The Szigliget maar/diatreme, Bakony-Balaton Highland Volcanic Field (Hungary)

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Abstract

Preliminary volcanological mapping has been carried out in the western part of the Bakony- Balaton Highland Volcanic Field (BBHVF) around Szigliget (Hungary) village. Pyroclastic rocks form the three distinct hillsides in the area, and show similar north-westward dip direction and textural and compositional characteristics, suggestive of a complex but closely related volcanic system in the area.

The pyroclastic deposits have been grouped into three units according to their textural, compositional and stratigraphic characteristics. Unit 1, which represents the lowermost stratigraphic position, crops out in the southern side of the study area. It consists of coarse-grained, matrix-supported massive to weakly bedded, accidental lithic clast-rich, block-bearing lapilli tuffs / tuff breccias, extremely rich in deep-seated accidental lithic and peridotite lherzolite clasts. Unit 2, which represents an intermediate stratigraphic position, crops out in the southern and north-east hilltops. It consists of coarse-grained accidental lithic clast-rich, normal graded, bedded, vitric lapilli tuffs / tuff beds. Deep-seated accidental lithic clasts are common, but large peridotite lherzolite fragments are relatively rare. Unit 3, which represents the highest stratigraphic position in the area, crops out in the northwestern side. It consists of fine-to-coarse grained, bedded, accidental lithic clast-rich vitric lapilli tuff / tuff beds. Deep-seated lithic clasts as well as peridotite lherzolite fragments are rare. Accidental lithic clasts, derived from shallow pre-volcanic strata (Neogene sediments), have a dominant proportion of pyroclastic rocks in this unit.

In each unit the volcanic glasses are angular, non- to highly vesiculated tephrite to phono-tephrite shards. The presence of sideromelane glass shards and the large amount of accidental lithic clasts in beds from each units indicate subsurface phreatomagmatic explosive processes during formation of pyroclastic rocks at Szigliget. The pyroclastic rocks are interpreted as part of a former crater rim deposit around a maar basin which subsequently subsided inward into a vent. Unit 1 is interpreted to be a lower diatreme deposit and Unit 2 and Unit 3 a series of near-vent pyroclastic density currents and fallout tephra.

Introduction/geological setting

Szigliget consists of a predominantly pyroclastic-covered series of three hills located on a small peninsula on the northern shoreline of Lake Balaton (Fig. 1). The pyroclastic rocks belong to the Late Miocene alkaline basaltic Bakony-Balaton Highland Volcanic Field (Hungary) (Jugovics 1969; Borsy et al. 1986). The basement has a general stratigraphy of Silurian schist (very low-grade metamorphised psammitic, pelitic beds: (Császár and Lelkesné-Felvári 1999)) and Permian Red Sandstone (continental alluvial formations:

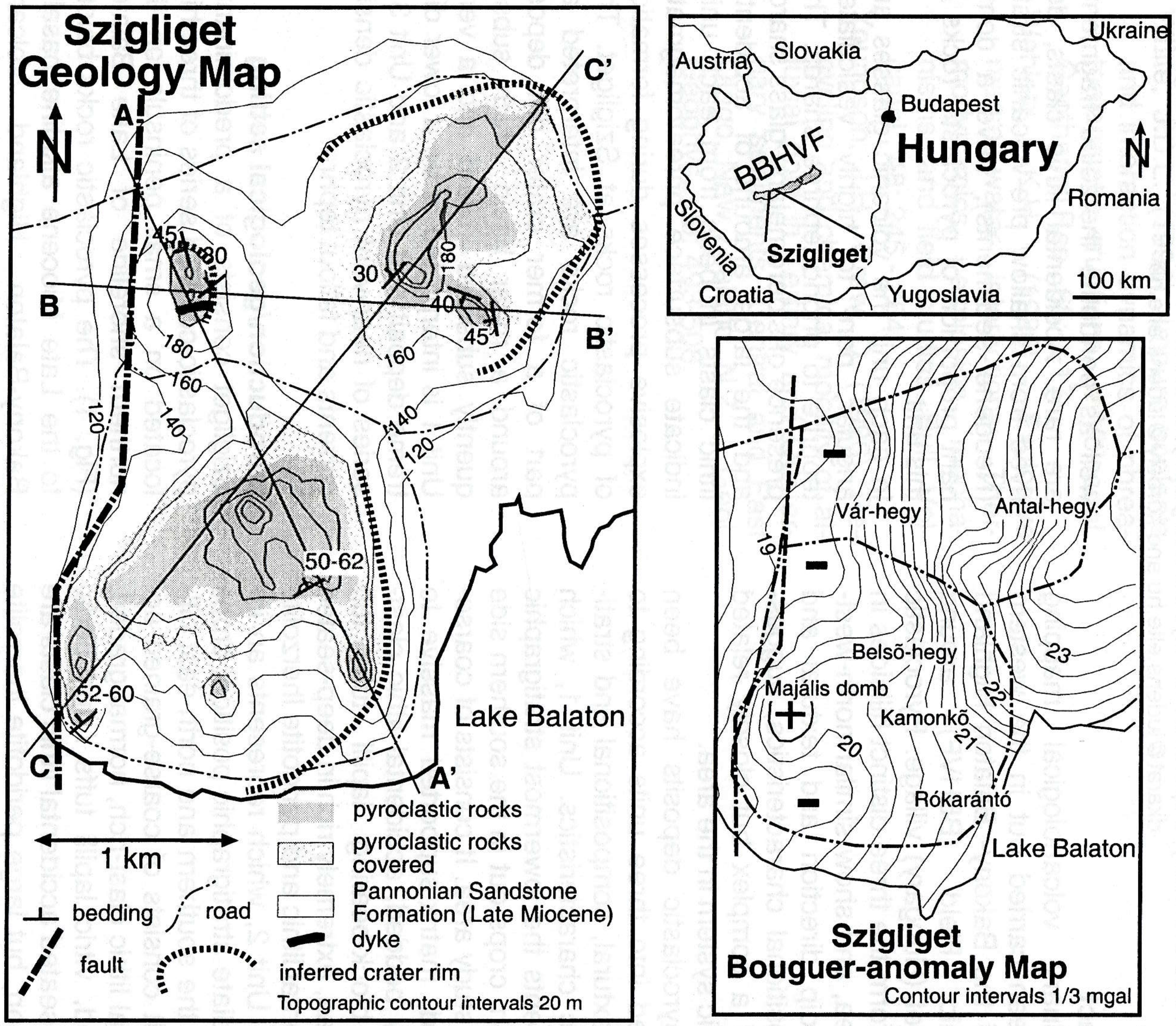

Fig. 1: Geology and Bouguer-anomaly map of Szigliget and its vicinity. Note the negative gravity anomaly region in the south-western side of the study area inferred to be a major vent site filled with low density unsorted, coarse-grained, accidental lithic- and peridotite lherzolite- rich lapilli tuff and tuff breccia (Unit 1). Straight lines represent cross-section lines.

(Majoros 1999)) (Majoros, 1999), overlain by Mesozoic, predominantly carbonate, sequences (Eastern Alps-type sequence: (Kázmér and Kovács 1985)) (Kázmér and Kovács, 1985). These beds are covered by thick Neogene sediments of gravels, sandstones and mudstones deposited from the Late Miocene Pannonian Lake and related fluvial systems (Bence et al. 1999). At Szigliget, the basement rocks are in progressively deeper positions towards the west following a series of N-S trending normal fault-displaced blocks. These form an elongated basin (Tapolca Basin) west of the studied area (Dudko, 1999). At Szigliget, the estimated depth of rock formations older than the Neogene sediments are ~200 m and it is believed that the schist beds are a few hundred metres below the surface (Dudko 1999). In general, the pre-volcanic Neogene sediments around Szigliget are in a subhorizontal position, but it is possible that the N-S trending faults might have caused large scale tilting of entire blocks (Csillag, 2000, pers. comm.).
In this short note we will provide a brief description of the separate pyroclastic units then a possible reconstruction of an eruptive mechanism and the position of the former volcanic landforms.

Pyroclastic succession of Szigliget

Unit 1

Description

Beds of this unit crop out in the southern part of the studied area, close to the present shoreline of Lake Balaton. This locality occupies the lowest topographic position in the entire BBHVF, although its stratigraphic position has been the subject of much debate (Jugovics 1969; Borsy et al. 1986). There is no visible contact with other units or the pre-volcanic strata. The unit consists of thickly bedded, massive, unsorted, matrix-supported lapilli tuff and/or tuff breccia. It is very rich in accidental lithic clasts from the pre-volcanic stratigraphic unit especially rich in large peridotite lherzolite, amfibolite clasts (Embey-Isztin 1976). The accidental lithic clasts are semi-rounded to angular, distributed chaotically in a quartzofeldspatic sand grain-rich matrix. Juvenile fragments, max 20 vol% by visual estimation, are angular to abraded moderately vesiculated sideromelane glass shards with a phono-tephrite composition. There are no bomb sags or other notable sedimentological features. Occasionally weak imbrication of schist clasts can be identified, but it is not very obvious. The occurrence of unit 1 is correlated with a large negative gravity anomaly in the area.

Interpretation

The matrix-supported, unsorted characteristics of this deposit without any well-developed bedding suggests "en masse" deposition of a collapsing phreatomagmatic eruption column and are interpreted as vent/conduit filling (lower diatreme) lapilli tuff / tuff breccia (White 1991, 1996). The presence of large amounts of deep-seated accidental lithic clasts suggests very active vent dynamics during explosive processes with possible repeated vent/conduit collapse. The presence of clasts from the deeper-known pre-volcanic stratigraphic units (i. e. schist) indicates that the explosion focus at this stage of the eruption must have been several hundred metres below the syn-volcanic surface (at least ~700 m plus erosion since the volcanism) and that the conduit must have been in a semi-sealed state.

Unit 2

Description

Unit 2 represents an intermediate stratigraphic position and crops out in the southern and north-eastern hilltops and forms the volumetrically largest amount of pyroclastic sequences at Szigliget. It consists of coarse-grained, unsorted, accidental lithic clast-rich, normal graded, bedded, vitric lapilli tuff and tuff beds. The bed surfaces are sharp, impact sags are occasionally present and they are usually shallow symmetric. Deep-seated accidental lithic clasts are common with an average of a few cms in diameter, but large peridotite lherzolite fragments are relatively rare (in the form of cm- or mm-sized olivine or broken fragments of peridotite lherzolite). The lapilli tuff beds are usually poorer in matrix, occasionally clast-supported and calcite-cemented; in contrast, the tuff beds are well-bedded and/or undulatory bedded, occasionally cross-bedded with low amplitude (cm to dcm) and long wavelength (metres) dunes. Bedding planes, especially in finer grained lapilli tuffs and/or tuffs, can vary, and beds are often discontinuous at greater distances. Large Neogene sandstone fragments often have thermally affected rim (i. e. radial cracks). Juvenile clasts are weakly to highly vesiculated, weakly to moderately microcrystalline sideromelane ash and lapilli with teprhite, phonotephrite composition, occasionally with an elongated, "fluidal" shape.

Interpretation

The presence of angular sideromelane glass shards mixed with finely dispersed accidental lithic clasts, the unsorted texture of beds and the mostly high-energy bedforms are suggestive of a primary, phreatomagmatic explosion origin for these beds. The presence of a large amount of accidental lithic clasts indicates subsurface explosions forming tuff rings and/or maars. The large amount of juvenile fragments and their higher vesicularity, together with the smaller amount of deeper-seated accidental lithic fragments in the beds indicates that the erupting vent must have been open and/or that the conduit wall had stabilised. The higher vesicularity of juvenile fragments also supports this conclusion. The fine-grained, thinly, and/or dune-bedded lapilli tuffs and tuffs were deposited by turbulent and possible low-concentration pyroclastic density currents (Fisher and Schmincke 1984; Cas and Wright 1987; Sohn and Chough 1989; Chough and Sohn, 1990) whereas the coarse-grained lapilli tuff beds more likely represent deposition by fallout from a phreatomagmatic eruption column.

Unit 3

Description

This unit represents the highest stratigraphic position in the area and crops out on the north-west side of the study area. It consists of fine-to-coarse grained, bedded, accidental lithic clast-rich vitric lapilli tuff and tuff. Deep-seated lithic clasts as well as peridotite lherzolite fragments are rare. Accidental lithic clasts represent the dominant proportion of the pyroclastic rocks derived from shallow pre-volcanic strata (Neogene sediments). The quartz grains are delicately dispersed in the unsorted matrix of the lapilli tuff and tuff. Accretionary lapilli beds have not been described yet, but quartz grain clots are very common both at mm and cm scale. Larger Neogene sediment fragments are surrounded by thermally affected rims. Large blocks did not cause well-developed impact sags, thus determination of transportation is not reliable. Larger Neogene sediments very often have irregular shapes even if they are slightly baked.

The unit has a sharp contact with the pre-volcanic Neogene sediments according to Borsy et al (1989), but it has not been confirmed due to extensive debris flanks, thus this information can be used only with caution. From the exposed lower part of the pyroclastic unit to the top of the section the unit is very uniform, the only change is that up-section an increase in the amount of juvenile, vesiculated glass shards can be traced. The intercalated, thin, dune-bedded sequences are more common in the middle part of the unit.

Interpretation

The presence of delicately dispersed angular, microvesicular sideromelane glass shards in an unsorted quartzo-feldspatic matrix indicates a primary explosive, phreatomagmatic origin of the beds of this unit. The large amount of accidental lithic clasts from shallow depths (Neogene sandstone) suggests shallow sub-surface phreatomagmatic explosive origin. The presence of baked margins around larger sand and mudstone fragments, especially up-section, is indicative of higher temperature/lower water content of these disrupted strata allowing occasional baking of the disrupted sand fragments. In contrast, the fluidal shape of large silt clasts, and the clot-like distribution of the quartzo-feldspatic sand grains are more indicative of wet conditions at the moment of magma/sediment contact. These conditions could be attained during a high magma discharge period, when a large amount of magma had sudden contact with wet, unconsolidated sediment. The undulatory, dune- or parallel bedding indicates deposition by low-concentration pyroclastic density currents and associated co-surge fallout (Sohn and Chough 1989). The stratigraphic position of unit 3 compared to units 1 and 2 suggests that it might be associated with a more distal crater rim sequence than unit 2, or that unit 3 represents an individual volcanic explosion pipe filled with a subsequently inwardly-subsiding former crater rim sequence (collapse structure) (Fig. 2).

Conclusion

The three units identified by our preliminary mapping at Szigliget are products of a phreatomagmatic explosive activity generating relatively low-concentration pyroclastic density currents and phreatomagmatic fallout tephra. According to the lithology, general distribution, and volume of the accidental lithic fragments in the beds of the units, the subsurface explosions must have extended up to 1000 metres depth relative to the syn-volcanic surface. Units 1 and 2 are closely related, probably stratigraphically, with the latter being the younger (Fig. 2). From the presently available data, however, it is hard to reconstruct their relation with unit 3. If the sharp contact with the pre-volcanic sandstone beds reported by Borsy et al (1989) is accepted (or can be confirmed in the future) it might indicate that unit 3 was deposited on the Neogene sediments as a pre-volcanic paleo-surface. In this view unit 3 should be interpreted as a distal "true" crater rim sequence related to a larger maar/diatreme structure as represented by units 1 and 2.

A general dip direction very similar in each pyroclastic bed (Fig. 1) implies the possibility of late tectonic movements in the entire area. There are two equally reasonable solutions (Figs. 2/1 and 2/2): (1) unit 3 alone represents the remnant of an individual volcanic pipe filled with subsequently inwardly-subsided and gently tilted former crater rim sequences (collapse structure) independent of the structures built up by unit 1 and 2; (2) unit 3 represents an early product of a more complex and

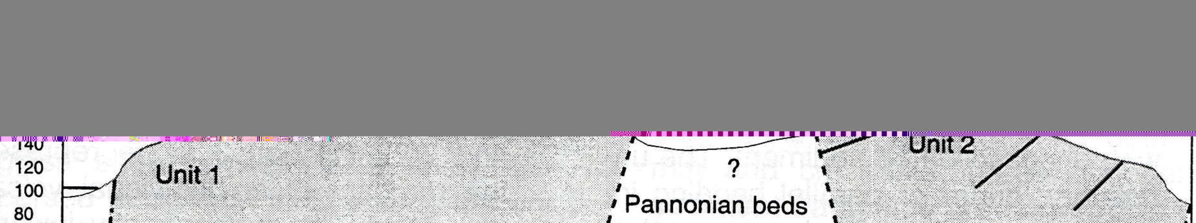

Fig. 2: Cross-sections through the study area. 1 and 2 represent two equally good solutions for the distribution of pyroclastic units.

larger remnant of volcanic conduit filled with tilted and slipped, former crater rim beds (subsequently tilted to the northwest) centred around the locality of unit 1 (Fig. 2/2). In the second hypothesis, unit 3 must represent a distal crater rim bed deposited early in the eruptive history on the pre-volcanic surface (Fig. 2/2). In this hypothesis, units 1 and 2 represent a more proximal facies of a subsequently developed sequence with a former crater rim sequence (unit 2) collapsed into a conduit.

At this stage of our study, it is difficult to say what the exact relation between the 3 hillsides and the described 3 pyroclastic units is. There is no positive evidence to reconstruct them either as individual diatremes or the entire area as a large diatreme. This question will provide the focus for further research in the area and possibly require drill core data between the hills.

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