Evolution of the Phreatomagmatic/Extrusive/Intrusive Complex of the Bulhary Maar-Diatreme Volcano in Southern Slovakia

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ABSTRACT. Extensive quarries next to the village of Bulhary in southern Slovakia exposed internal parts of one of the maar-diatreme volcanoes in the Pliocene/Quaternary Southern Slovakia Alkali Basalt Field. The volcano evolved in 5 stages: (1) maar formation by phreatomagmatic eruptions; (2) emplacement of a laccolith-like intrusive body into maar/diatreme filling; (3) creation of hyaloclastite breccias and phreatomagmatic tuffs with spatter due to a direct contact of magma with water in the maar lake; (4) several cycles of the Surtseyan- and Hawaiian-type eruptions; (5) final Hawaiian-type eruptions giving rise to the capping horizon of cinder and spatter.

KEY WORDS: alkali basalt, intrusion, peperite, hyaloclastite, lava flow, spatter, palagonite tuff.

Introduction

The Bulhary maar-diatreme volcano, 1 km in diameter, forms a part of a more extensive complex of maars, cinder cones and lava flows 3 km NE of Fiľakovo (Fig. 1), in the northern part of the Southern Slovakia Alkali Basalt Field (Konečný et al. 1995). Superposition of lava flows and cinder cones on top of the maar/diatreme filling indicates, that the maar evolution represented an early phase of volcanic activity in this area. Radiometric dating of the maar-related intrusion by K/Ar method has given the result 1.60 ± 0.15 Ma, while lava flows and related cinder cones show ages in the interval 1.51 ± 0.22 to 1.16 ± 0.3 Ma (Konečný et al. 2002). The maar and related diatreme have evolved in the environment of Lower Miocene sedimentary rocks, mostly water-saturated unconsolidated fine-grained sands and silts. Their thickness in the area of the volcano is about 600 m. At their base, they contain water-saturated gravel horizons of the Lučenec and Číž formations (Vass et al. 1992).

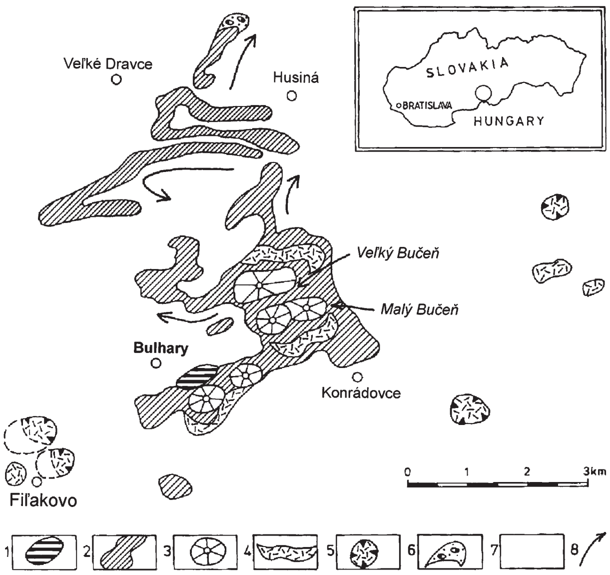

Fig. 1. A scheme of the NW part of the Southern Slovakia Alkali Basalt Field. 1 – Bulhary maar, 2 – lava flows, 3 – scoria cones, 4 – palagonite tuffs, 5 – maars, 6 – fluvial gravel, 7 – Lower Miocene sedimentary rocks, 8 – flow direction.

Internal parts of the Bulhary maar and the underlying diatreme are accessible thanks to extensive quarries opened to extract high-quality stone of a laccolith-like intrusion (used to produce curbstones and old-fashioned pavement cubes). A panoramic view of the quarries is presented in Fig. 2, showing the extent of the intrusion as well as the relative position of features described in the text. The Bulhary maar/diatreme complex demonstrates a multistage evolution, governed by the water/magma interaction in the depth as well as in the maar lake.

Description of the maar/diatreme filling

The central part of the maar/diatreme complex is occupied by an extensive laccolith-like intrusion. Platy to blocky jointing shows onion-like internal structure, implying ballooning as the principal mode of its emplacement. In the SW, it lies at direct contact with the surrounding Lower Miocene sedimentary rocks (Fig. 2). The thermal effect of the intrusion on sedimentary rocks is almost negligible, limited to a meter or two of induration. Insulation of sedimentary rocks was provided by a zone of peperitic and hyaloclastite breccias, implying a presence of water.

The situation is different in the NE. Here, the intrusion invaded palagonite tuffs of the early maar/diatreme filling (Fig. 3). Strongly deformed palagonite tuffs are mostly fine-grained, sorted and stratified, composed of vesiculated basalt particles, rare accretionary lapilli and variable amount of sand admixture. The observed textures imply alternating base-surge and fall deposits, corresponding to the early violent phreatomagmatic activity. The intrusion shows a distinct platy jointing close to the contact, parallel to the contact. At the contact itself, a zone

0.5–5 m thick is present, formed of slightly vesiculated hyaloclastite and/or peperite breccia (Fig. 3, detail), implying a saturation of the maar/diatreme filling with water at the time of the intrusion emplacement. A succession of three aa-type lava flows separated by horizons of coarser palagonite tuffs is present at the top of the quarry wall, filling a local depression on the eroded surface of former units.

The apical part of the intrusion is exposed at upper levels of the SE wall of the quarry (Figs. 4 and 5). Apparently the intrusion at this place was at a direct contact with water in

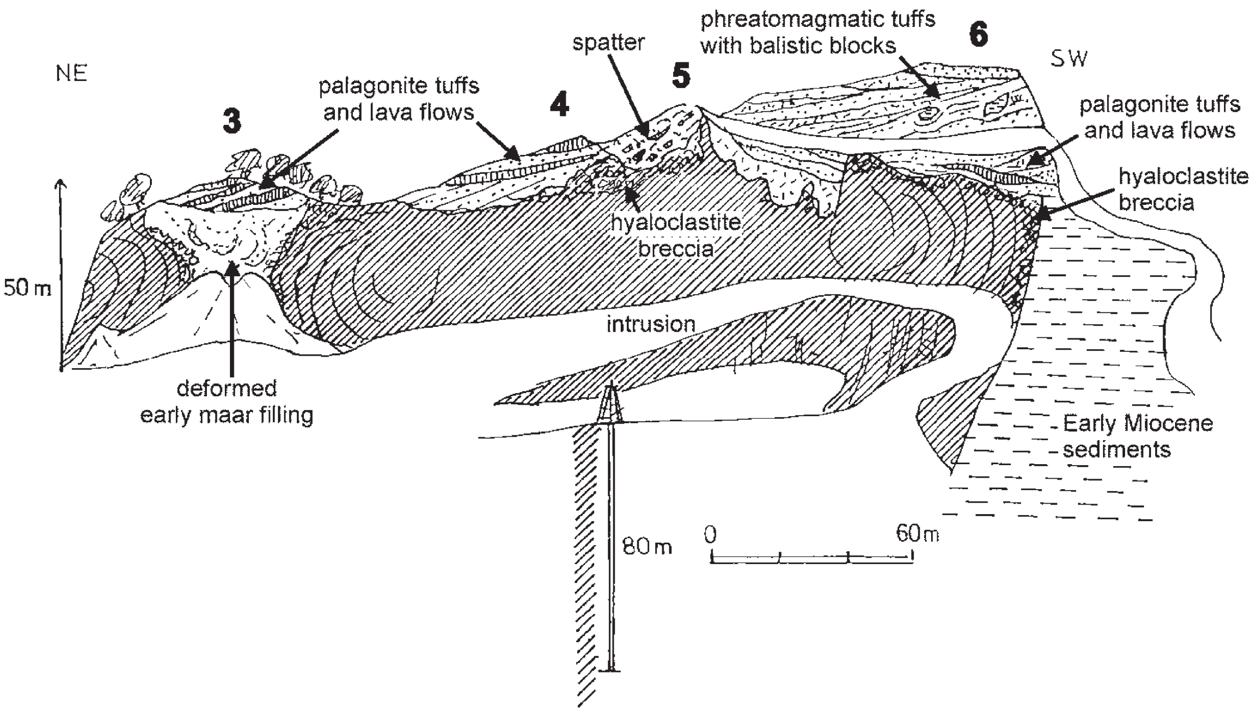

Fig. 2. A panoramic scheme of quarries in the Bulhary maar, looking from the northwest. Numbers indicate positions of Figs. 3–6.

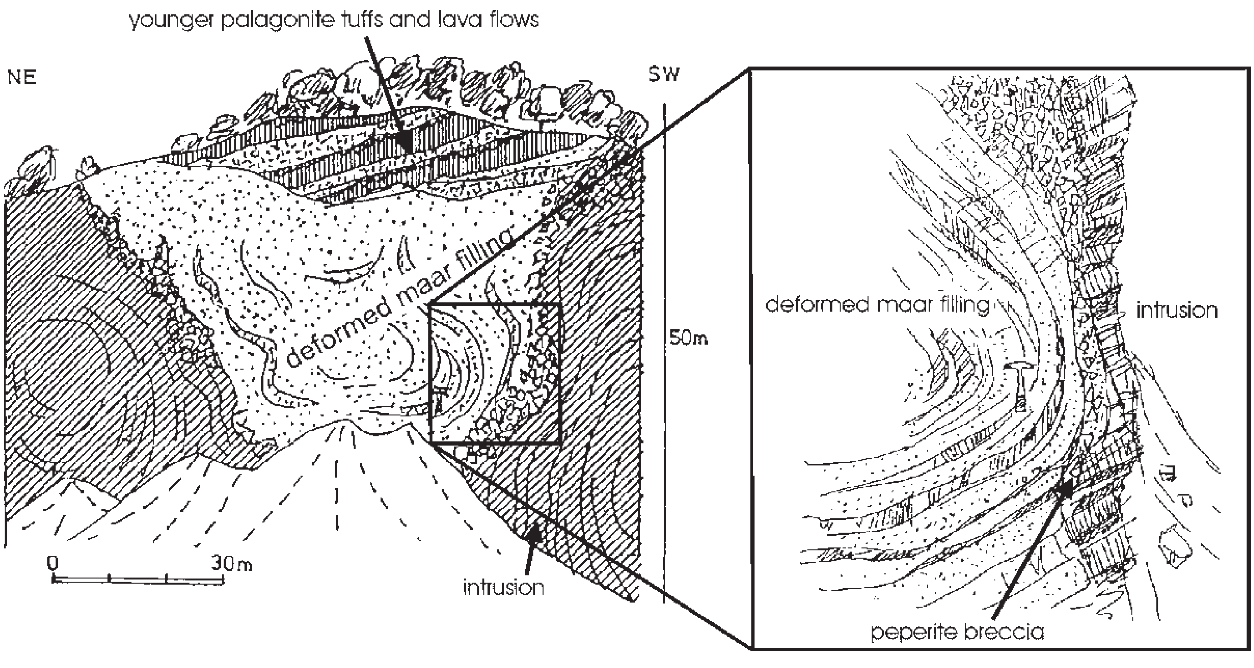

Fig. 3. A view of the NE part of the quarry showing the intrusion invading deformed palagonite tuffs of the early maar/diatreme filling and the younger succession of palagonite tuffs and lava flows.

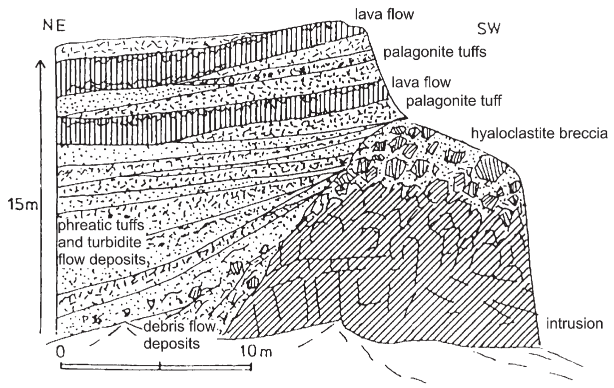

Fig. 4. A scheme of the outcrop at the SE edge of the quarry, showing hyaloclastite breccias and related onlapping succession of reworked material (mostly fines carried out of the breccia by boiling and phreatic explosions).

the maar lake as it is capped by a thick zone of greenish to reddish vesiculated hyaloclastite breccia, variegated colours and the presence of nontronite and hematite implying a boiling system. Fig. 4 demonstrates an onlapping succession of reddish debris-flow and turbidite-flow deposits (including phreatic and/or phreatomagmatic tuffs ?), representing mobilized material from the neighboring heap of boiling breccia. Fig. 5 shows a local accumulation of bombs and spatter with palagonite tuff admixture in matrix. Cauliflower- and brocolli-type surfaces of bombs indicate a phreatic component in the relevant explosive activity. The spatter accumulation reminds secondary littoral cones known to occur where magma enters a shallow water environment.

In the SW wall of the quarry, the intrusion passes upward into several lava tongues separated by thick accumulations of hyaloclastite breccia. At this place, lava of the intrusion was at a direct contact with water of the maar lake. Higher up, on the upper terraces of the quarry, these breccias are covered by a succession of alternating lava flows and stratified palagonite tuffs from local centres along the margin of the maar (Fig. 6). Lava flows and tuffs fill a local depression, showing features of mantle bedding and slumping. Further up, this succession is in turn covered by marginal parts of a cinder cone situated at the southern edge of the maar (it might not be an integral part of the volcano – compare ages in the introduction).

Evolution of the Bulhary maar-diatreme volcano

The observed phenomena indicate the following evolution of the volcano (Fig. 7):

1. The initial maar and diatreme formation by strong phreatomagmatic eruptions owing to the water/magma interaction with water in the water-saturated Tertiary sedimentary complex (compare e.g. Lorenz 1986). Maar/diatreme filling of this stage is represented by fine to coarse palagonite tuffs with a variable sand/silt admixture.
2. No more water/magma interaction at the depth. A pause in volcanic eruptions allowed water from surrounding sediments fill up the maar lake. Subsequent ascent of basaltic magma to the top of the maar/diatreme fill resulted in the emplacement of the laccolith-like intrusive body, strongly bulging up and deforming the pre-existing maar/diatreme fill. Water-saturated palagonite tuff deposits caused formation of hyaloclastite and peperite breccias at contacts of the basalt intrusion.
3. Protruding basalt intrusive bodies eventually pierced through the maar/diatreme fill and got to a direct contact with water in the maar lake, creating a succession of lava tongues and hyaloclastite breccias. Boiling and related phreatomagmatic eruptions took place in the shallowest part (similar to secondary

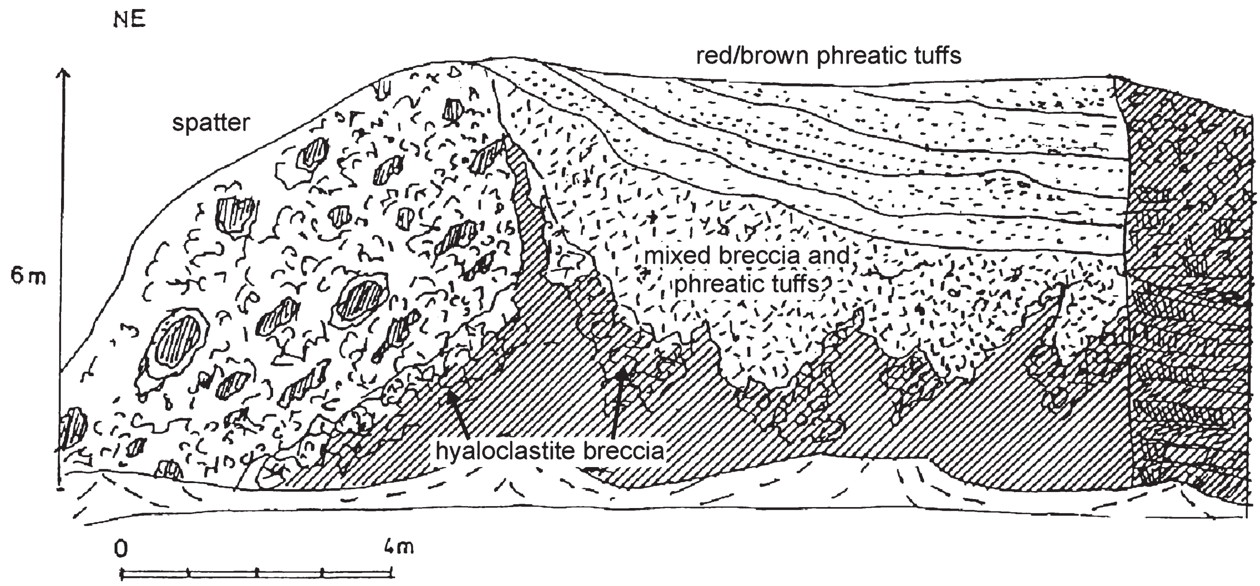

Fig. 5. A scheme of the outcrop at the SE edge of the quarry, showing hyaloclastite breccias and related reddish spatter and phreatomagmaticic tuffs at the top of the intrusion.

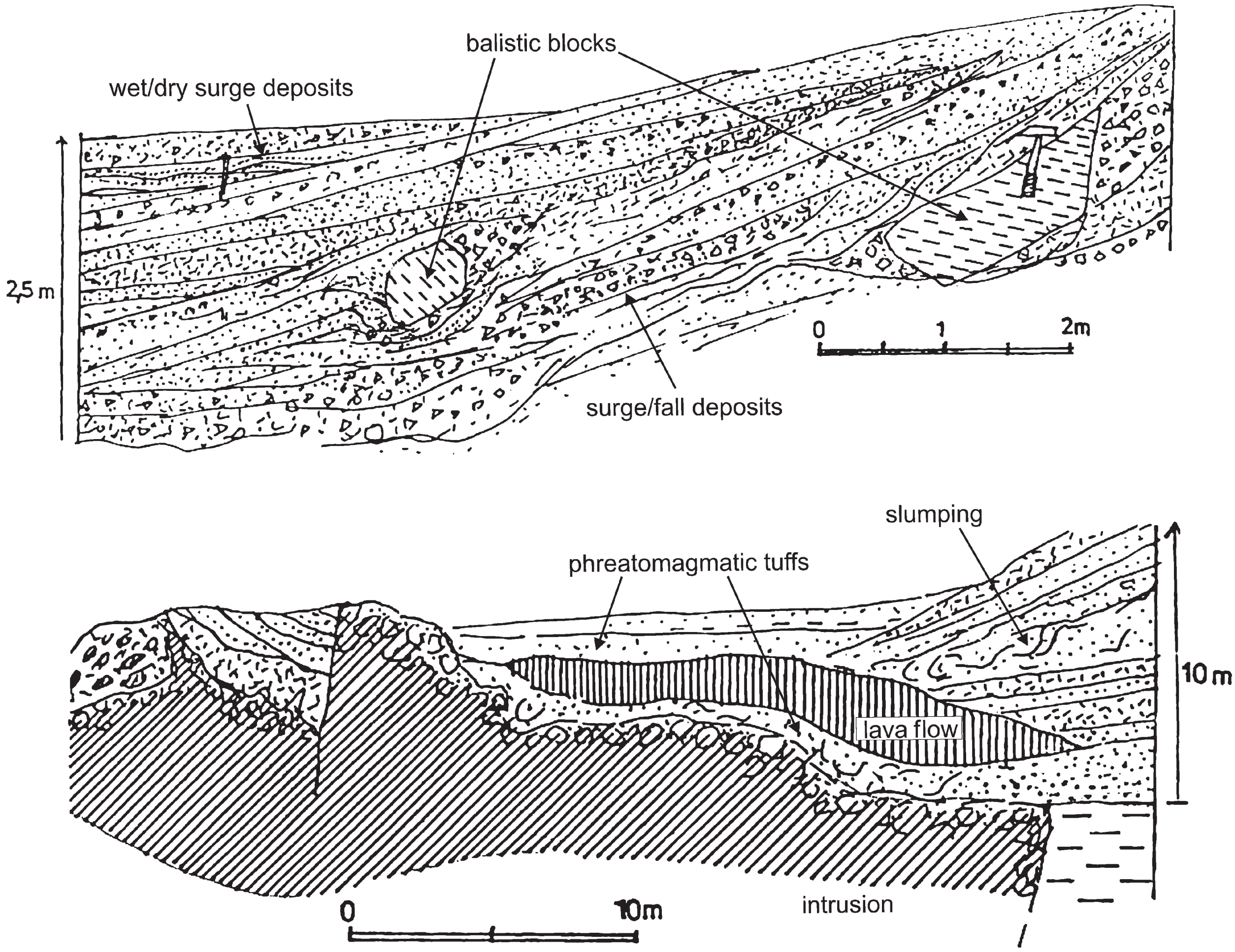

Fig. 6. A scheme of the outcrop at the SW side of the quarry, showing the younger succession of palagonite tuffs and lava flows.

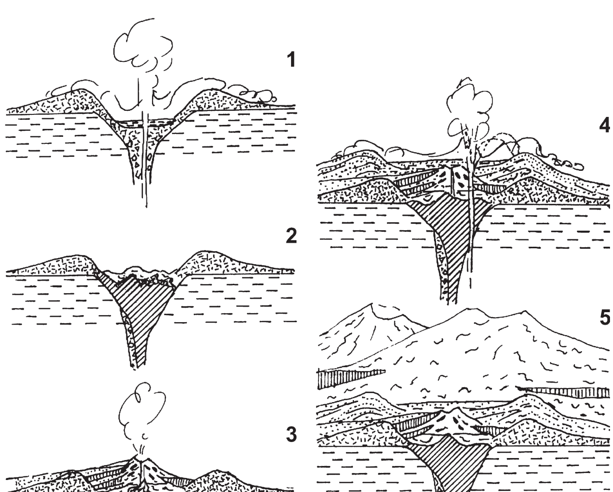

Fig. 7. Evolutionary scheme of the Bulhary maar. For explanation see the text.

phreatomagmatic cones observed with the lava flows entering a shallow water environment). Alternatively, under dry conditions, the Hawaiian-type fire fountaining created spatter accumulations.

4. A continued supply of basalt magma into the maar, with a rather shallow and spatially limited lake at this stage, resulted in several cycles of the Surtseyan- and Hawaiian-type eruptions, giving rise to a succession of alternating palagonite tuffs, breccias and lava flows.
5. A final elimination of the maar lake due to accumulation of volcanic products resulted in the Hawaiian-type eruptions giving rise to the uppermost horizon of cinder and spatter.

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