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Chapter 6

Second International Maar Conference — Hungary–Slovakia–Germany

Concluding remarks

Contents

Summary

On the basis of volcanological research of the past 10 years it can be concluded that the Neogene alkaline basaltic rocks in the western Pannonian Basin (Plate 6.1) represent eroded remnants of former maars, tuff rings, tuff cones, scoria cones, dykes, sills and lava fields. The erosional remnants can be clearly identified on satellite images as semicircular buttes (Plate 6.1). The number of studied sites almost includes every location where pyroclastic rocks have been reported over the past hundred years of research history of the western Pannonian region (LÓCZY 1913, 1920, MAURITZ and HARWOOD 1936, 1937a, b, c, d, 1939, HOFFER 1943a, b, BUDAI and CSILLAG 1998, 1999, BUDAI et al. 1999). Each of the studied sites show clear evidence of some degree of magma-water interaction during the eruption of the alkaline basaltic magma. The evidence includes

1. the common presence of volcanic glass shards (HEIKEN and WOHLETZ 1986, ZIMANOWSKI 1998, BÜTTNER et al. 1999, 2002),
2. large volume of predominantly non-volcanic lithics that are often angular in shape and samples of the entire known pre-volcanic rock formations (LORENZ 1986, WHITE 1991, ORT et al. 1998),
3. common presence of peperite (WHITE et al. 2000, SKILLING et al. 2002, WOHLETZ 2002, ZIMANOWSKI and BÜTTNER 2002) along intrusive bodies and/or in the foot zone of lava flows (SKILLING 2002) and
4. typical bedforms such as pyroclastic breccia, sandwave, massive and planar beds (WOHLETZ and SHERIDAN 1979, WOHLETZ and HEIKEN 1992) that are characteristic for base surge transportation. Such textural characteristics of the studied pyroclastic rocks and their contact with intrusive and/or effusive bodies are common in the western Pannonian region, and indicate that phreatomagmatism was a key issue during the eruption of these volcanoes. The eruption style (e.g. predominance of phreatomagmatism) and the present state of erosion (e.g. the level of exposures) make the western Pannonian region comparable to other known eroded phreatomagmatic volcanic fields, such as the Hopi Butte in the western US (WHITE 1990), the western Snake River (Idaho) volcanic field (GODCHAUX, et al. 1992, WOOD and CLEMENS 2004), Waipiata in southern New Zealand (NÉMETH and WHITE 2003) or the Saar-Nahe Basin in Germany (LORENZ and HANEKE 2004).

By total volume of eruptive products, however, the western Pannonian volcanic fields together do not reach the total erupted volume estimated for the Hopi Buttes, western Snake River fields nor the Waipiata fields. A preliminary estimation of the total erupted volume has been made for the Bakony – Balaton Highland Volcanic Field (BBHVF) and gave around 4 km^3 (NÉMETH et al. 2000). The relatively smaller size and the smaller number of known vents of the Little Hungarian Plain Volcanic Field (LHPVF) and the Styrian Basin Volcanic Field (SBVF) probably would not add significantly more to the total erupted volume to reach more than 10 km^3 of eruptive products over 6 million years of eruption history in the western Pannonian region. This volume estimate is preliminary, and perhaps two major facts may alter this number such as (1) the estimation of erosion and (2) the existence of covered volcanic rocks. There is evidence from seismic sectioning, gravimetry, magnetic surveys, and drill cores that there are buried Neogene alkaline basaltic rocks (effusive, intrusive and pyroclastic) in the western Pannonian region, especially in the LHPVF (NEMESI et al. 1994, TÓTH 1994). Similarly, there is evidence from various geophysical studies that along the axis of the Lake Balaton, buried volcanic rocks are likely to exist (CSERNY and CORRADA 1989, SACCHI and HORVÁTH 2002). The exact location of these remnants and their interpretation could be a future research subject, and may contribute significantly to refine our knowledge about the total magma involvement in the Neogene alkaline basaltic volcanism in the western Pannonian region.

The duration of the volcanism in the western Pannonian region estimated to be approximately 6 My (BALOGH et al. 1982, BORSY et al. 1986, BALOGH and PÉCSKAY 2001, BALOGH and NÉMETH 2004), which generally indicates a long lasting volcanic activity in comparison to other similar volcanic fields (CONNOR and CONWAY 2000). This time length also suggests a relatively low recurrence rate of the volcanism in this region in comparison to other similar volcanic fields (CONDIT and CONNOR 1996, CONWAY et al. 1998). The available data base is not sufficient to state more about age grouping of volcanic events in the region and therefore this also needs to be addressed in future research subjects.

The general stratigraphical relationship of various pyroclastic successions indicates an initial phreatomagmatic phase which commonly turned into a purely magmatic phase. This stratigraphic relationship also indicates that the water sources have been exhausted during the initial state of the magma uprise, and subsequently magmatic gas-driven fragmentation followed. This relationship is in good agreement with the model of LORENZ (1986) and therefore, the western Pannonian volcanic fields are similar to other maar volcanic fields world-wide. However, there is evidence that deep groundwater reservoirs commonly have been involved in the magma-water interaction especially in those areas, where the cover of immediate pre-volcanic siliciclastic rocks was thin (tens of metres). In these areas, the initial interaction between magma and the water from the porous media aquifer is inferred to have been significantly influenced by water stored in fracture controlled aquifers (e.g. karst water). In extreme case when no such water was involved in the magma-water interaction just a limited magma-water interaction may have occurred and built a thin tephra ring sequence that was topped by scoria cones. In contrast, where water from fracture controlled (e.g. karst water) aquifers was significantly involved the magma-water interaction may have lasted long enough to build deep maars. It is suggested, that due to the seasonality of the fracture controlled (e.g. karst water) aquifers, some sort of control could be expected in a volcanic field, which developed over such pre-volcanic buildup (NÉMETH et al. 2001). The studied pyroclastic successions in the western Pannonian region all exhibit textural features indicating that the immediate pre-volcanic Neogene silicilastic sediments must have been water saturated and unconsolidated soft rock environment. These sediments functioned as an impure coolant (WHITE 1996) during the magma–water interaction. In areas where the thickness of this immediate pre-volcanic sediments exceeded a few hundreds of metres, lateral excavation of craters led to the formation of broad, shallow volcanic depressions, like e.g. in the LHPVF. In contrast, where the fracture controlled aquifer was near to the syn-volcanic palaeosurface, steep walled maars are inferred to have been formed. In either case, the resulting pyroclastic rocks became rich in finely dispersed siliciclastic rock fragments and/or mineral phases derived from such sediments (e.g. quartz, muscovite). This textural appearance of the pyroclastic rocks from the western Pannonian region commonly led to the interpretation that these rocks are the result of contemporaneous volcanism and sedimentation (KULCSÁR and GUCYZNÉ SOMOGYI 1962, JÁMBOR 1980). Indeed, to distinguish accidental lithic fragment rich pyroclastic rocks from normal volcanogenic sediments from any environment (e.g. subaqueous or terrestrial) is extremely difficult (RIGGS and BUSBY-SPERA 1990, RIGGS et al. 1997, BULL and CAS 2000). In spite of these difficulties most of the lapilli tuff and tuff units are interpreted to be the result of deposition form base surges and or phreatomagmatic fall out on the basis of their bedding characteristics and/or the general 3D relationships mapped in these areas. Similarly, detailed revision of drill core data with interbedded volcaniclastic and Neogene siliciclastic units suggested that such apparent interfingering is rather a result of near crater rim subsidence of tuff ring beds (e.g. Pula) that may cause apparent bed repetition (JÁMBOR and SOLTI 1975, 1976). There have also been interpretations, which concluded that the volcanic rocks were quickly covered by the immediate pre-volcanic silt and sand. These observations gave an impression, that the Late Miocene siliciclastic sedimentation was contemporaneous with the volcanism (JÁMBOR 1980), and therefore the volcanoes were interpreted to have been evolved in a shallow marine environment (JÁMBOR and SOLTI 1976). There is evidence that such siliciclastic sediments that become deposited above the volcanic successions often resulted from sedimentation in a volcanic depression, e.g. Fekete-hegy (MARTIN et al. 2002, 2003) or Kis-Somlyó (MARTIN and NÉMETH 2004a). However, there is also growing evidence, that coherent alkaline basaltic bodies interbedded with siliciclastic rock units, are inferred to be predominantly intrusive bodies, e.g. volcanic region north of the Keszthely Mts. In the LHPVF, where flat volcanic edifices, such as broad tuff rings, have developed during the magma/water interaction, is evidence, that such craters have been flooded by water and subsequently siliciclastic sediments became deposited in their crater. At this stage it is not yet understood whether this events are related to

1. general basin subsidence,
2. temporal increase of water input into the sedimentary basin (e.g. climatic forcing) or
3. they are just local events with no significant regional implication.

It is also evident that maar basins became flooded by water either quickly, or rather slowly. These two end members resulted in significantly different volcanic facies association from

1. complete scoria cones (feeding intra-crater lava flows that in case of subsequent flooding could have been covered by siliciclastic maar crater deposits) and/or
2. Surtseyan volcanoes that may evolved in maar basins that have been flooded quickly.

The complicated stratigraphic relationship of various volcanic rock units and their relationship to the pre- and post-volcanic non-volcanic succession suggests that the studied volcanoes in the western Pannonian region are complex and cannot be really classified as pure monogenetic volcanoes. At this stage it is also not clear, if various volcanic facies in the same location truly represent volcanic events that took place more or less in the same time. There is evidence in a few cases, that a complex volcano has been constructed in a short period of time (MARTIN and NÉMETH 2004b). However, their eruptive time may already exceed the common time that is necessary to freeze a feeder dyke and, therefore, a volcano, regardless of its small volume in some instances could rather be viewed as a closely spaced group of individual vents that may even have been fed from completely different sources.

One of the major outcomes of the research in the past 10 years is the recognition the complexity of the small-volume intraplate volcanoes in the western Pannonian Basin. There is evidence showing the recurrence of volcanic activity in the same locations. In a relatively small area, such as e.g. the Szigliget volcanoes, each preserved hill in an area of 2 km^2 is interpreted as an individual diatreme pipe. One of these closely spaced vents, recognised recently, may be even more complex and represent a nested diatreme in an area smaller than 500 metres across.

In summary it can be stated that phreatomagmatism was the main eruptive mechanism that created the original volcanic landforms in these volcanic fields. The palaeoenvironment of the volcanic fields are best modelled as relatively flat lying areas, where fluvial incision was insignificant during onset of volcanism. In the relatively broad, flat land, elongated valleys likely have been temporarily flooded by surface water, and/or occupied by flat, shallow lakes all enhancing the development of phreatomagmatic volcanoes during magma uprise. The fine distinction between volcanoes that formed purely subaerially (maars and/or tuff rings) from volcanoes that may have been at least in their initial eruptive phase subaqueous is still a subject of future long term research plans in the region. Overall, to study the volcanism in the western Pannonian Basin may contribute to our understanding of a pre- syn and post-volcanic sedimentary environment and its relationship with an ongoing intraplate predominantly alkaline basaltic volcanism. In this respect, the evolution of the western Pannonian Basin and its Mio/Pliocene intraplate volcanism is remarkably similar to the Neogene to present volcanic fields of the Basin and Range Province, where large lacustrine systems have been present before, during and after the volcanism, such as e.g. Lake Idaho (SMITH et al. 1989). Such lacustrine systems actively were effected by the volcanism causing base level fluctuations and associated sudden, often dramatic drainage as well as flooding (ORE et al. 1996, SADLER and LINK 1996, TALBOT and ALLEN 1996). In such lacustrine systems complex subaqueous to emergent volcanoes (e.g. Pahvant Butte, Utah - WHITE 1996, 2001) developed in time of high water stand and purely subaerial phreatomagmatic ones in low water stands (e.g. Western Snake River Plain — WOMER et al. 1980, GODCHAUX et al. 1992) often associated with complex volcano-sedimentary (e.g. Challis volcanic field, Idaho — PALMER and SHAWKEY 1997) deposition. In the western Pannonian Basin active shallow marine to lacustrine sedimentation (Lake Pannon) took place at least up to 8 My ago (MAGYAR et al. 1999). Subsequent Pliocene lacustrine sedimentation in the region is generally assumed, but was never constrained well on the basis of large scale sedimentary basin analysis. However, preliminary results highlight the difficulty to identify different lacustrine events on the basis of texturally similar siliciclastic successions (SACCHI and HORVÁTH 2002) a common problem in terrestrial sedimentary facies analysis (e.g. YOUNGSON et al. 1998). The western Pannonian Basin is an excellent area to study volcanic rocks resulted during Neogene intraplate volcanism. The region is also an area where deeper levels (crater or diatreme) of small volume intraplate volcanoes are exposed partially due to quarrying. In this regard, the volcanic regions in the area of the western Pannonian Basin are suitable for full development of volcanic national monuments, volcanological exhibition sites and perhaps to be part of a larger geopark networks in Central Europe as it has been suggested in several places already (e.g. NÉMETH 1996, CSILLAG 2004).

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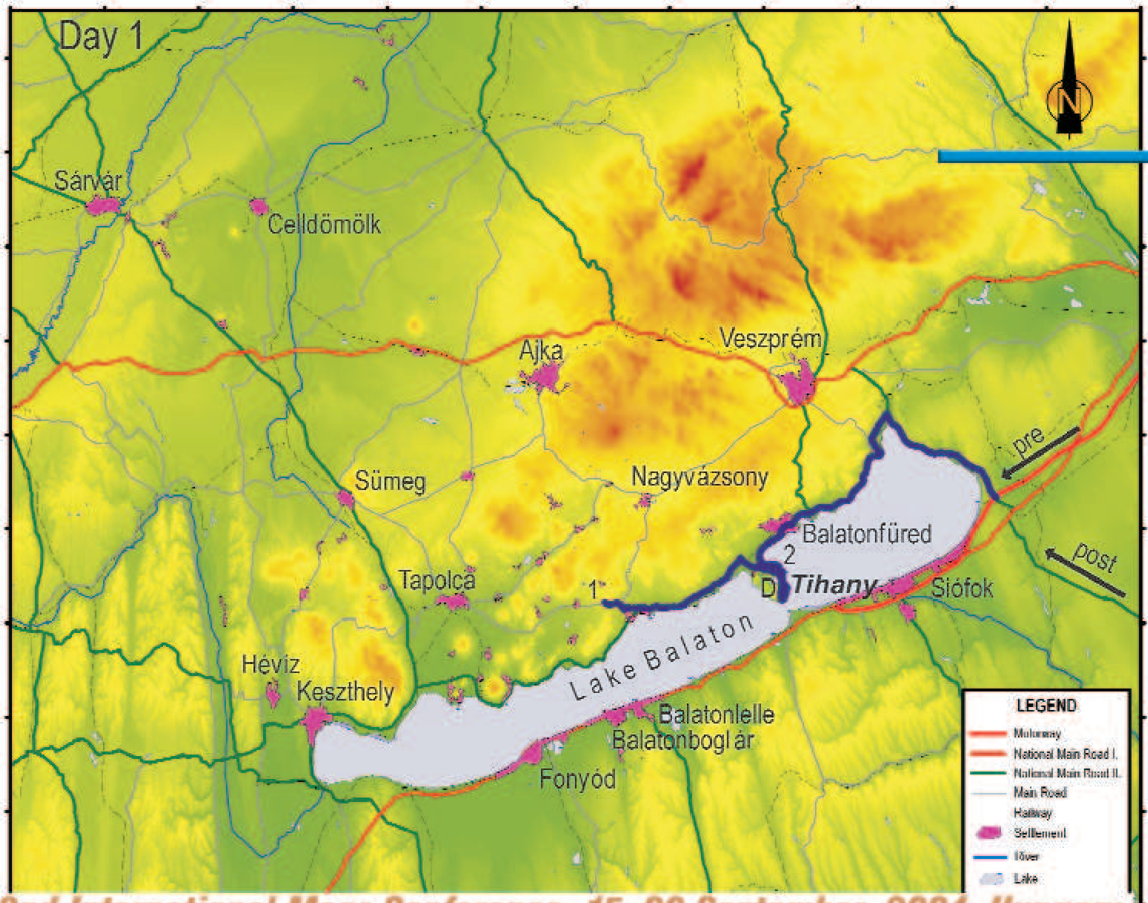
MrSID satellite image (NASA) of the Bakony – Balaton Highland Volcanic Field
Selected vent remnants are marked, 1 — Szigliget, 2 — Badacsony, 3 — Gulács, 4 — Szent György-hegy, 5 — Agár-tető, 6 — Bondoró, 7 — Fekete-hegy, 8 — Tihany, 9 — Kab-hegy, 10 — Tátika, 11 — Haláp, 12 — Fonyód, 13 — Boglár, 14 — Somló (part of the Little Hugnarian Plain Volcanic Field). [Green is forest, pink is agricultural land.] View is 70×50 km

MrSID satellite image (NASA) of the Little Hungarian Plain Volcanic Field.
Vent remnants are marked, 1 — Ság-hegy, 2 — Kis-Somlyó, 3 — Somló. 4 — Gérce, 5 — Hercseg-hegy (Sitke), 6 — Várkesző. [Green is forest, pink is agricultural land.] View is 60×40 km



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