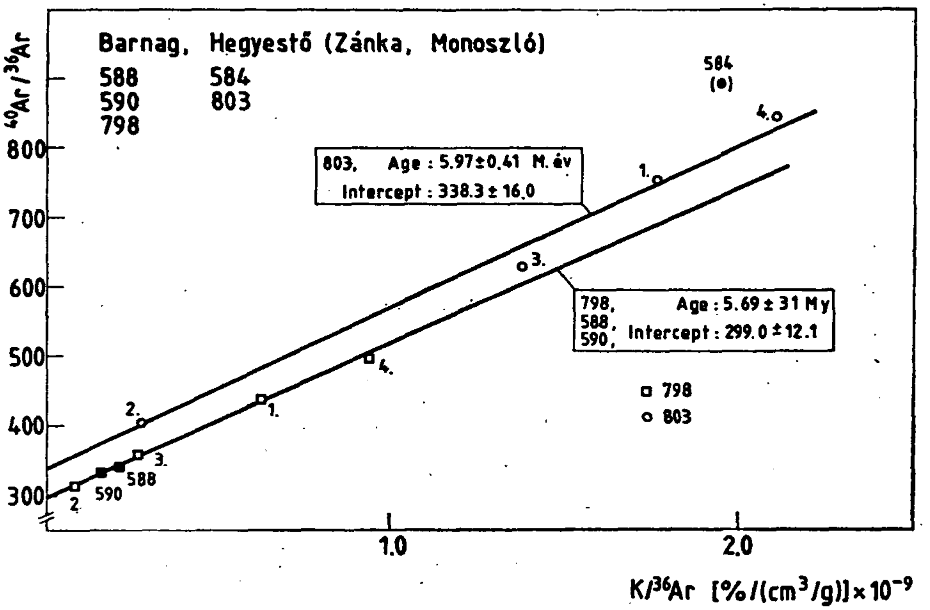
VÖRÖS, I. (1966): Volcanological and structural relations of the Kabhegy-area. (In Hungarian). Földt. Közl., **96,** 292—300.

*Manuscript received, 10 October, 1985*

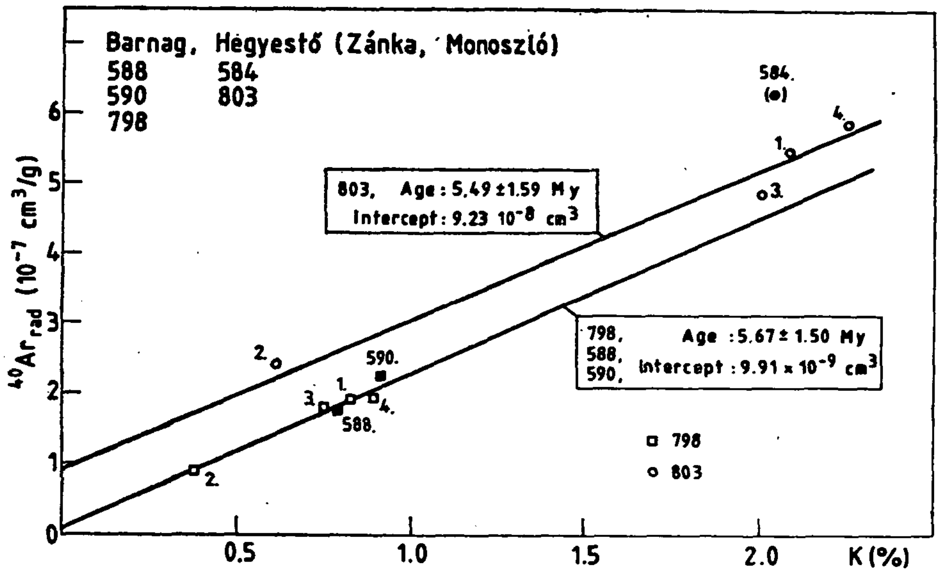
## Appendix

Isochron diagrams

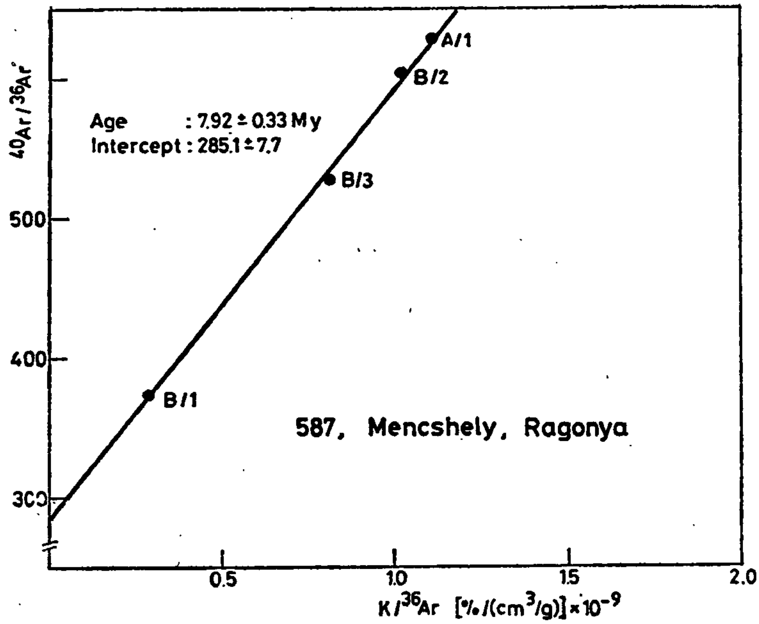
I



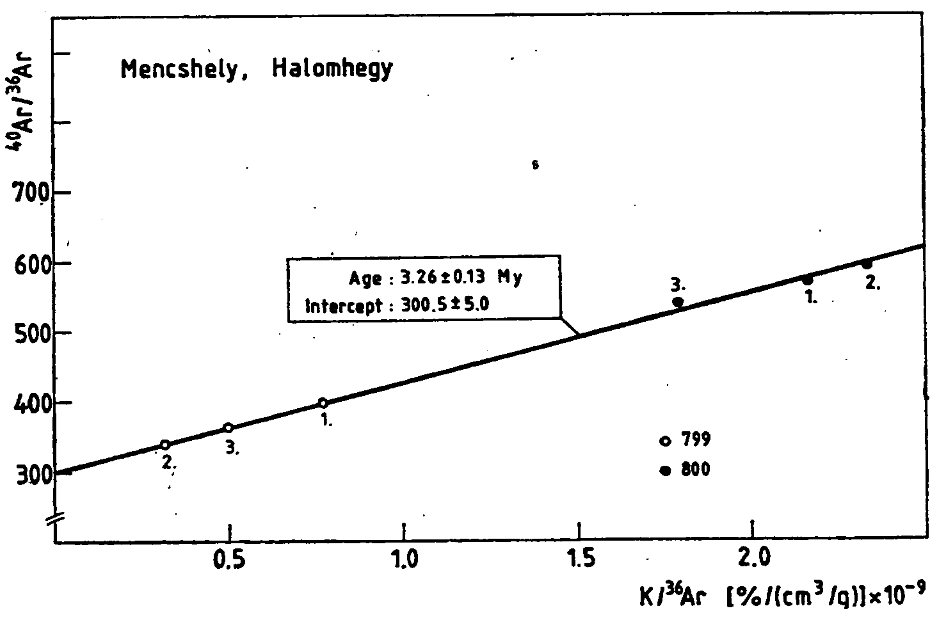

II



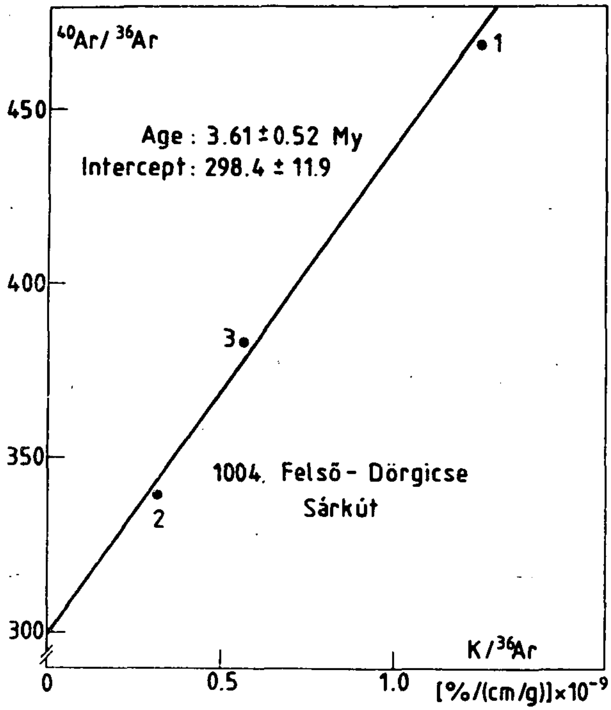
III


Age : 7.92 ± 0.33 My
Intercept : 285.1 ± 7.7
A/1
B/2
B/3
B/1
587, Mencshely, Ragonya
$^{40}Ar/^{36}Ar$
500
400
300
0.5
1.0
1.5
2.0
$K/^{36}Ar$ [%/(cm$^3$/g)] × $10^{-9}$

IV

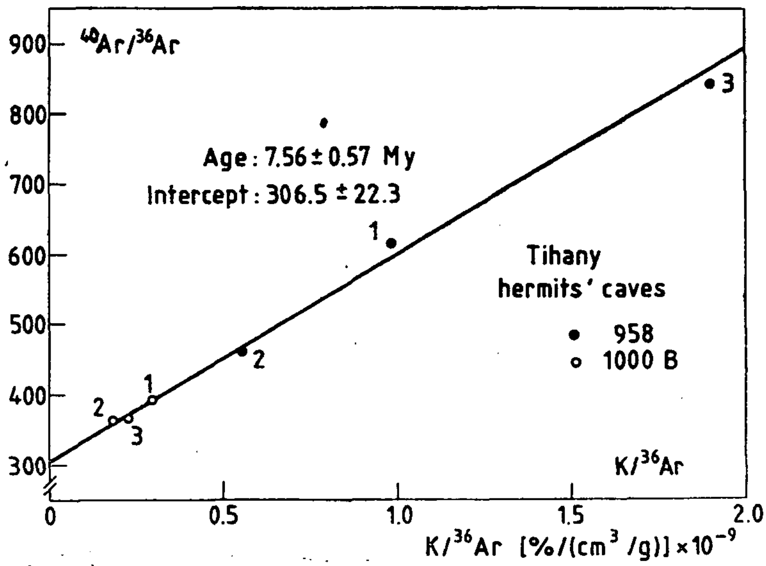

Mencshely, Halomhegy
Age : 3.26 ± 0.13 My
Intercept : 300.5 ± 5.0
$^{40}Ar/^{36}Ar$
700
600
500
400
300
o 799
• 800
0.5
1.0
1.5
2.0
$K/^{36}Ar$ [%/(cm$^3$/g)] × $10^{-9}$

V



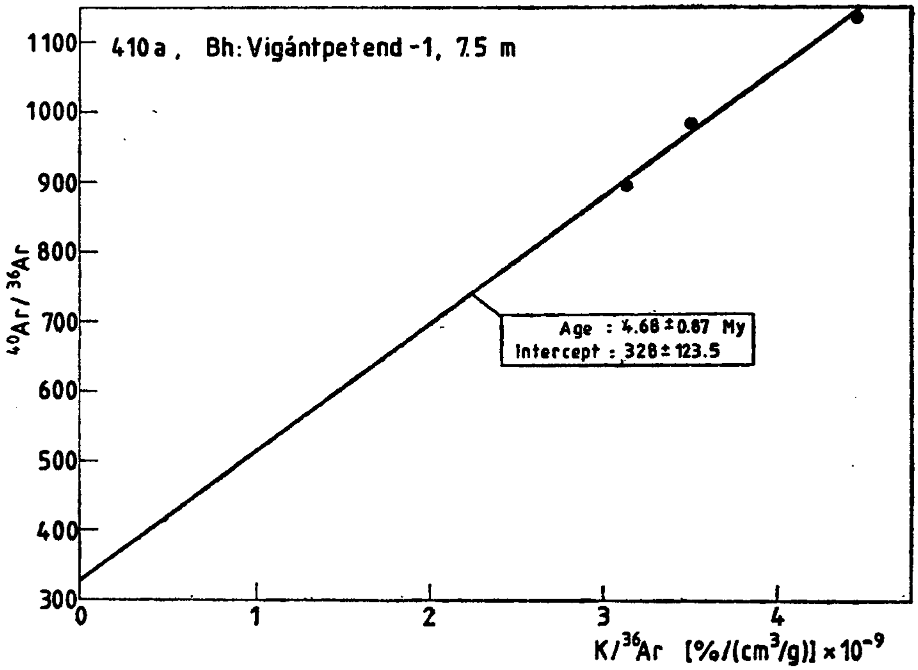
$^{40}Ar/^{36}Ar$
450
400
350
300
Age : 3.61 ± 0.52 My
Intercept : 298.4 ± 11.9
1
3
2
1004. Felső - Dörgicse
Sárkút
$K/^{36}Ar$
0
0.5
1.0
[%/(cm/g)] × $10^{-9}$


VI



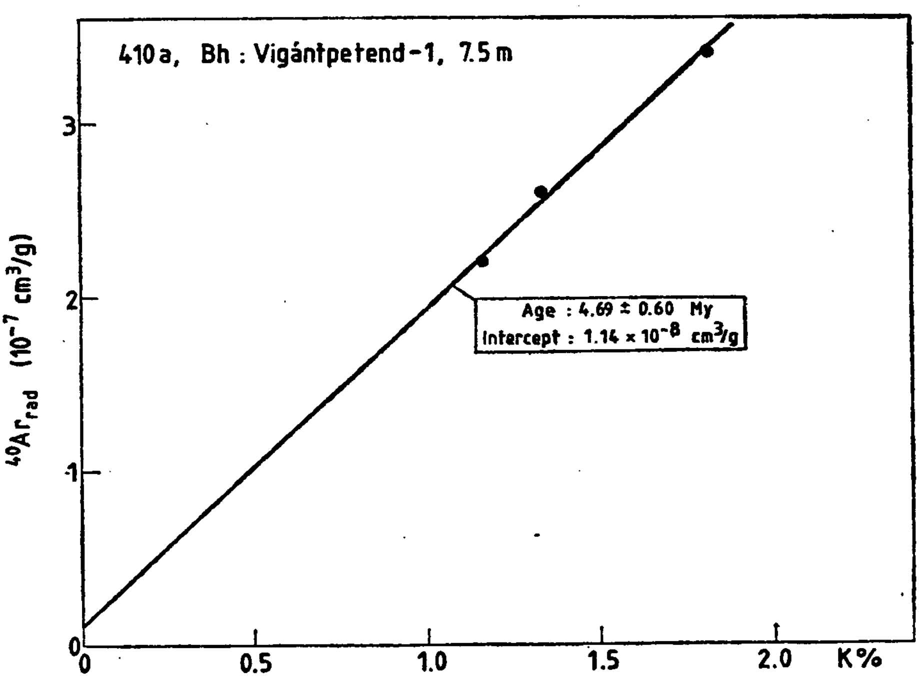
$^{40}Ar/^{36}Ar$
900
800
700
600
500
400
300
Age : 7.56 ± 0.57 My
Intercept : 306.5 ± 22.3
3
1
2
1
2
3
Tihany
hermits' caves
958
1000 B
$K/^{36}Ar$
0
0.5
1.0
1.5
2.0
$K/^{36}Ar$ [%/(cm$^3$/g)] × $10^{-9}$

VII



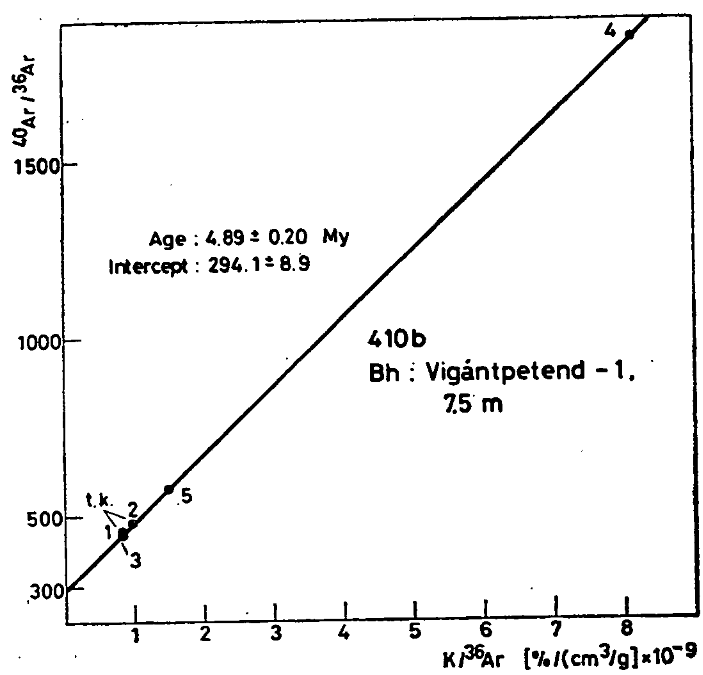
410 a , Bh: Vigántpetend -1, 7.5 m
Age : 4.68 ± 0.87 My
Intercept : 328 ± 123.5
$^{40}Ar/^{36}Ar$
1100
1000
900
800
700
600
500
400
300
0
1
2
3
4
$K/^{36}Ar$ [%/(cm$^3$/g)] × $10^{-9}$


VIII



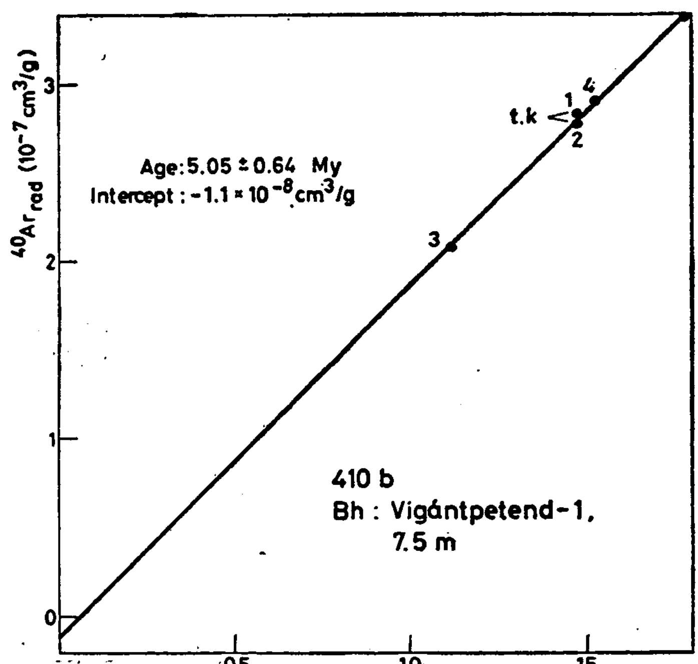
410 a, Bh : Vigántpetend -1, 7.5 m
Age : 4.69 ± 0.60 My
Intercept : 1.14 × $10^{-8}$ cm$^3$/g
$^{40}Ar_{rad}$ ($10^{-7}$ cm$^3$/g)
3
2
1
0
0
0.5
1.0
1.5
2.0
K%

IX



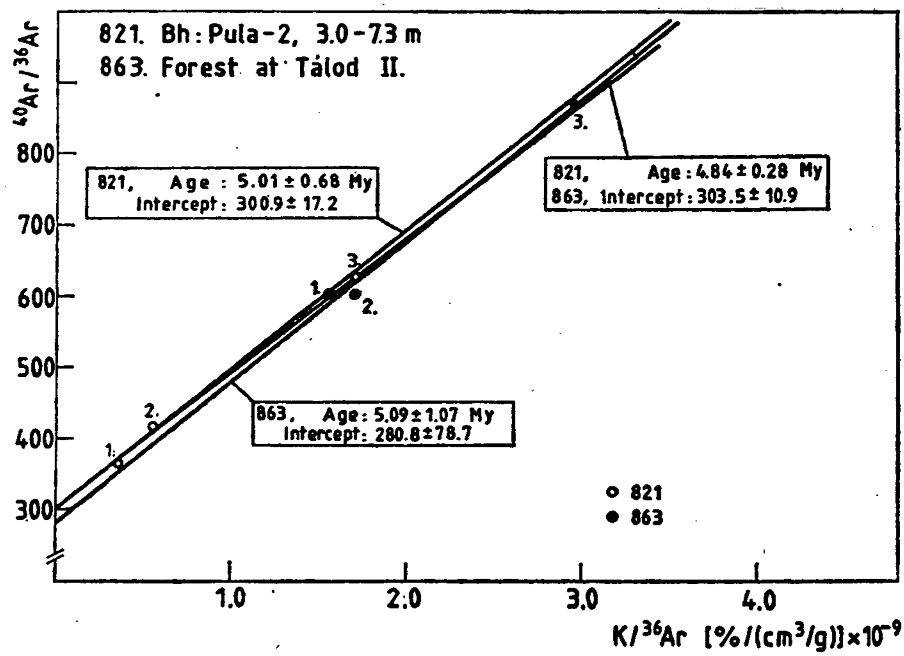
$^{40}Ar/^{36}Ar$
1500
1000
500
300
Age : 4.89 ± 0.20 My
Intercept : 294.1 ± 8.9
410b
Bh : Vigántpetend - 1,
7.5 m
t.k.
1
2
3
4
5
1
2
3
4
5
6
7
8
K/$^{36}$Ar [%/(cm$^3$/g] × 10$^{-9}$


X



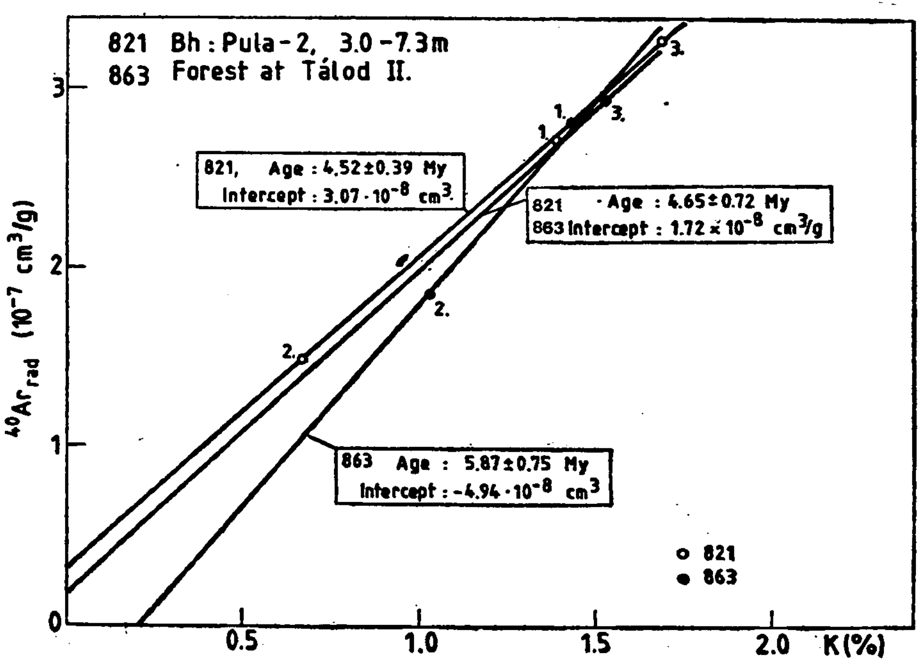
$^{40}Ar_{rad}$ ($10^{-7}$ cm$^3$/g)
3
2
1
0
Age: 5.05 ± 0.64 My
Intercept : -1.1 × $10^{-8}$ cm$^3$/g
t.k
1
2
3
4
410 b
Bh : Vigántpetend-1,
7.5 m
0.5
1.0
1.5
K %

XI



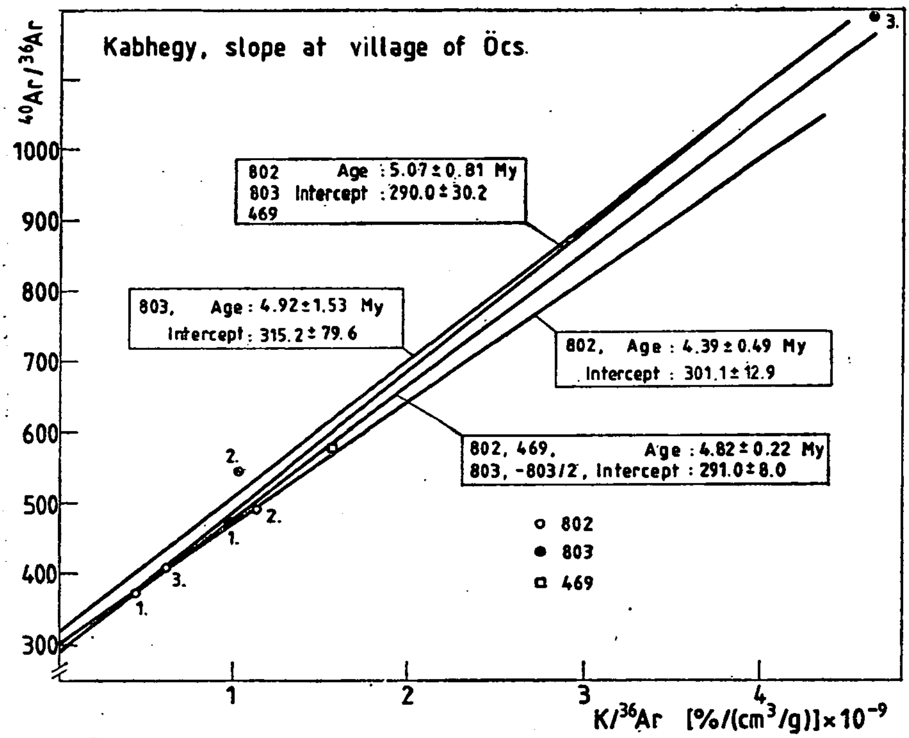
821. Bh: Pula-2, 3.0-7.3 m
863. Forest at Tálod II.
821, Age: 5.01 ± 0.68 My
Intercept: 300.9 ± 17.2
821, Age: 4.84 ± 0.28 My
863, Intercept: 303.5 ± 10.9
863, Age: 5.09 ± 1.07 My
Intercept: 280.8 ± 78.7
o 821
● 863
$^{40}Ar/^{36}Ar$
800
700
600
500
400
300
1.0
2.0
3.0
4.0
$K/^{36}Ar$ [%/(cm$^3$/g)] × $10^{-9}$


XII

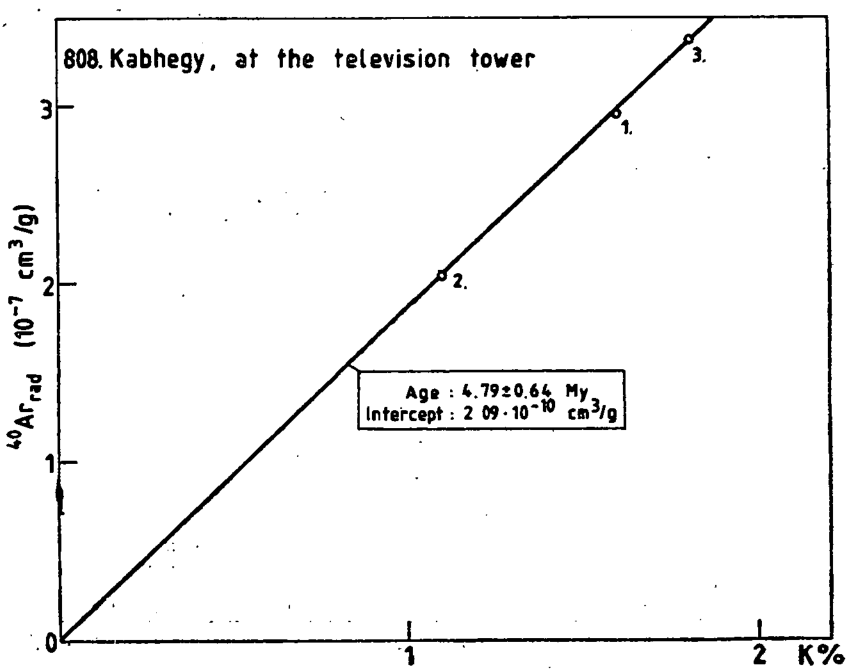


821 Bh: Pula-2, 3.0-7.3m
863 Forest at Tálod II.
821, Age: 4.52±0.39 My
Intercept: 3.07 · $10^{-8}$ cm$^3$
821 Age: 4.65±0.72 My
863 Intercept: 1.72 × $10^{-8}$ cm$^3$/g
863 Age: 5.87±0.75 My
Intercept: -4.94 · $10^{-8}$ cm$^3$
o 821
● 863
$^{40}Ar_{rad}$ ($10^{-7}$ cm$^3$/g)
0
1
2
3
0.5
1.0
1.5
2.0
K(%)

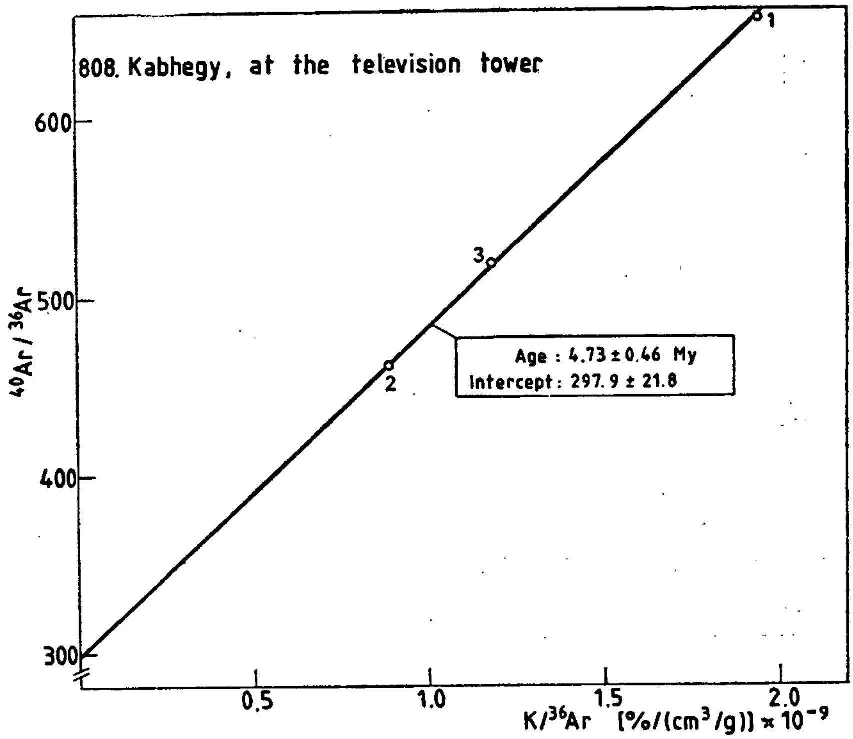
XIII


Kabhegy, slope at village of Öcs.
802 Age : 5.07 ± 0.81 My
803 Intercept : 290.0 ± 30.2
469
803, Age : 4.92 ± 1.53 My
Intercept : 315.2 ± 79.6
802, Age : 4.39 ± 0.49 My
Intercept : 301.1 ± 12.9
802, 469, Age : 4.82 ± 0.22 My
803, -803/2, Intercept : 291.0 ± 8.0
o 802
● 803
□ 469
$^{40}Ar/^{36}Ar$
$K/^{36}Ar$ [%/(cm$^3$/g)] × $10^{-9}$

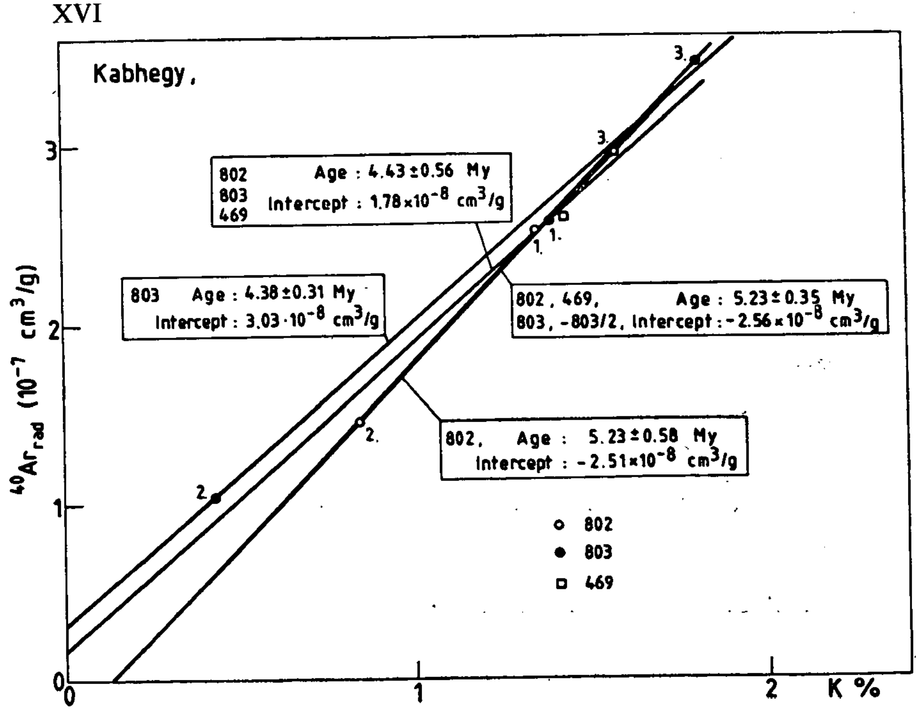
XIV


808. Kabhegy, at the television tower
Age : 4.79 ± 0.64 My
Intercept : 2 09 · $10^{-10}$ cm$^3$/g
$^{40}Ar_{rad}$ ($10^{-7}$ cm$^3$/g)
K%

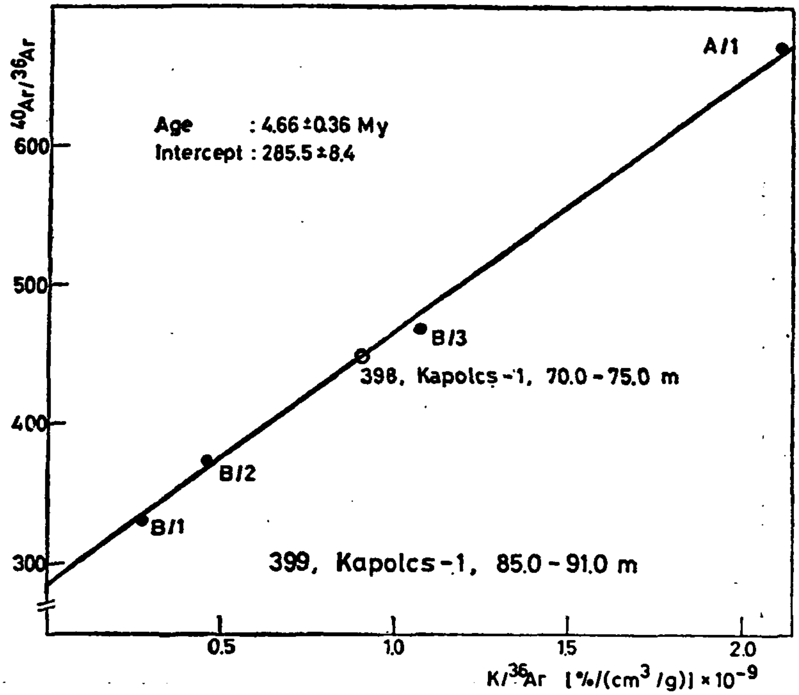
XV


808. Kabhegy, at the television tower
Age : 4.73 ± 0.46 My
Intercept : 297.9 ± 21.8
$^{40}Ar / ^{36}Ar$
$K/^{36}Ar$ [%/(cm$^3$/g)] × $10^{-9}$
600
500
400
300
0.5
1.0
1.5
2.0

XVI

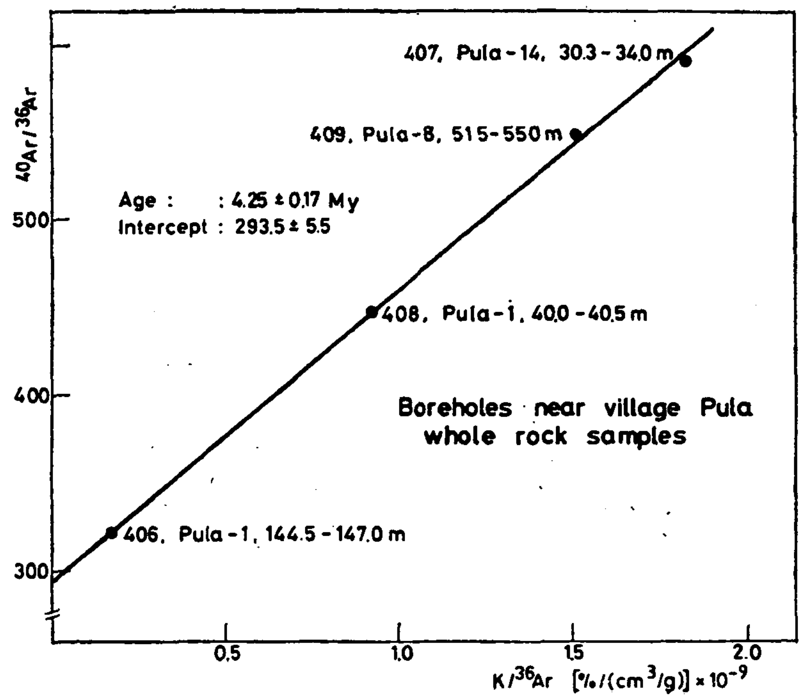

Kabhegy,
802 803 469 Age : 4.43 ± 0.56 My
Intercept : 1.78×10$^{-8}$ cm$^3$/g
803 Age : 4.38 ± 0.31 My
Intercept : 3.03·10$^{-8}$ cm$^3$/g
802, 469, 803, -803/2, Age : 5.23 ± 0.35 My
Intercept : -2.56×10$^{-8}$ cm$^3$/g
802, Age : 5.23 ± 0.58 My
Intercept : -2.51×10$^{-8}$ cm$^3$/g
802
803
469
$^{40}Ar_{rad}$ ($10^{-7}$ cm$^3$/g)
K %
0
1
2
3

XVII



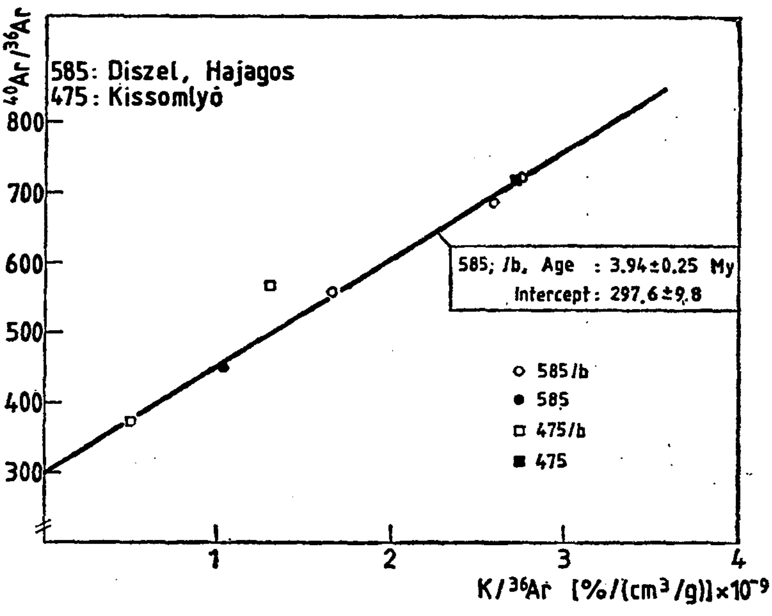
A/1
Age : 4.66 ± 0.36 My
Intercept : 285.5 ± 8.4
B/3
398, Kapolcs-1, 70.0-75.0 m
B/2
B/1
399, Kapolcs-1, 85.0-91.0 m
$^{40}Ar/^{36}Ar$
600
500
400
300
0.5
1.0
1.5
2.0
$K/^{36}Ar$ [%/(cm$^3$/g)] × $10^{-9}$


XVIII

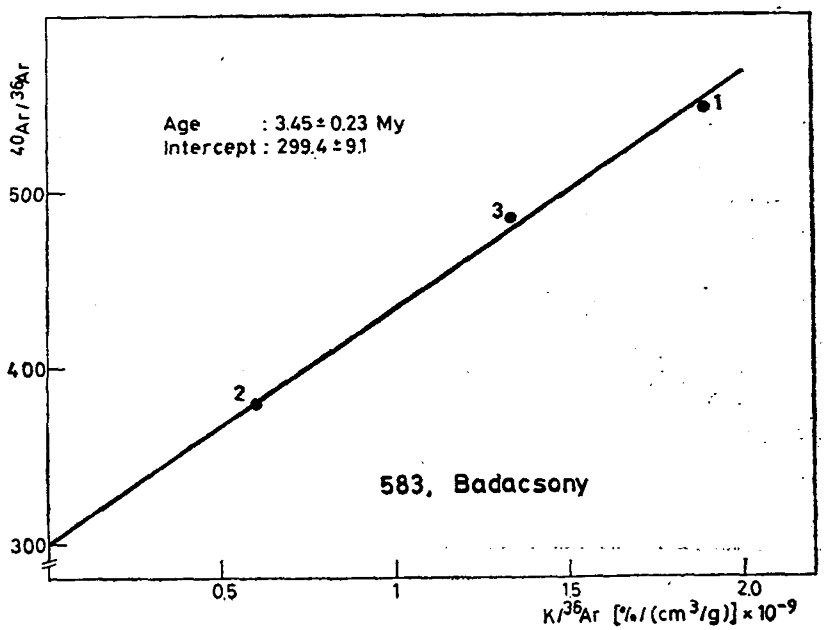


407, Pula-14, 30.3-34.0 m
409, Pula-8, 515-550 m
Age : : 4.25 ± 0.17 My
Intercept : 293.5 ± 5.5
408, Pula-1, 40.0-40.5 m
Boreholes near village Pula
whole rock samples
406, Pula-1, 144.5-147.0 m
$^{40}Ar/^{36}Ar$
500
400
300
0.5
1.0
1.5
2.0
$K/^{36}Ar$ [%/(cm$^3$/g)] × $10^{-9}$

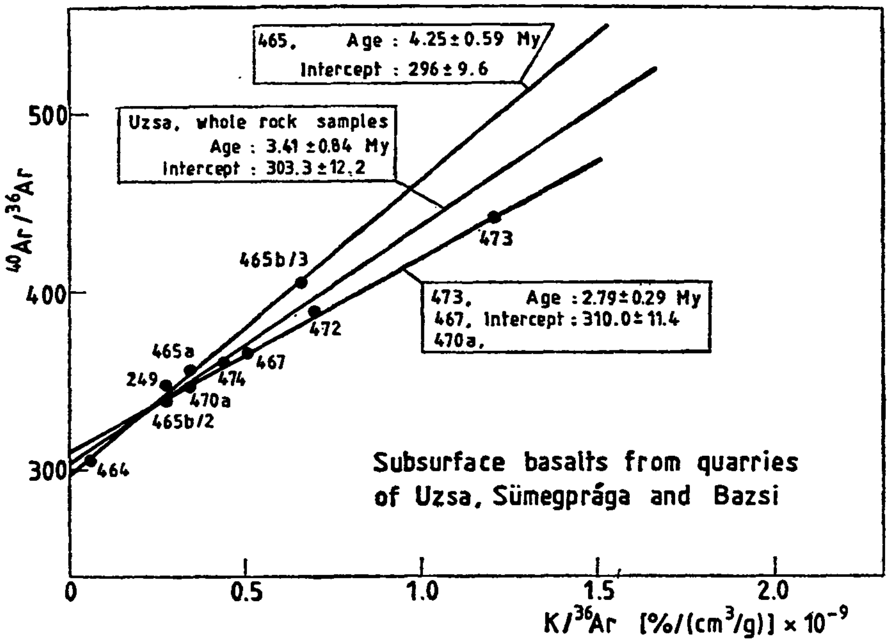
XIX


585: Diszel, Hajagos
475: Kissomlyó
$^{40}Ar/^{36}Ar$
800
700
600
500
400
300
585; /b, Age : 3.94±0.25 My
Intercept: 297.6±9.8
585/b
585
475/b
475
1
2
3
4
$K/^{36}Ar$ [%/(cm$^3$/g)]×$10^{-9}$

XX

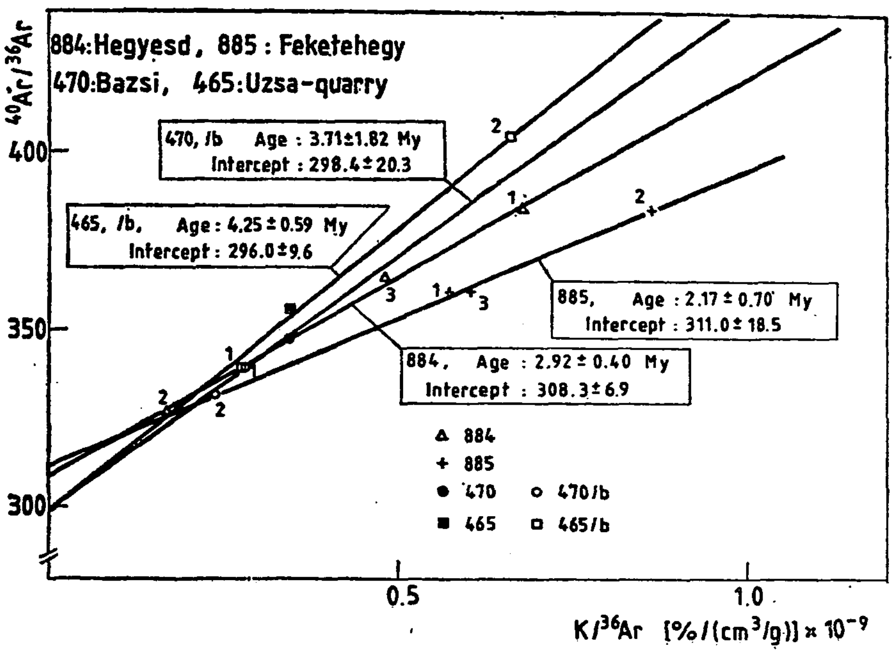

$^{40}Ar/^{36}Ar$
Age : 3.45 ± 0.23 My
Intercept : 299.4 ± 9.1
1
3
2
500
400
300
583, Badacsony
0.5
1
1.5
2.0
$K/^{36}Ar$ [%/(cm$^3$/g)] × $10^{-9}$

XXI



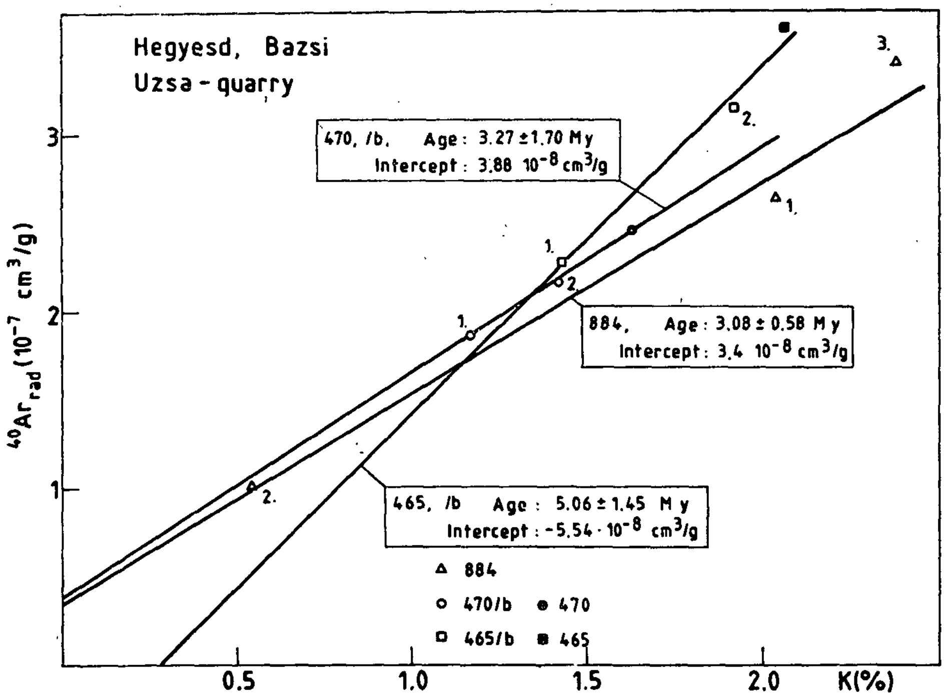
465, Age : 4.25 ± 0.59 My
Intercept : 296 ± 9.6
Uzsa, whole rock samples
Age : 3.41 ± 0.84 My
Intercept : 303.3 ± 12.2
473, Age : 2.79 ± 0.29 My
467, Intercept : 310.0 ± 11.4
470a,
465b/3
473
472
465a
249
474
467
470a
465b/2
464
Subsurface basalts from quarries
of Uzsa, Sümegprága and Bazsi
500
400
300
0
0.5
1.0
1.5
2.0
$^{40}Ar/^{36}Ar$
$K/^{36}Ar$ [%/(cm$^3$/g)] × $10^{-9}$


XXII

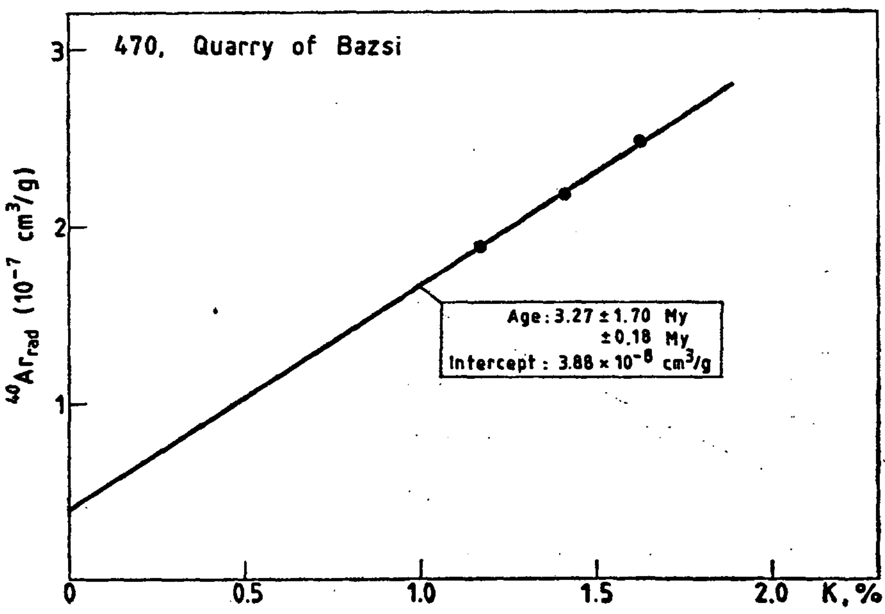


884:Hegyesd, 885 : Feketehegy
470:Bazsi, 465:Uzsa-quarry
470, /b Age : 3.71±1.82 My
Intercept : 298.4±20.3
465, /b, Age : 4.25 ± 0.59 My
Intercept : 296.0±9.6
885, Age : 2.17 ± 0.70 My
Intercept : 311.0 ± 18.5
884, Age : 2.92 ± 0.40 My
Intercept : 308.3 ± 6.9
884
885
470
470/b
465
465/b
400
350
300
0.5
1.0
$^{40}Ar/^{36}Ar$
$K/^{36}Ar$ [%/(cm$^3$/g)] × $10^{-9}$

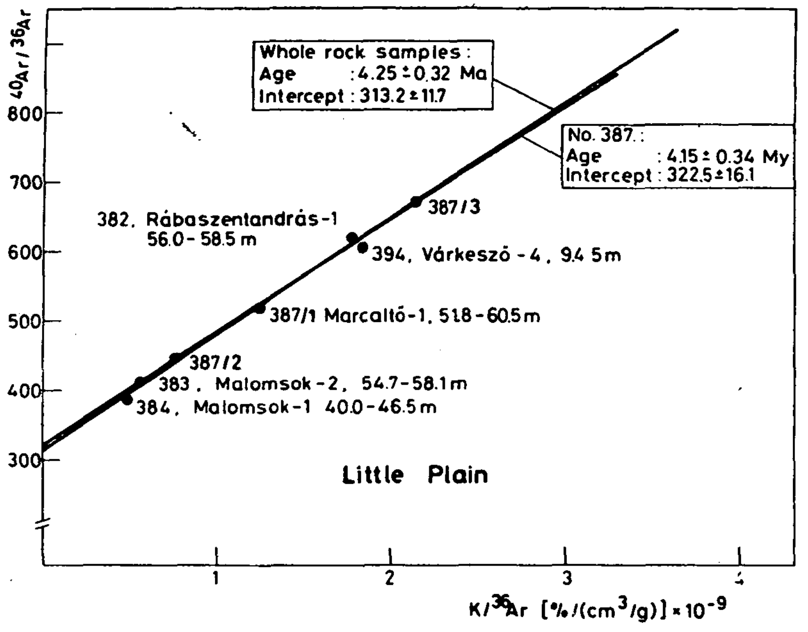
XXIII


Hegyesd, Bazsi
Uzsa - quarry
470, /b. Age: 3.27 ± 1.70 My
Intercept: 3.88 10^-8 cm^3/g
884, Age: 3.08 ± 0.58 My
Intercept: 3.4 10^-8 cm^3/g
465, /b Age: 5.06 ± 1.45 My
Intercept: -5.54 · 10^-8 cm^3/g
884
470/b
470
465/b
465
40Ar rad (10^-7 cm^3/g)
K(%)

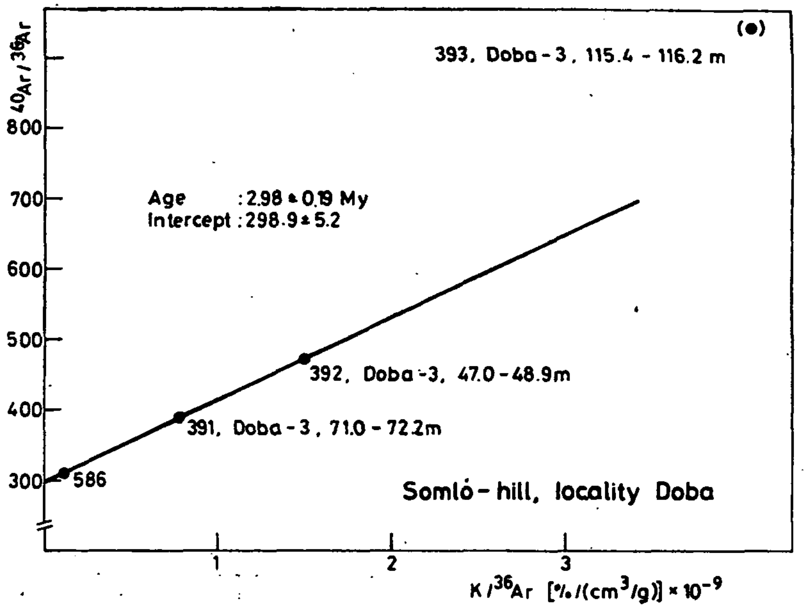
XXIV


470, Quarry of Bazsi
Age: 3.27 ± 1.70 My
± 0.18 My
Intercept: 3.88 × 10^-8 cm^3/g
40Ar rad (10^-7 cm^3/g)
K, %

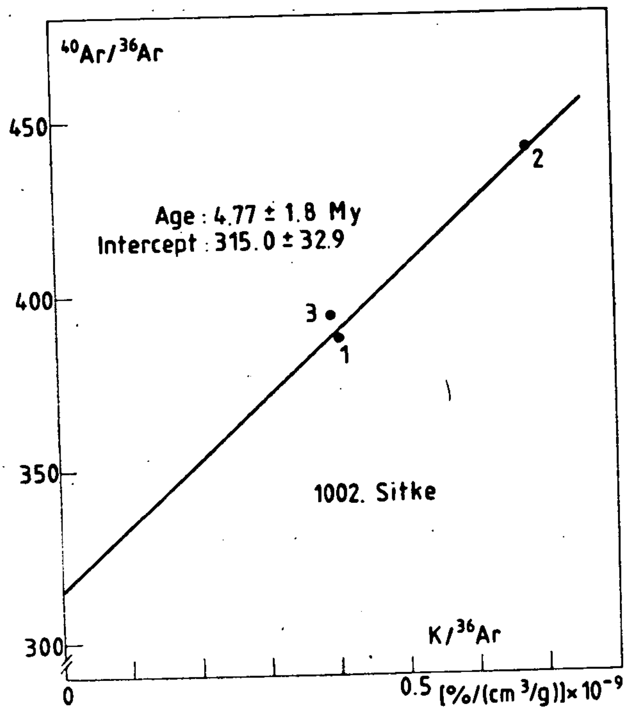
XXV


Whole rock samples:
Age :4.25 ± 0.32 Ma
Intercept : 313.2 ± 11.7
No. 387.:
Age : 4.15 ± 0.34 My
Intercept : 322.5 ± 16.1
382. Rábaszentandrás-1
56.0 - 58.5 m
387/3
394. Várkeszó - 4. 9.4 5m
387/1 Marcaltő-1. 51.8 - 60.5m
387/2
383. Malomsok-2. 54.7-58.1m
384. Malomsok-1 40.0-46.5m
Little Plain
$^{40}Ar/^{36}Ar$
800
700
600
500
400
300
1
2
3
4
$K/^{36}Ar$ [%/(cm$^3$/g)] × $10^{-9}$

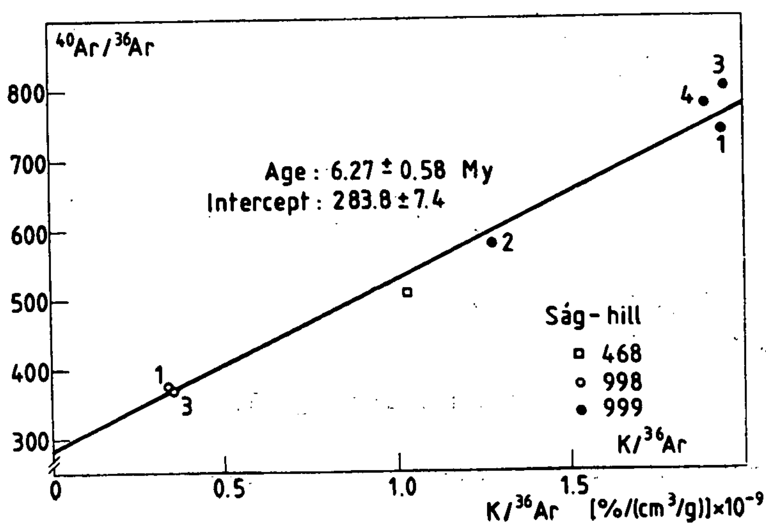
XXVI


(●)
393. Doba-3. 115.4 - 116.2 m
Age : 2.98 ± 0.19 My
Intercept : 298.9 ± 5.2
392. Doba-3. 47.0-48.9m
391. Doba-3. 71.0 - 72.2m
586
Somló-hill, locality Doba
$^{40}Ar/^{36}Ar$
800
700
600
500
400
300
1
2
3
$K/^{36}Ar$ [%/(cm$^3$/g)] × $10^{-9}$

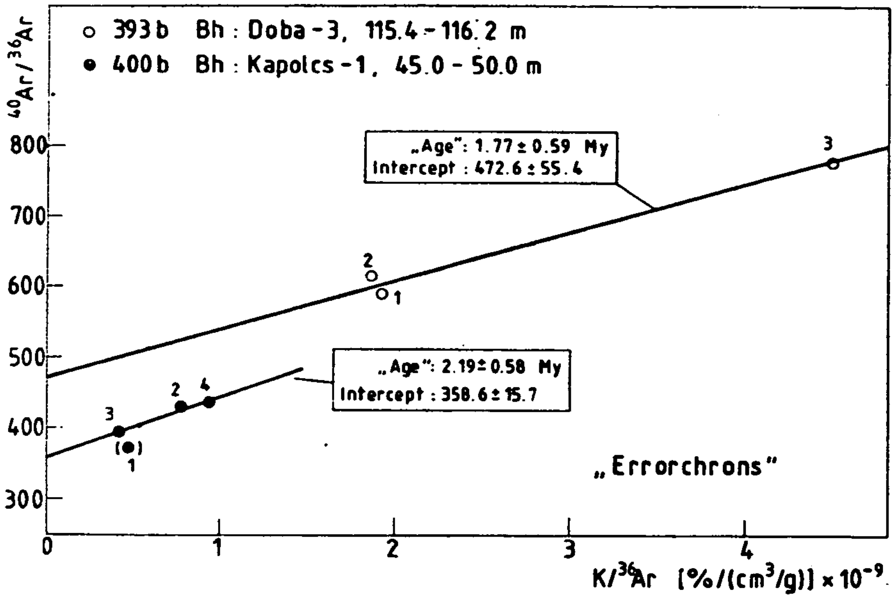
XXVII



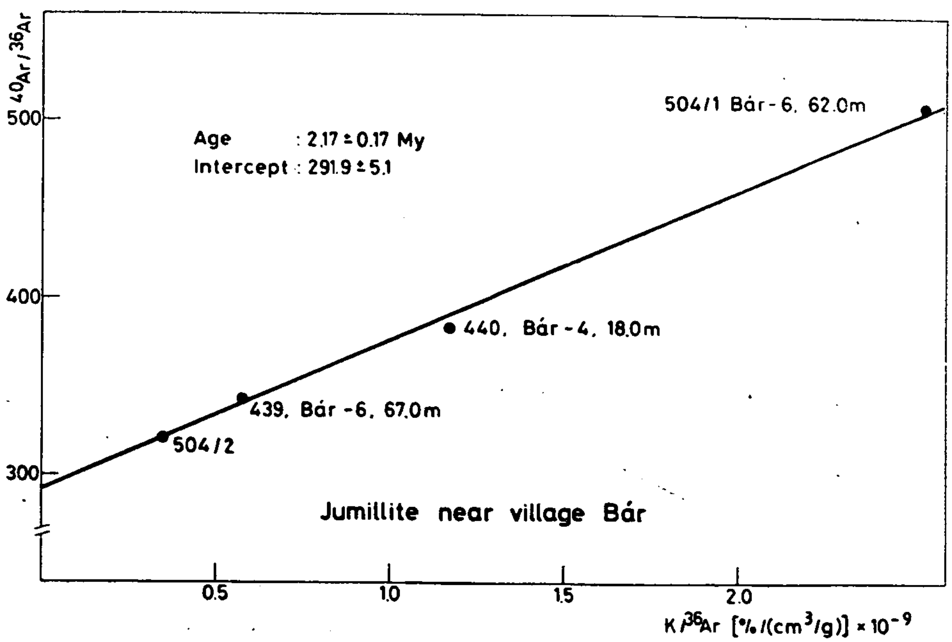

XXVIII



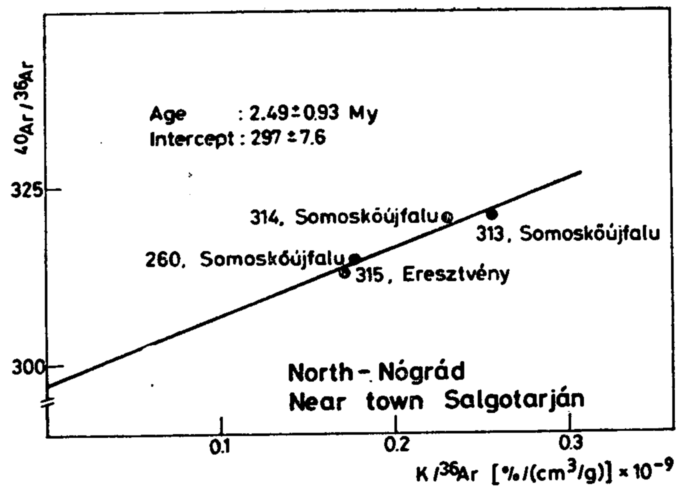
XXIX


393b Bh: Doba-3, 115.4 - 116.2 m
400b Bh: Kapolcs-1, 45.0 - 50.0 m
„Age": 1.77 ± 0.59 My
Intercept: 472.6 ± 55.4
„Age": 2.19 ± 0.58 My
Intercept: 358.6 ± 15.7
„Errorchrons"
$^{40}Ar/^{36}Ar$
$K/^{36}Ar$ [%/(cm$^3$/g)] × $10^{-9}$

XXX

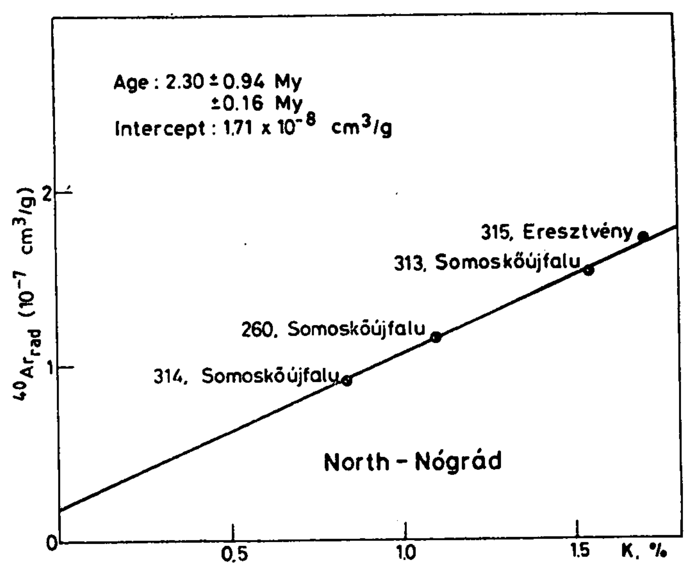

Age : 2.17 ± 0.17 My
Intercept : 291.9 ± 5.1
504/1 Bár-6, 62.0m
440, Bár-4, 18.0m
439, Bár-6, 67.0m
504/2
Jumillite near village Bár
$^{40}Ar/^{36}Ar$
$K/^{36}Ar$ [%/(cm$^3$/g)] × $10^{-9}$

XXXI



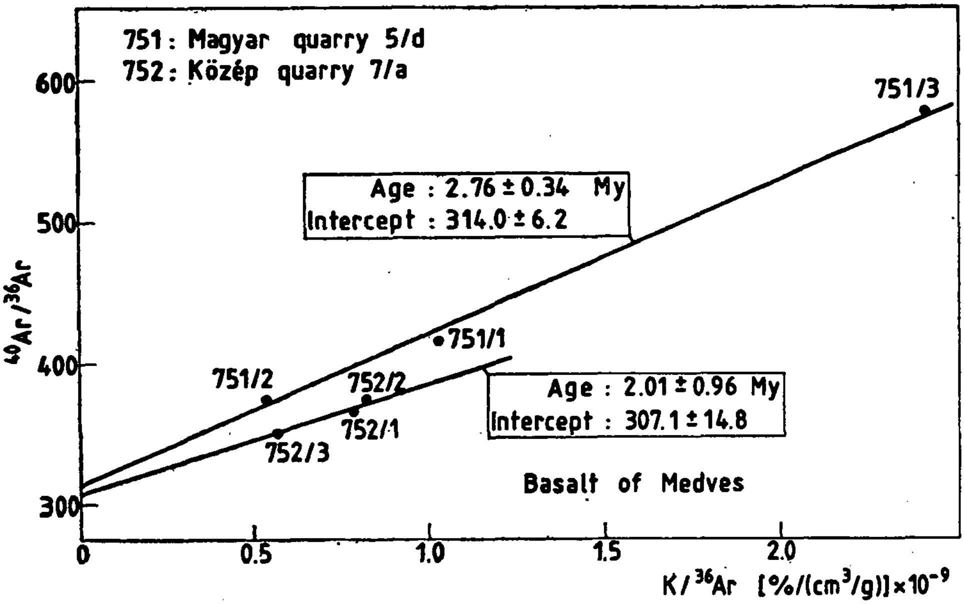
Age : 2.49±0.93 My
Intercept : 297 ±7.6
314, Somoskőújfalu
313, Somoskőújfalu
260, Somoskőújfalu
315, Eresztvény
North - Nógrád
Near town Salgotarján
325
300
0.1
0.2
0.3
$^{40}Ar/^{36}Ar$
$K/^{36}Ar$ [%/(cm$^3$/g)] ×10$^{-9}$


XXXII



Age : 2.30 ± 0.94 My
±0.16 My
Intercept : 1.71 x 10$^{-8}$ cm$^3$/g
315, Eresztvény
313, Somoskőújfalu
260, Somoskőújfalu
314, Somoskőújfalu
North - Nógrád
$^{40}Ar_{rad}$ (10$^{-7}$ cm$^3$/g)
0
1
2
0.5
1.0
1.5
K, %

XXXIII




XXXIV