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INHERITED ZIRCONS OF AN ANISIAN TUFFITE FROM THE SILICA NAPPE (NE HUNGARY): EVIDENCE FOR A HIDDEN CAMBRIAN BASEMENT IN THE TETHYS REALM

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Abstract: A tuffite of Illyrian age containing inherited zircons is present at the base of the Middle Triassic (Anisian) platform carbonate sequence in the Silica Nappe of NE Hungary. The original aim of the study was to date the zircons using the U-Pb Isotopic-Dilution-TIMS method, thereby making the age determination from fossils more precise by establishing the absolute age of the zircons. The upper intercept age of the zircons is 502-23/+26 Ma, which most probably refers to the age of the basement of the Silica Nappe and not the age of the reef because the zircons are inherited. The original basement of the Silica Nappe is today unknown, but the nearest volcanites of similar age are known from the Gelnica unit of the Gemericum in the Vlachovo Formation (Slovakia) which are mostly acid metavolcanics of Late Cambrian-Ordivician age.

Key words: Middle Triassic, Aggtelek-Rudabánya Mts, U-Pb Isotopic-Dilution-TIMS method for single zircons, X-ray diffraction analyses.

1. INTRODUCTION

The investigated zircons originate from a 3cm thick tuffite intercalation from the base of the Upper Anisian (Illyrian) Aggtelek reef which is the oldest Triassic barrier reef in the western Tethys realm.

The original aim of the study was the dating of the acid tuffite with the U-Pb Isotopic-Dilution-TIMS method of single zircons. We wanted to make our age determination gained from conodonts and radiolarians more precisely by way of establishing the absolute age of the zircons. In that way to get valuable information about the age of this unique reef, which yields a very important step in the Early-Middle Triassic reef recovery process after the Permian/Triassic extinction event.

The mineralogical composition of the tuffitic sample (Fj13) has been determined by X-ray diffraction in the Geological Institute of Hungary. The absolute age of the zircons in the sample have been determined in the Laboratory of Institut für Geowissenschaften und Lithosphärenforschung (Giessen, Germany).

To our surprise, all of the zircons investigated were inherited. Consequently instead of determining the age of the reef recovery, we were able to shed light on the age of the original basement. The situation is even more complicated, because the section is from the rootless Silica Nappe, so the original basement from which the zircons originate is presently unknown.

2. GEOLOGICAL SETTING

The Aggtelek reef is situated between Aggtelek and Jósvafő, on the Aggtelek karst. On the surface it can be followed for a distance of 3,5 km with widths varying between 0,4 – 1,3 km and the thickness is ~700m. The Triassic platform formations building up the Aggtelek karst belong to the Silica Nappe which is the uppermost nappe of the Inner West Carpathians (IWC) (Kozur & Mock 1973) (Fig. 1a, 1b, 1c, 2).

In the Triassic the IWC was situated on the northern shelf of the opening Neotethys ocean (Kovács 1982, Tollmann 1987). The rifting of the Neotethys ocean had a profound influence on the evolution of the Silica Nappe.

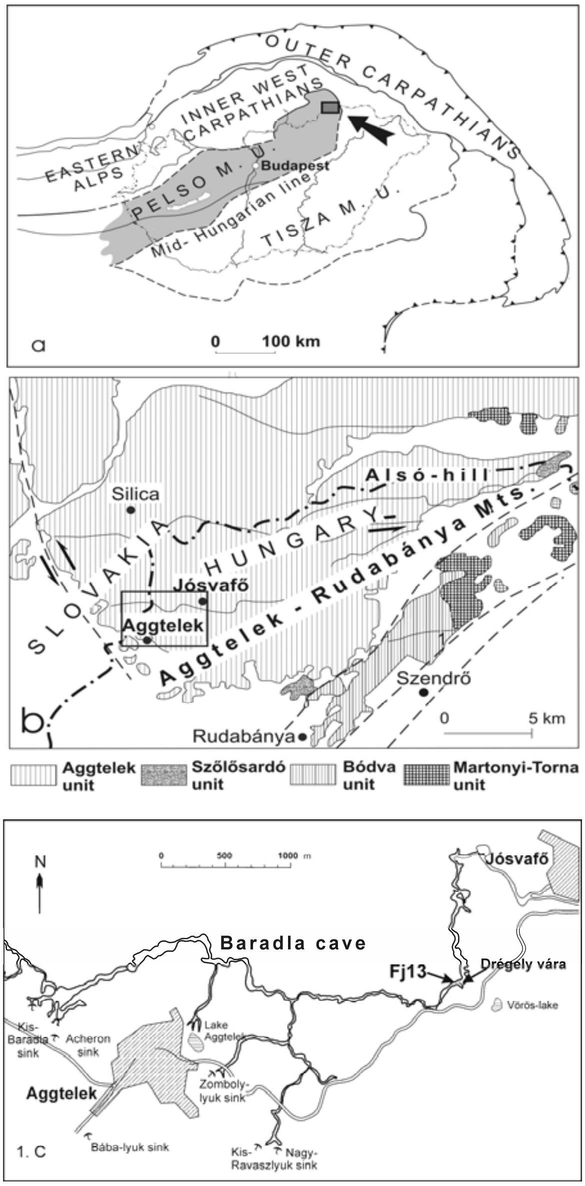

Figure 1a: Location of the studied area and the major geological units of the Pannonian Basin.
Figure 1b: Tectonofacies (facies) units of the Silica Nappe, after the Middle Triassic differentiation of the basement. Simplified after Less, 1998.
Figure 1c: Location of the investigated tuffite layer (FJ13) in the Baradla cave. The arrow indicates the investigated layer.

Triassic layers of the Silica nappe were detached from its original (today unknown) basement along the Upper Permian-Lower Scythian evaporites.

3. SAMPLE DESCRIPTION AND ANALYSIS

3.1. Sample description

The investigated zircons originate from a 3 cm thick tuffite layer (sample Fj13) from the base of the reef limestone (Wetterstein reef; Fig. 3). The tuffite can be found in the Baradla cave at "Drégely vára" on the W side of the cave.

The footwall of the reef is the Illyrian deep water limestone (Jenei Formation). Its age is determined by conodonts (Gondolella szaboi, G. excelsa, G. liebermani, G. constricta cornuta, Gladigondolella tethydis, Gl. budurovi refer to Early – Middle Illyrian (a time interval: Trinodosus Zone up to the most part of the Reitzi Zone). All conodonts were determined by the late S. Kovács.

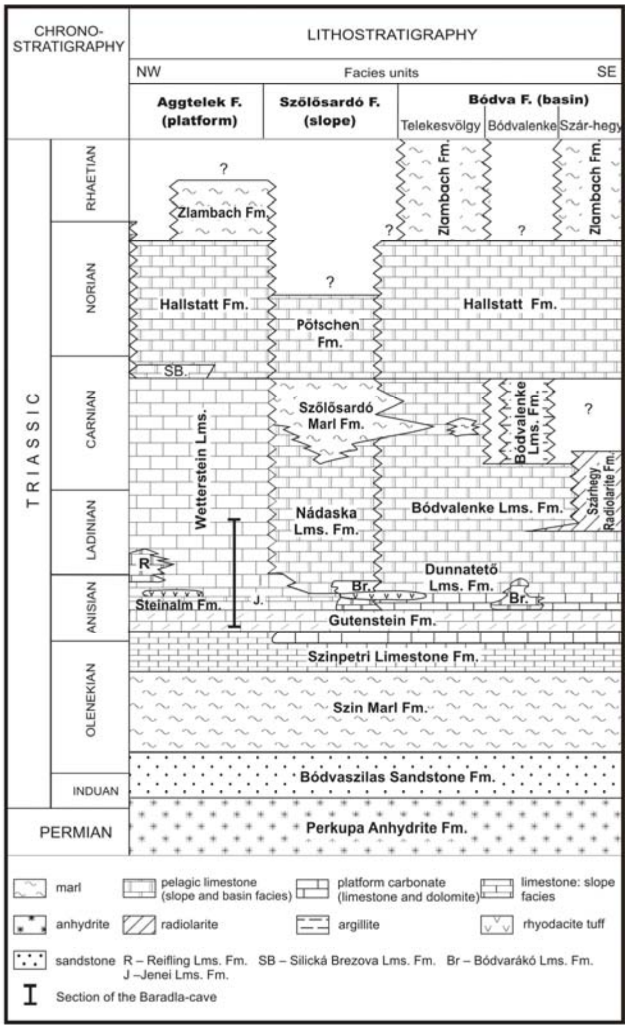

Figure 2. Lithostratigraphical units of the Aggtelek platform in the Triassic. I indicates the Middle Triassic sequence of the Aggtelek platform. The studied inherited zircons originate from a tuffite layer from the base of the reef limestone (Wetterstein Limestone) (see also Fig. 3).

The top of the Jenei Formation is followed by four radiolarite layers, each of which is 2 cm thick. The fourth radiolarite layer is covered by the 3 cm thick acid tuffite layer in which the zircons were found. This is followed by a 2 cm thick limestone layer, on the top of which a thin radiolarite layer appears again.

The radiolarians (Annulotriassocampe campanilis Kozur and Mostler, Eptingium manfredi Dumitrica gr., Eptingium cf. ramovsi Kozur, Krainer and Mostler, Pararuesticyrtium ? cf. illyricum (Kozur and Mostler), Pseudostylosphaera sp., Spongosilicarmiger scabiturritus Sugiyama Spongostephanidium cf. spongiosum Dumitrica) of the radiolarite layers are proof of an Illyrian (?Late-Illyrian) age (detetmined by P. Dumitrică).

The first sponge of the reef appeared immediately above the last radiolarite layer. The radiolarite and the tuffite layers are followed by a 640 m thick reef limestone. The top of the reef turned into lagoonal sediments in the Lower Ladinian (Fig. 3).

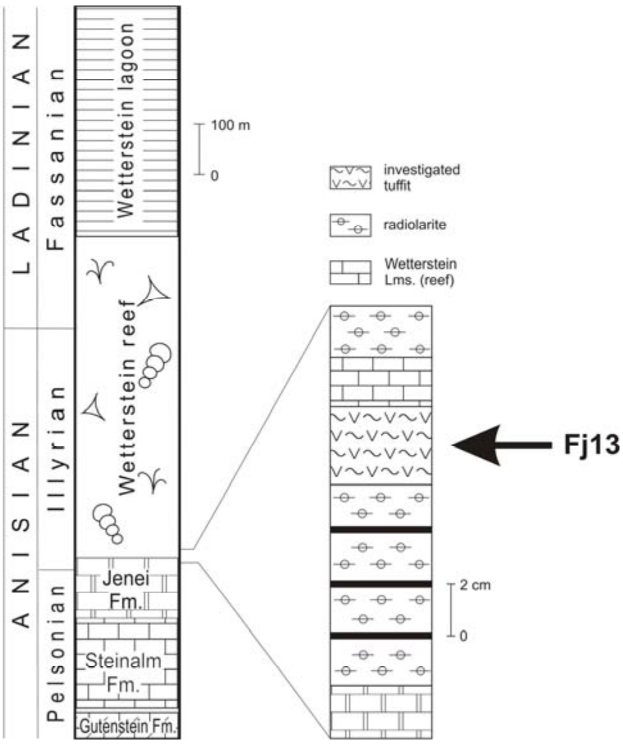

Figure 3. Geological profile of the Baradla cave.

3.2. Mineralogy and petrography of the tuffite

The X-ray diffraction analyses were done using a Philips PW 1730 diffractometer under the following conditions: Cu anti-cathode, 40 kV and 30 mA tube-current, graphite monochromator, and goniometer speed 2°/minute. The mineral composition was calculated on the basis of the relative intensity rates of the reflections characteristic of the minerals, with reference to the literature or to experimental corundum factors relevant to the minerals.

On the original powder photographs the clay minerals generally appear to be poorly ordered. For more detailed research, orientated samples were prepared from the <2 μ clay-mineral fraction separated by an Atterberg cylinder. The samples were analysed by X-ray diffraction in an untreated state (FN), treated with ethylene-glycol (EG — 60°C/9 hour), and heated (H — 490 °C/4 hour).

The original sample comprised illite and illite-montmorillonite mixed-layer clay minerals (61%), calcite (24%), goethite (6%), quartz (2%) and amorphous phase (6%).

Analysing the smaller than 2μ fraction of the same sample, we determined the following mineralogical composition: illite-vermiculite-smectite? randomly mixed-layer clay mineral (22%), illite $2M_1$ (58%) and kaolinite (20%), (Fig. 4). The mixed-layer clay mineral also contains discrete smectite which did not appear in the untreated diffractogram (d value 11,5Å) although it can be observed in the form of a slight swelling in the diffractogram treated with ethylene-glycol (d value 10,8Å). The kaolinite is relatively well ordered, since it demonstrates both the $1\bar{1}0$ and $1\bar{1}\bar{1}$ reflections, and it is still present after raising the temperature up to 490°C.

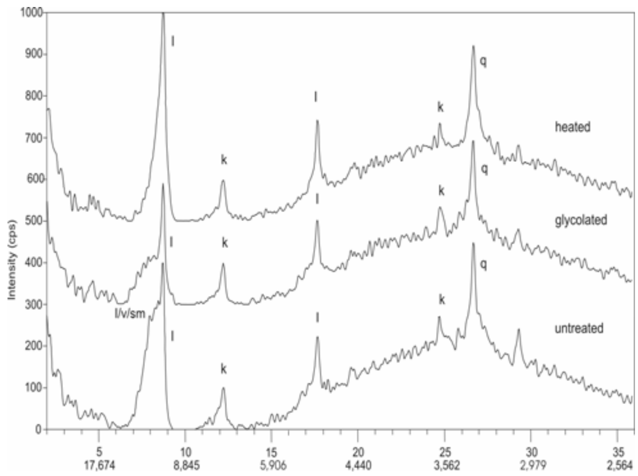

Figure 4. X-ray diffractogram of the <2μ fraction of the sample Aggtelek FJ13. Legend: i (illite), i/v/sm (illite-vermiculite-smectite? mixed layer), k (kaolinite), q (quartz). See text for explanation.

Based on the above-mentioned composition, we can assume that from the biotite of the acidic vulcanite an illite-vermiculite-smectite? randomly mixed-layer clay mineral was formed, while from the feldspar kaolinite was formed. The $2M_1$ illite has a detrital origin, and may be a consequence of erosion. Based on the above-mentioned mineralogical composition it can be stated that the original rock could be acidic vulcanite (rhyolite-rhyodacite-dacite) which originated either in situ through halmirolysis, or it was eroded from the continent nearby.

3.3. U-Pb Isotopic-Dilution-TIMS method for single zircons

After the removal of the weathered surfaces, the sample was crushed and sieved. Heavy mineral concentrates were obtained using bromoform and a magnetic separation (Frantz). Zircons, free of inclusions, were selected for isotopic analyses. The zircons were abraded for 6 to 24 hours with pyrite and washed with HNO_3 and 2N HCl in an ultrasonic bath (Krogh, 1982). Dissolution and separation of U and Pb were carried out after Krogh (1973). Single zircons were mixed with a ^{235}U-^{205}Pb spike in a teflon vessel within an autoclave, and digested over six days at 180 °C with 24N HF. After removal of the SiF_4 and excess HF at 80 °C, the samples were treated for one day at 180°C with 3N HCl. The U-Pb separation was carried out with 80 µl columns containing an ion-exchange resin (Bio-Rad, AG 1x8, 100–200 mesh) in a stepwise eluation process. The isotopic ratios were measured with a Finnigan MAT 261 solid-source mass spectrometer in multi-collector static mode simultaneously with an ion-counting system for ^{204}Pb at the Justus-Liebig-Universität Giessen, Germany. The measured Pb isotopic ratios were corrected for mass fractionation (1.12 ± 0.18 ‰ per a.m.u.), blank, and initial Pb. Pb blanks were about 3–5 pg with isotopic ratios of $^{208}Pb/^{204}Pb$ = 37.5, $^{207}Pb/^{204}Pb$ = 15.52 and $^{206}Pb/^{204}Pb$ = 17.72. The isotopic ratio of the initial Pb was taken from Stacey and Kramers (1975). The calculation and correlation of errors for $^{206}Pb/^{238}U$ and $^{207}Pb/^{235}U$ were carried out using the program PbDat (Ludwig, 1988). Ages were calculated using the decay constants of Jaffey et al., (1971). Regression lines and concordia diagrams were constructed using the program Isoplot (Ludwig 2000).

4. RESULTS

The investigated Triassic clay contains only a few zircons, which are different in colour, shape and age. All the euhedral zircons display faces combinations which are typical for magmatic zircons (Pupin 1980). The red coloured single zircon 2597 (P-type according to Pupin 1980) is close to concordia at ca. 480 Ma and define together with the colourless single S-type zircon 2596 and the red coloured P-type zircon a discordia with an MSWD of 0.91 and an upper intercept with the concordia curve at 502 – 23/+26 Ma and a lower intercept at 79 ± 34 Ma (Tables 1-2, Fig. 5). A small fraction (2601) of three pink coloured P-type zircons and large fragment of a pink coloured zircon (2589) have higher apparent U-Pb ages and plot far away from the discordia. There is no evidence of Triassic zircons in the tuffite. All the U-Pb analyses point to inherited zircons.

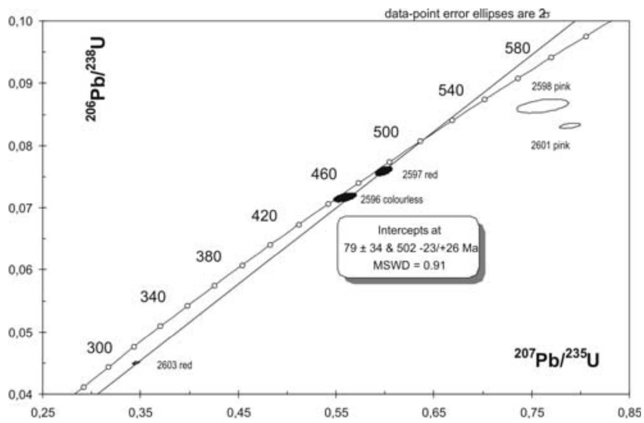

Figure 5. Concordia diagramm of the Triassic tuff layer (sample Aggtelek FJ13). Errors are quoted at 2 sigma level.

Table 1: U-Pb isotopic dilution TIMS data of the tuffite layer (sample Aggtelek FJ13).

Sample	Weight µg	U ppm	Pb r. ppm	Pb i. ppm	$^{206}Pb/^{204}Pb$	$^{206}Pb/^{238}U$	±2σ %	$^{207}Pb/^{235}U$	±2σ %	$^{207}Pb/^{206}Pb$	±2σ %	Cor.
2597-P-r	14	184.9	13.8	1.19	751	0.07576	±0.83	0.59868	±1.20	0.05731	±2.83	0.50
2596-S-c	14	175.6	11.6	2.01	408	0.07155	±0.87	0.55941	±1.76	0.05670	±1.50	0.53
2603-P-r	19	343.1	15.1	1.07	923	0.04485	±0.54	0.34546	±0.89	0.05587	±0.67	0.66
2601-P-p	18	261.2	21.3	1.15	1208	0.08310	±0.42	0.78901	±1.10	0.06886	±0.98	0.46
2598-p	11	139.1	12.3	6.52	133	0.08624	±1.11	0.76119	±2.82	0.06402	±2.53	0.44

Errors are quoted at 2 sigma level. An asterisk means corrected for mass fractionation (1.12 ± 0.18 ‰ per a.m.u.), ^{205}Pb-spike contribution and analytical blank. Pb r. = radiogenic lead; Pb i. = initial common lead; Cor. = correlation coefficient of ^{207}Pb / ^{235}U to ^{206}Pb / ^{238}U errors. P = P-type zircon after Pupin (1980); S = S-type zircon after Pupin (1980); r = red colour; c = colourless; p = pink colour.

Table 2. Apparent ages (Ma) based on the U-Pb isotopic dilution TIMS data

Sample	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$
2597-P-r	471±4	476±5	503±58
2596-S-c	446±4	451±9	481±33
2603-P-r	283±2	301±3	447±15
2601-P-p	515±3	591±6	895±20
2598-p	533±5	575±16	742±54

5. DISCUSSION

There are different explanations for the origin of the zircons, as follows:

1. The zircons originated from the surrounding limestone and were recycled during the recovery of the Triassic reefs.
2. The zircons are reworked from clastic sediments of the section from a horst or half graben structure and were recycled into the tuffite.
3. The zircons were incorporated during the magma ascent during the Illyrian time and were transported through the air along with the pyroclastic rocks.

There are a lot of arguments against the first and second explanations, so only the most important facts will be discussed here.

Ad 1. The Aggtelek unit (Silica nappe) is interpreted as a tectonostratigraphic unit, which was close to the oceanic realm in the Triassic. It is too far away to have been fed with clastic material from the continent. Formations of the Aggtelek unit are built up of autochthon limestone and chemical sediments: evaporites, primary dolomites, algal mats, sponge and Tubyphites reefs. None of these sediments contain detrital material larger than 2 µm.

Ad 2. There is only the Bódvaszilas sandstone in the section which is still covered by the carbonate platform formed during the Illyrian. No tectonic activity is known from the Early Triassic which could have produced half grabens. The sandstone could not be the region of origin of the tuffite.

Ad 3. The Illyrian tuffite together with the large (up to 200 µm) euhedral magmatic zircons (Pupin 1980) is an exotic igneous rock in the West-Carpathian realm.

Most probably this volcanic activity was connected with the opening of the Vardar-Meliata branch of the Neotethys Ocean. There are a few round-edged zircons but the majority have a euhedral shape which could not have traveled from far away. The zircons must have been transported in a medium which preserved the euhedral shape. In acid magmas the zirconium saturation is always high, so that large inherited zircons are able to survive (Watson & Harrison, 1983). Acid volcanoes of Triassic age are known from the South Alpine realm, which could be the source of the tuffite. The upper intercept age of 502 –23/+26 Ma probably reflects the age of the basement, where the magma of the acid tuffite was generated. The nearest volcanites of similar age are known from the Gelnica unit of the Gemericum, from the Vlachovo Formation (Slovakia). These are mostly acid metavolcanics of Late Cambrian-Ordovician age (Snopková & Snopko, 1979).

There are many examples of ca. 500 Ma U-Pb dating of igneous rocks in the Western Alps (Raumer et al., 2002, many works undertaken by Schaltergger et al., 1997), Crete (Romano et al., 2004, Dörr et al., 2004) and Turkey (Hetzel & Reischmann, 1996; Hetzel et al., 1998). Our finding could probably close the West-Carpathian information gap.

6. SUMMARY

According to facies analogy, Triassic sequences of the Silica nappe were deposited on the northern shelf of the opening Vardar-Meliata Ocean (Kovács 1982, Kováč 2002). The Illyrian volcanic activity acted as a sampling tool and transported the euhedral basement zircons within an ashflow into the Aggtelek section. The Silica nappe was later detached from its basement along its Upper Permian-Lower Scythian evaporitic horizon. The original basement of the Silica nappe is today unknown, but the zircons examined by us provide information about the original basement of the nappe, and thus they can make a significant contribution to the further investigations concerning the basement of the Silica nappe.

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