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Upper Pliocene alkali basalt at Grad, northeastern Slovenia

Zgornjepliocenski alkalni bazalt pri Gradu, severovzhodna Slovenija

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Abstract

The Grad area, northeastern Slovenia is characterised by Upper Pliocene volcanic activity, which produced minor alkali basaltic lava flows and scoria deposits. In the late-stage of volcanic activity, hydrovolcanism predominated, and it produced pyroclastic surge deposits. Volcanism occurred on the surface of alluvial fan. Small lava flows were partially mixed with abundant loose sediments - gravels, sands and silts forming peperites. Owing to rapid cooling, peperites were easily autobrecciated. Autoclasts were easily redeposited by large debris flows, triggered by late-stage hydrovolcanic activity, and also, by fluvial currents. Today, the original lava flows are not preserved any more, at least on the surface. They are encountered only as boulders and cobbles in debris flow deposits, or as pebbles in volcaniclastic sandstones.

Kratka vsebina

Območju Grada v severovzhodni Sloveniji daje pečat zgornjepliocenska vulkanska aktivnost, s katero so nastali manjši izlivi lave in piroklastiti, ki sestoje iz lapilov skorije. V poznem obdobju vulkanske aktivnosti so prevladovale hidrovulkanske eksplozije, s katerimi so nastali piroklastični valovi. Vulkanizem je deloval na površju aluvijalnega vršaja. Majhni izlivi lave so se deloma mešali z okolnimi sedimenti - prodi, peski in melji, zaradi česar so nastajali peperiti. Zaradi naglega ohlajanja so se peperiti z lahkoto avtobrečirali. Nastali avtoklasti so bili nato presedimentirani z velikimi tokovi drobirja, katere so sprožile hidrovulkanske eksplozije, pa tudi z rečnimi tokovi. Prvotni tokovi lave danes na površju niso več ohranjeni. Najdemo jih le v obliki večjih in manjših blokov v sedimentih tokov drobirja in kot prodnike ali drobnejši grušč v vulkanoklastičnih peščenjakih.

Introduction

Upper Pliocene alkali basaltic volcanism in the Grad area, northeastern Slovenia (Fig. 1), is continental in character and closely related to extension of the Mura basin. It is associated with alkali basaltic volcanism in the neighbouring Styrian basin, which is separated from the Mura basin by the horst of South Burgenland. In the horst of South Burgenland, coherent volcanics outcrop being basanites and nephelinites in composition. In other parts of the Styrian basin, explosive volcanics predominate. The most famous occurrences are Beistein at Fehring, Pertelstein, Bad Gleichenberg, Kapfenstein and Neuhaus (Poschl, 1991; Winkler, 1927; Poulditis, 1981).

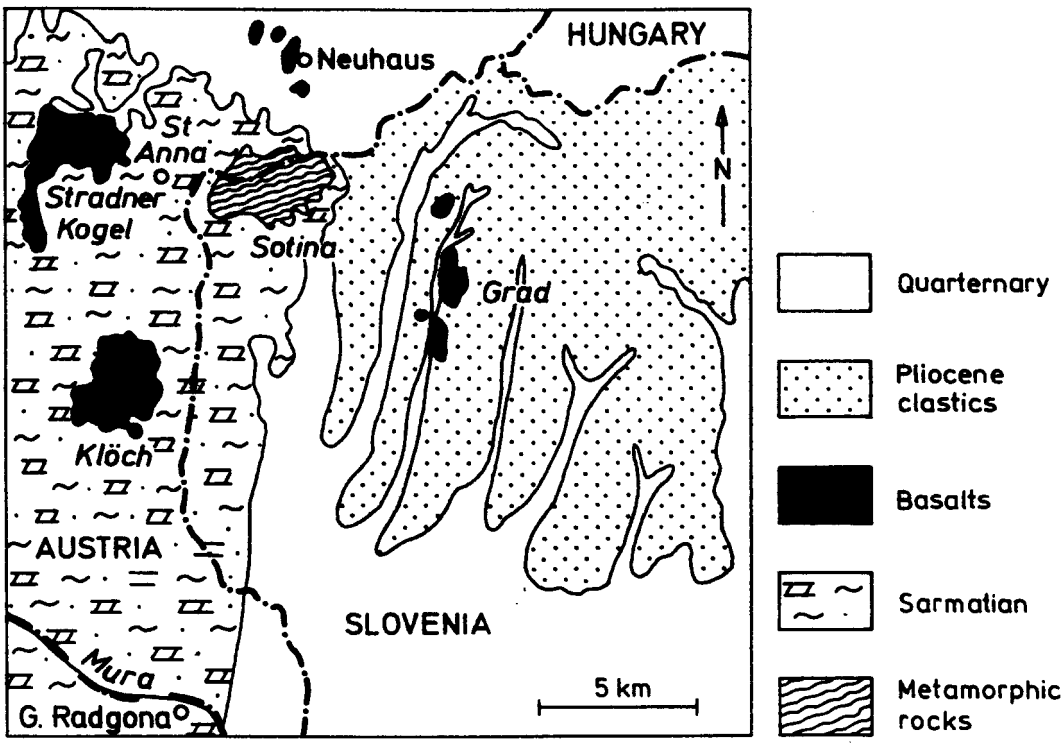

Fig. 1. Simplified geological map of the Grad area (after Pleničar, 1968)
Sl. 1. Poenostavljena geološka karta področja Grada (po Pleničarju, 1968)

Alkali basaltic volcanism at Grad occurred on the surface of alluvial fan. In the early stage, small cinder cone(s) developed, and they were probably composed of scoria-fall deposits and minor lava flows. Late-stage hydrovolcanic eruptions destroyed cinder cone(s), and the material was resedimented with hydroclasts in pyroclastic surges. In the periods between volcanic eruptions, fluvial currents were active. Eroded volcanic material was resedimented with fluvial gravels, sands and silts forming fluvial deposit of mixed composition.

Boulders and cobbles of coherent volcanic rocks and scoria lapilli in fluvial sediments of mixed composition are the only proof of their former existence in the primary setting. Their study was helpful in reconstruction of the history of volcanic activity in the Grad area and enable a determination of its petrological and geochemical character.

Short description of lithofacieses encountered in the Grad fluvial - volcaniclastic complex

Lithofacieses, recognised in the Grad fluvial - volcaniclastic complex were subdivided into the following groups (Kralj, 1995):

- pyroclastic flow deposits
- pyroclastic surge deposits
- debris flow deposits
- hyperconcentrated flow deposits, and
- diluted debris flow deposits

Pyroclastic flow deposits and pyroclastic surge deposits are very rare in occurrence and they are encountered only as small-scale erosional remains among the predominating redistributed mixed sediments. Pyroclastic flow deposits form up to 7 m thick lensoidal deposits with massive structure, which mainly consist of scoria lapilli.

Table 1: Chemical composition of basaltic lavas (1, the average of 18 samples) and a peperite (2, the average of 7 samples) from the Grad fluvial - volcaniclastic complex

Preglednica 1: Kemijska sestava bazaltne lave (1, povprečje 18 vzorcev) in peperita (2, povprečje 7 vzorcev) iz fluvialno - vulkanoklastičnega kompleksa Grada

Major oxides (wt. %)	1	2
SiO_2	43,8	46,8
TiO_2	1,88	1,80
Al_2O_3	13,6	14,4
Fe_2O_3	5,00	4,34
FeO	4,4	4,8
MnO	0,21	0,19
MgO	5,88	6,49
CaO	10,8	9,16
Na_2O	3,22	3,22
K_2O	1,91	2,02
P_2O_5	0,98	0,98
H_2O^+	4,6	2,7
H_2O^-	1,9	1,4
CO_2	0,49	0,32
L.O.I.	5,88	4,32

Overlying mass-flow deposits are up to 0,7 m thick and contain armoured mud balls.

Pyroclastic surge deposits are characterised by low-angle cross stratification and horizontal stratification. The main constituents are lapilli of scoria and basaltic lithics; non-volcanic detritus form up to 35% of the bulk rock. The rock is strongly fines-depleted. Some strata are very rich in accretionary lapilli (K r a l j , 2000).

Debris flow deposits are the dominant lithofacies in the Grad complex. According to their grain-size analyses, they are gravelly sands or sandy gravels with subordinate amounts of silt (7 - 25 %), and up to 3 % of clay. They form massive, up to 50 m thick deposits with erosional base contacts. Debris flow deposits contain many blocks and cobbles of fragmented lava flows and peperites. They may contain some accretionary lapilli.

Hyperconcentrated flow deposits are horizontally- and cross-stratified conglomeratic sands and coarse-grained sands with very common inverse gradation. They are overlain by, or interstratified with diluted debris flow deposits.

Trace elements (ppm)	1	2
Be	4	5
Be	10	20
Sc	11,8	14,3
V	190	170
Cr	93	120
Co	36	37
Ni	82	97
Cu	24,5	33,3
Zn	120	117
As	4	6
Se	3	3
Rb	56	55
Sr	1610	1280
Y	22	28
Zr	297	326
Nb	118	128
Cd	3	1
Sb	0,4	0,6
Cs	4	1
Ba	1046	1106
La	76,8	76,2
Ce	138	139
Nd	56	54
Sm	9,3	8,9
Eu	2,8	2,7
Tb	1,0	1,1
Yb	2,1	2,3
Lu	0,29	0,33
Hf	6	7
Ta	6	6
W	87	120
Pb	2	2
Th	10	11
U	3,9	3,7

Fragments of lava flows and peperites

Studies with the polarising microscope have shown that some of the fragments belong to alkali basaltic lavas, which locally formed peperites when mixing with fine-grained fluvial sediments.

Lava fragments are actually redistributed hyaloclasts which vary in size from cobbles to the sand and silt fraction. Most commonly, they are very angular (Plate 1 - Fig. 1), but some of them may have smooth, curviplanar surfaces (Plate 1 - Fig. 2). Both

types indicate chill-and-quench fragmentation. At Neuhaus in Austrian Styria, an alkali basaltic lava of the same age as the Grad volcanics, intruded into fluvial sands. A sample of coherent lava, frozen in a solution of hydrogene peroxide, disintegrated into pebble- and sand-sized hyaloclasts (Plate 1 - Fig. 3). This example indicates the efficiency of lava fragmentation in a fluvial environment. In the Grad area, hyaloclasts were redistributed in a short distance and mixed with terrigenous clastic material.

Resedimented lava hyaloclasts consist of altered glassy groundmass, augite microlites, and microphenocrysts and phenocrysts of augite and olivine. Very rarely, sanidine and nepheline also occur. Glassy groundmass commonly encompasses over 65 vol.% of the bulk rock. Volcanic glass is rarely fresh. More frequently, it is altered to palagonite or a semi-transparent mixture of iron oxides and clay minerals. Olivine is less abundant than augite and quite often, the crystals are skeletal owing to the magma corrosion. The most common accessory fragments are quartzite pebbles and quartz grains, siltstone intraclasts and metamorphic rock fragments of the greenschist facies. Quartzite pebbles are commonly corroded by lava. As a reaction rim, stubby pyroxenes or apophyllite commonly developed.

Some of the fragments are alkali basaltic lava - sandy siltstone peperites (Plate 1 - Fig. 4). For a long time, the largest outcropping fragment of a coherent basaltic rock in the Kaniža ridge was assumed to be a part of a lava flow. Drilling, performed in the year 1979 (Ciglar, 1979a, b) has shown, that it is a boulder only. The boulder is a peperite, a mixture of alkali basaltic lava and sandy silt. Owing to hydrothermal reactions caused by overheated pore waters in the sediment, phillipsite and analcime developed.

Chemical composition of peperite does not differ significantly from basaltic lavas (Table 1). Silica content is somewhat higher, ranging from 2 % to 4 %, although under the microscope, the content of quartz is much higher, and may amount up to 10 %.

Conclusions

In the early episode of the development of the Grad fluvial - volcaniclastic complex in northeastern Slovenia, lavas extruded on the surface of an alluvial fan, where clastic sedimentation took place. Lava flows are not preserved any more as in such dynamic fluvial environment, they were easily disintegrated and resedimented with fluvial clastics. In the contact with wet, unconsol-

Plate 1 - Tabla 1

Fig. 1. Basaltic rock fragments. Angular shapes indicate chill-and-quench fragmentation

Sl. 1. Fragmenti bazaltnih kamnin. Oglate oblike kažejo na fragmentacijo zaradi nenadnega ohlajanja

Fig. 2. Basaltic rock fragments with smoother surfaces

Sl. 2. Fragmenti bazaltnih kamnin z zaobljenimi površinami

Fig. 3. A lava sample from Neuhaus (Austria) which disintegrated into hyaloclasts after being frozen in a solution of hydrogene peroxyde. The largest clast is about 3,5 cm long.

Sl. 3. Vzorec lave iz Neuhausa (Avstrija), ki je po zmrzovanju v raztopini vodikovega peroksida razpadel v številne hialoklaste. Največji klast je dolg približno 3,5 cm.

Fig. 4. Basaltic lava - sandy silt peperite from the Kaniža ridge

Sl. 4. Peperit bazaltne lave in peščenega melja iz grebena Kaniža

1

2

3

4

idated sediments, lavas were rapidly autobrecciated owing to chill-and-quench processes producing hyaloclastites. Mixing of lava and the enclosing sediment produced peperites. The largest lava block outcropping on the Kaniža ridge is actually a peperite. Heat transfer from the cooling lava caused overheating of pore waters in the admixed sediment, and consequently, phillipsite and analcime crystallised. Autobrecciated lava flows and peperites were redeposited by a debris flow, which was probably triggered by the late-stage hydrovolcanic eruption. Blocks of lavas and peperites in the mixed fluvial-volcaniclastic rocks in the Grad area are the only evidence of the former existence of extrusive volcanic activity.

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