Doctoral School of Geosciences

RESULTS OF THE COMPLEX ANALYSES OF THE GYŰRŰFŰ RHYOLITE FORMATION IN THE TISZA MEGA-UNIT (HUNGARY)

THESES OF THE DOCTORAL DISSERTATION

MÁTÉ ANDRÁS SZEMERÉDI

Supervisor: *Dr. Andrea Raucsikné Varga*

assistant professor, Department of Mineralogy, Geochemistry and Petrology, University of Szeged

Consultant: *Dr. Réka Haranginé Lukács*

researcher, MTA-ELTE Volcanology Research Group

Department of Mineralogy, Geochemistry and Petrology

Faculty of Science and Informatics

University of Szeged

2020

Szeged

RESULTS OF THE COMPLEX ANALYSES OF THE GYŰRŰFŰ RHYOLITE FORMATION IN THE TISZA MEGA-UNIT (HUNGARY)

Theses of the doctoral dissertation (Máté András Szemerédi)

INTRODUCTION AND AIMS

The Gyűrűfű Rhyolite Formation is the only magmatic association within the thick Permo-Carboniferous intramontane molasse sequence of the Tisza Mega-unit (Hungary). The formation crops out in the Western Mecsek Mts, Southern Transdanubia; however, it was penetrated by uranium ore (S Transdanubia) and hydrocarbon exploration (eastern Pannonian Basin, SE Hungary) boreholes during the second half of the 20th century. Based on these wells, the following principal subsurface areas of the Gyűrűfű Rhyolite were separated: (1) the Western Mecsek Mts, (2) the northern foreland of the Villány Mts and (3) the Máriakéménd–Báta Basement Range in S Transdanubia as well as (4) the Kelebia area and (5) the Battonya–Pusztaföldvár Basement Ridge in the eastern Pannonian Basin. Recognition of the volcanic rocks was associated with the previous reports of the exploration works (e.g., Szederkényi 1962; Szepesházy 1967; Fazekas 1978; Barabásné Stuhl 1988), according to which the formation was basically interpreted as rhyolitic lava (‘quartz-porphyry’), while other lithologies (e.g., pyroclastite, subvolcanic rock) were supposed to be subordinate.

The possible pyroclastic origin was already raised in the early stage of the research (Pantó in Boczán et al. 1966) and more than 40 years later supported by petrographic studies (e.g., Varga 2009; Hidasi et al. 2015). Based on the identification of oriented, devitrified pumices (fiammes) in the drill cores and the gravel material in the Western Mecsek Mts, suggesting unequivocally pyroclastic

(ignimbrite) origin, the attention was drew to the significance of the reconsideration of archive reports. Besides the question of the dominant eruption style (effusive or explosive), limited geochemical information and no zircon U–Pb datings were available for the Gyűrűfű Rhyolite. The latter are important regarding the stratigraphic marker role of the formation (supposed to be a Lower Permian horizon) in the Late Palaeozoic sedimentary sequences.

Thus, the major aims of the PhD research were (1) the petrographic (re)examination of almost all the available drill cores and outcrops (including archive samples and the associated reports), (2) the geochemical analyses (including major and trace elements) of the samples and (3) to obtain the crucial zircon U–Pb radiometric ages. The new results were integrated at larger-scale in order to explore the Permian magmatic system of the Gyűrűfű Rhyolite (source, geotectonic setting, eruption styles, volcanic eposides etc.). Moreover, the results were compared to those of the other Permian felsic volcanic rocks in the Central European Variscides (especially in the Carpathian–Pannonian region, e.g., Central Transdanubia, Central Western Carpathians, Apuseni Mts) to come up with the preliminary results of the local to regional correlation of the Tisza Mega-unit.

APPLIED METHODS

Almost all the available drill cores and outcrop rock samples of the Gyűrűfű Rhyolite Formation were targeted by petrographic observations and reinterpreted, using archive data (e.g., drilling

reports) of the previous uranium ore and hydrocarbon exploration works. Drill core (hand specimen and thin section) collections include those of (1) the Department of Mineralogy, Geochemistry and Petrology, University of Szeged, (2) the Department of Petrology and Geochemistry, Eötvös Loránd University and (3) the Mecsek Ore Mining Company (present-day Mecsekérc Ltd.). Petrographic observations were done at the Department of Mineralogy, Geochemistry and Petrology, University of Szeged using Brunel SP-300-P and Olympus BX41 polarizing microscopes.

A total of 18 samples were selected for whole-rock geochemistry representing all the outcrop and subsurface occurrences of the Gyűrűfű Rhyolite. These specimens were powdered and analyzed at the Bureau Veritas Mineral Laboratories (AcmeLabs, Vancouver, Canada) by ICP-ES (major elements) and ICP-MS (trace elements including rare earth elements).

Moreover, zircon crystals were separated (standard heavy mineral seperation method including crushing, sieving, heavy liquid separation, magnetic separation and hand picking) from five samples of the Gyűrűfű Rhyolite representing its outcrop locality and three distinct subsurface areas. Cathodoluminescence mapping was done at the Department of Petrology and Geochemistry, Eötvös Loránd University using an AMRAY 1830 scanning electron microscope equipped with a GATAN MiniCL. In situ U–Pb radiometric age determinations were performed at the ETH, Zürich, Switzerland and

the Georg-August University, Göttingen, Germany by Réka Lukács and István Dunkl, respectively.

NEW SCIENTIFIC RESULTS

T1 Based on the detailed textural observation of the outcrop rock samples of the Permian Gyűrűfű Rhyolite Formation (Gyűrűfű area, Western Mecsek Mts), several characteristic features of pyroclastic rocks (e.g., devitrified fiammes, altered glass shards, poor sorting, broken phenocrysts, lithic clasts) were identified. The abovementioned features refer to pumiceous pyroclastic flow (ignimbrite) origin of the studied rocks. According to the deformation of the juvenile components, two distinct lithofacies have been separated among the observed samples: (1) eutaxitic, welded and (2) non-welded crystal-rich, pumice-bearing lapilli tuffs. The former might represent the moderate to greater depths of the proximal part of a valley-filling pyroclastic flow, while the latter could be derived from its upper, lowermost, sideward or distal part. My observations conflict the traditional lava interpretation of the Gyűrűfű Rhyolite (e.g., uranium ore exploration works) in the study area and support the explosive eruption origin of the drill cores from the Western Mecsek Mts.

T2 All the available archive rock samples and thin sections of the Gyűrűfű Rhyolite Formation exposed by boreholes at the northern foreland of the Villány Mts (Bisse-1, Egerág-7, Peterd-1, Szalánta-3,

Szava-1, Vókány-2) were studied in the light of modern volcanological views. Based on my detailed petrographic observations, felsic pyroclastic rocks (Peterd-1 borehole and the upper volcanic sequences of the Bisse-1, the Egerág-7, the Szalánta-3 and the Vókány-2 boreholes) and lavas/subvolcanic rocks (Szava-1 borehole and the lower volcanic sequences of the Bisse-1, the Egerág-7, the Szalánta-3 and the Vókány-2 boreholes) have been revealed in the study area. My results contradict the previous hypotheses according to which a wide range of volcanic rock types (e.g., volcanic vent facies, 'microgranite porphyry', lavas with tuff intercalations) occur in the study area and the importance of pyroclastic rocks is subordinate. The Permian felsic volcanism at the northern foreland of the Villány Mts could be reconstructed by a more simple model, suggesting the formation of felsic lava domes and associated flow mechanism, afterwards covered by an extensive, probably several hundred metres thick ignimbrite sheet.

T3 All the available rock samples of the Gyűrűfű Rhyolite Formation in SE Hungary (Battonya–Pusztaföldvár Basement Ridge), exposed by hydrocarbon exploration boreholes, were observed in details. The following rock varieties have been revealed: devitrified fiamme-bearing welded and rheomorphic ignimbrites (crystal-poor lapilli tuffs, Battonya area), lava-like ash tuffs (Tótkomlós area) and volcaniclastites (Biharugra and Tótkomlós areas). Based on textural features, the phases of re-crystallization for each lithofacies were

given, as well. Based on my observations, the previous lava ('quartz-porphyry') interpretation in the study area has been confuted, too. The studied samples give the most evolved, rhyolitic composition among the Gyűrűfű Rhyolite samples suggesting that they represent the most evolved known magma composition of the Permian regional volcanism in the Tisza Mega-unit. Supplemented by zircon U–Pb ages, it was revealed that the Variscan "Battonya granite" and the Permian felsic volcanic rocks of the Battonya area could not be in a plutonic–volcanic connection.

T4 All the available archive and new whole-rock (major and trace elements) geochemical data of the Gyűrűfű Rhyolite Formation were interpreted (representing outcrop rock samples and drill cores of the Western Mecsek Mts, the northern foreland of the Villány Mts, the Máriakéménd–Báta Basement Range, the Kelebia area and the Battonya–Pusztaföldvár Basement Ridge). It was revealed that the observed rocks were dominantly affected by significant post-magmatic alterations (e.g., K-metasomatism); thus, their major element composition is not suitable for rock classification and genetic interpretations. It has been pointed out that their lithological caterogization is not straitforward and should not be done based solely on the mineralogical and major element compositions.

T5 Based on the trace element (rare earth and high field strength elements) data, all the available felsic volcanic rocks of the Gyűrűfű

Rhyolite Formation proved to be geochemically similar; thus, their petrogenetic processes could have been similar, too. Immobile element compositions showed that the rocks of Southern Transdanubia (Western Mecsek Mts, northern foreland of the Villány Mts, Máriakéménd–Báta Basement Range) and the Kelebia area are rhyodacites–dacites, while rhyolitic pyroclastic rocks were only exposed by the boreholes in the Battonya–Pusztaföldvár Basement Ridge. Trace element compositions refer to a post-collisional extensional environment which is fitting well to the geotectonic setting (continental rifting) of the analogous formations in the European Variscides.

T6 Zircon crystals were separated and observed (e.g., binocular, back-scattered and cathodoluminescence microscopy) representing samples of all the outcrop and subsurface occurrences of the Gyűrűfű Rhyolite Formation. The representative new zircon U–Pb ages, being derived from the crystal mounts prepared by myself, were interpreted in the aspect of the Late Palaeozoic evolution of the region. Based on the geochronological results, it was pointed out that the Gyűrűfű Rhyolite is the product of Mid-Permian (~ 269–260 Ma) magmatic events. The latter contradicts the previous hypotheses, according to which the Gyűrűfű Rhyolite was formed by a single volcanic episode and represent a Lower Permian marker horizon. In accordance with the abovementioned results, the lithostratigraphic position of the whole

Permian sequence of the Tisza Mega-unit (especially in Southern Transdanubia) should be reconsidered and modified.

T7 Based on the complex results, besides the local correlation, the regional correlation of the Gyűrűfű Rhyolite Formation was performed, as well. It was proved that there is no genetic connection between the Gyűrűfű Rhyolite and the other well-known Permian felsic volcanic formation in Hungary, the so-called Kékkút Dacite (Central Transdanubia, ALCAPA Mega-unit). Based on my observations, the latter is the result of an older (~ 281 Ma), Lower Permian, geochemically distinct magmatic event. However, close relationship has been found between the Permian felsic volcanic rocks of the Apuseni Mts (Tisza Mega-unit) and the Gyűrűfű Rhyolite that might represent the same or similar magmatic system. Moreover, the theory has been raised that the abovementioned rocks could be in a volcanic–plutonic connection with the Permian (~ 268–264 Ma) granitoid rocks of the Highiş massif (SW Apuseni Mts). However, the verification of this connection needs further studies and evidence. Slighter correlations were found between the Gyűrűfű Rhyolite and the Permian felsic volcanic rocks in the Central Western Carpathians (Silicic and Southern Gemeric Units).

REFERENCES

Barabásné Stuhl Á (1988) A Dél-Baranyai dombság és a Villányi hegység permi képződményeinek kutatásáról készített összefoglaló jelentés IV. fejezete a permi képződményekről. Mecsekérc Ltd. (former Mecsek Ore Mining Company), pp 100–213 **(in Hungarian)**

Boczán B, Franyó F, Frits J, Láng S, Moldvay L, Pantó G, Rónai A, Stefanovits P (1966) M-34-XXXIV. Sátoraljaújhely. Magyarázó Magyarország 200 000-es földtani térképsorozatához. MÁFI, Budapest **(in Hungarian)**

Fazekas V (1978) Kutatási Zárójelentés: A magyarországi felső-paleozoos vulkanitok ásvány-kőzettani-, kémiai-, valamint sugárzóanyag-tartalom vizsgálata. Closing report, Mecsek Ore Mining Company (J-3033) **(in Hungarian)**

Hidasi T, Varga A, Pál-Molnár E (2015) Petrographic analysis of Gyűrűfű Rhyolite Formation using the thin section collection of Mecsek Ore Company. Földtani Közlöny 145(1):3–22 **(in Hungarian with English abstract)**

Szederkényi T (1962) Földtani jelentés a Ny-Mecseki (Gyűrűfű) kvarcporfír földtani, kőzettani és radiológiai vizsgálatának eredményeiről. Report, Mecsekérc Ltd. (former Mecsek Ore Mining Company) **(in Hungarian)**

Szepesházy K (1967) Kőzettani adatok a battonyai gránit megismeréséhez. Annual report of the Geological Institute of Hungary from 1967, pp 227–266 **(in Hungarian)**

Varga A (2009) A dél-dunántúli paleozoos–alsó-triász sziliciklasztos kőzetek kőzettani és geokémiai vizsgálatának eredményei. PhD Thesis,

Department of Petrology and Geochemistry, Eötvös Loránd University, Budapest **(in Hungarian)**

LIST OF PUBLICATIONS RELATED TO THE PHD THESIS

Máté Szemerédi (MTMT author ID: 10055671)

1) Articles used for the PhD Thesis

Szemerédi M, Varga A, Szepesi J, Pál-Molnár E, Lukács R (2020) Lavas or ignimbrites? Permian felsic volcanic rocks of the Tisza Mega-unit (SE Hungary) revisited: A petrographic study. Central European Geology (in press)

Szemerédi M, Lukács R, Varga A, Dunkl I, Józsa S, Tatu M, Pál-Molnár E, Szepesi J, Guillong M, Szakmány Gy, Harangi Sz (2020) Permian felsic volcanic rocks in the Pannonian Basin (Hungary): new petrographic, geochemical, and geochronological results. International Journal of Earth Sciences, 109, 101–125 (impact factor in 2018: 2.295)

Szemerédi M, Varga A, Lukács R, Pál-Molnár E (2017) A Gyűrűfűi Riolit Formáció kőzettani vizsgálatának eredményei a Villányi-hegység északi előterében (in English: Petrography of the Gyűrűfű Rhyolite Formation, northern foreland of the Villány Mts, Hungary). Földtani Közlöny, 147/4, 357–382 (**in Hungarian with English abstract)**

Szemerédi M, Varga A, Lukács R, Pál-Molnár E (2016) A Gyűrűfűi Riolit Formáció kőzettani vizsgálata a felszíni előfordulások alapján (Nyugati-Mecsek) (in English: Petrography of the Gyűrűfű Rhyolite Formation, Western Mecsek Mts, Hungary). Földtani Közlöny, 146/4, 335–354 **(in Hungarian with English abstract)**

2) Other publications

Szemerédi M (2017) Cirkonvizsgálatok a Gyűrűfűi Riolit Formáció felszíni feltárásainak kőzetanyagából (Nyugati-Mecsek). essay, XXXIII National Scientific Students' Associations Conference, Debrecen **(in Hungarian)**

Szemerédi M (2015) A Gyűrűfűi Riolit Formáció kőzettani jellemzése a Gyűrűfű és Dinnyeberki közötti felszíni feltárások alapján). essay, XXXII National Scientific Students' Associations Conference, Cluj-Napoca **(in Hungarian)**

3) Conferences, abstracts

Szemerédi M, Lukács R, Varga A, Dunkl I, Seghedi I, Tatu M, Pál-Molnár E, Szepesi J, Harangi Sz (2020) Permian magmatism in the Carpathian–Panonnian region (Hungary and Romania): New geochronological and geochemical results, conference abstract, European Geosciences Union General Assembly, Vienna, EGU2020-8405.

Szemerédi M, Lukács R, Varga A, Dunkl I, Seghedi I, Pál-Molnár E, Harangi Sz (2019) Permian felsic volcanism in the Tisza Mega-unit (basement of the Pannonian Basin and Apuseni Mts) – Zircon U-Pb dating and geotectonic implications from a regional marker horizon. conference abstract, ILP 2019 :14th Workshop of the International Lithosphere Program Task Force Sedimentary Basins, Hévíz, pp 159–161

Raucsik B, **Szemerédi M**, Mészáros E, Varga A, Dunkl I, Lukács R, Pál-Molnár E, Harangi Sz (2019) Kisfokú metamorfózis nyomai permi aljzati képződményekben (Kelebia, Békés-Codrui Egység).

conference abstract, 10th Assembly of Petrology and Geochemistry, Mátraháza, p.74 **(in Hungarian)**

Szemerédi M, Vígh Cs, Lukács R, Varga A, Seghedi I, Pál-Molnár E, Dunkl I, Fehér K, Harangi Sz (2019) Magmás gránátok: kulcsszerep a Tisia permi Si-gazdag vulkanitjainak petrogenetikájában? conference abstract, 10th Assembly of Petrology and Geochemistry, Mátraháza, pp 82–85 **(in Hungarian)**

Szemerédi M, Varga A, Szepesi J, Pál-Molnár E, Lukács R (2019) Láva vagy ignimbrit? Átalakult és felülírt szövetek permi savanyú vulkáni kőzetekből (DK-Magyarország, Tiszai-főegység, Békés-Codru szerkezeti öv). conference abstract, 10th Assembly of Petrology and Geochemistry, Mátraháza, p 81 **(in Hungarian)**

Szemerédi M, Lukács R, Varga A, Dunkl I, Tatu M, Seghedi I, Pál-Molnár E, Harangi Sz (2019) Could Permian felsic volcanic rocks and granites in the Tisza Mega-unit (Pannonian Basin) be in a plutonic–volcanic connection? Implications from zircon U-Pb geochronology and whole-rock geochemistry. conference abstract, European Geosciences Union General Assembly, Vienna, paper EGU2019-253.

Szemerédi M, Lukács R, Varga A, Seghedi I, Tatu M, Dunkl I, Pál-Molnár E, Harangi Sz (2018) Permian volcanism in the Tisza Mega-unit: new petrographic, geochemical and geochronological results from Hungary and Romania, conference abstract, XXI International Congress of the Carpathian Balkan Geological Association (CBGA), Salzburg, p 127

Szemerédi M, Varga A, Lukács R, Dunkl I, Seghedi I, Tatu M, Pál-Molnár E, Harangi Sz (2018) A Tisia permi vulkanizmusa: petrográfiai,

geokémiai és geokronológiai eredmények (in English: Permian volcanism in the Tisia Terrane: petrographic, geochemical and geochronological results). conference abstract, 9th Assembly of Petrology and Geochemistry, Szentkút, pp 161–162 **(in Hungarian with English summary)**

Szemerédi M, Varga A, Tatu M, Seghedi I, Dunkl I, Pál-Molnár E, Lukács R (2018) Permian volcanism vs. Alpine nappe stacking: petrographic and geochemical observations for regional correlation of the Permian felsic volcanic rocks, Tisza Mega-unit (Hungary and Romania). conference abstract, European Geosciences Union General Assembly, Vienna, paper EGU2018-1771.

Szemerédi M, Varga A, Lukács R, Pál-Molnár E (2016) A Gyűrűfűi Riolit Formáció kőzeteinek komplex vizsgálata a Szava–1 és a Vókány–2 mélyfúrásokban. conference abstract, 7th Assembly of Petrology and Geochemistry, Debrecen, pp 91–94 **(in Hungarian)**

Raucsik B, Varga A, Mészáros E, **Szemerédi M** (2016) Very low-grade metamorphism of the Cisuralian basement formations (Korpád Sandstone, Gyűrűfű Rhyolite) near Kelebia, Békés–Codru Unit, Hungary. conference abstract, 8th Mid-European Clay Conference, Košice, p 181

Szemerédi M, Varga A, Lukács R, Schubert F, Pál-Molnár E (2015) Cirkonvizsgálatok a Gyűrűfűi Riolit Formáció felszíni feltárásainak kőzetanyagából (Nyugati-Mecsek), conference abstract, 6th Assembly of Petrology and Geochemistry, Păuliş, p 110 **(in Hungarian)**

Szemerédi M (2015) A Gyűrűfűi Riolit Formáció kőzettani jellemzése a Gyűrűfű és Dinnyeberki közötti felszíni feltárások alapján.

conference abstract, Abstract book of the XXXII National Scientific Students' Associations Conference – Physics, Earth Sciences and Mathematics Session, Cluj-Napoca **(in Hungarian)**

Szemerédi M, Varga A, Lukács R (2014) A Gyűrűfűi Riolit Formáció kőzettani jellemzése a Gyűrűfű és Dinnyeberki közötti felszíni feltárások alapján). conference abstract, 5th Assembly of Petrology and Geochemistry, Révfülöp, p 84 **(in Hungarian)**