

EVOLUTION OF THE CENTRAL SLOVAKIA NEOGENE VOLCANIC FIELD RELATED TO THE HORST/GRABEN STRUCTURE

V. KONEČNÝ and J LEXA

¹Geological Survey of Slovak Republic, Mlynská dol. 1, 817 04 Bratislava, Slovakia

Abstract: Basement covered by volcanic rocks of the Central Slovakia Volcanic Field shows a well pronounced horst/graben structure. Its evolution during the Middle and Late Miocene time (16,5-6 Ma) was accompanied by an extensive, dominantly andesitic volcanic activity, giving rise to a number of andesite stratovolcanoes and dome/flow complexes. A back arc extension related to the subduction rollback and a contemporaneous uprise of asthenospheric mantle were the major driving forces.

Key words: Slovakia, Neogene, volcanic activity, horst/graben structure, back arc extension

Introduction

Konečný et al. (1975, 1978) demonstrated, that volcanic rocks of the Central Slovakia Volcanic Field (CSVF)(fig. 1) cover a spectacular system of horst and grabens with relative displacement amplitudes up to 3 000 m. The most prominent features of this system there are (fig. 2): (a) dominant N-S trending horsts and grabens at the central part of the system, (b) mostly NE-SW trending horsts and grabens elsewhere, (c) obscured NW-SE trending structural elements, (d) volcano-tectonic features including Kremnica graben, Štiavnica caldera and resurgent horst, Javorie graben, Poľana depression and (e) a frequent occurrence of asymmetric horsts and grabens, including halfgrabens.

Evolution of the horst/graben system was accompanied by an extensive, dominantly andesitic volcanic activity, giving rise to a number of andesite stratovolcanoes and dome/flow complexes (fig. 3). Relationship of volcanic formations to marginal faults of horsts and grabens as well as biostratigraphic evaluation of sediments filling the grabens and radiometric dating of volcanic rocks offer a possibility to analyse in a greater detail the mutual relationship among the evolution of volcanic activity and horst/graben structure.

Evolution of volcanic activity and horst/graben structure

Evolution of the horst/graben structure and related volcanism during the Middle to Late Miocene (Badenian to Pontian) time took place in seven definable stages, each one of the stages having some specific features.

Early Badenian

The Early Badenian evolution of the area followed the Early Miocene denudation and levelling. Grabens controlled dominantly by NW-SE trending faults were filled with fluvial and limnic sediments including rare lignite layers (Zvolen - Handlová - Prievidza graben). At the South (Krupina Plateau) a transgression of the shallow epicontinental sea took place, spreading over older fluvial/limnic deposits. Eventually, the transgression reached via a narrow corridor in the central part of the region into the mentioned graben.

The early evolution of grabens was accompanied by volcanic activity of garnet bearing andesites, giving rise to dispersed extrusive domes accompanied by related breccias and tuffs. Individual volcanic centers were situated especially along marginal faults of grabens and along N-S striking faults. Emplacement of submarine extrusive domes (and related accumulations of breccias and epiclastic rocks) at the southern edge of the Krupina Plateau was controlled by the NE-SW trending Čelovce-Lysec volcanotectonic zone.

Middle to Late Badenian

An intense pyroxene and pyroxene-amphibole andesite volcanic activity during the late Early to early Late Badenian was responsible for the formation of two monogene volcanoes and several extensive stratovolcanoes. Čelovce and Lysec monogene pyroclastic volcanoes formed in the central, resp. NE part of the Čelovce-Lysec volcano-tectonic zone in sea-shore environment. Their evolution was contemporaneous with the subsidence of the Krupina and Trenč grabens north and south of the zone.

The most extensive Štiavnica stratovolcano occupies the central and SE parts of the region. Relatively smaller Javorie, Poľana and Kremnica stratovolcanoes extend over the E, NE, and N parts of the region respectively. At the beginning their evolution took place variably in the fluvial, limnic or shallow marine environment evidenced by the presence of hyaloclastites. Later they evolved in the terrestrial environment, the sea-shore being displaced southward. A coeval subsidence has been recorded only in the Upper Nitra depression at the NE edge of the region, where distal facies of the Štiavnica and Kremnica stratovolcanoes

accumulated. No significant graben subsidence accompanied evolution of the stratovolcanoes at this stage.

Late Badenian to Early Sarmatian

During the Late Badenian the subsidence of the Upper Nitra depression at the NE edge of the region continued by the evolution of Handlová and Nováky coal-basins. The extensive stratovolcanoes in other parts of the region passed through the stage of the caldera or volcanotectonic graben formation. A collapse of a caldera 22 x 18 km in diameter took place in the central part of the Štiavnica stratovolcano. Its subsidence 350 - 500 m was compensated by the accumulation of explosive and extrusive products of differentiated biotite - amphibole andesite. Subsidence of volcanotectonic grabens in the central and northern parts of the Javorie stratovolcano was accompanied at first by the accumulation of basaltic andesite lava flows and hyaloclastite breccias in thickness over 350 m, later by extrusions of differentiated pyroxene-amphibole and amphibole andesites to dacites.

A collapse of the caldera 3 km in diameter accompanied by explosive and extrusive rhyodacite volcanic activity in the central part of the Poľana stratovolcano was followed later by the collapse of a NE-SW trending graben connected to the graben in the northern part of the Javorie stratovolcano.

At the central and northern part of the CSVF a distinct N-S trending Kremnica graben formed, extending northward as the Turiec basin. The subsiding graben was filled up at first by lava flows, hyaloclastite breccias and pyroclastic rocks of basalts and pyroxene andesites, later by the effusive complex of pyroxene-amphibole andesites. Total thickness of the graben filling is over 1200 m.

Early - Middle Sarmatian

Evolution of the stratovolcanoes continued during this time interval by a renewed activity of mostly undifferentiated pyroxene and pyroxene-amphibole andesites. Differentiated andesites with amphibole and biotite occur only at the Štiavnica stratovolcano. Products of this activity - effusive and stratovolcanic complexes rest upon the eroded surface of Badenian formations, often covering marginal faults of calderas and volcanotectonic grabens from the preceding stage. These faults also localise majority of relevant volcanic centers. Several minor andesitic volcanoes evolved within the Štiavnica caldera and close to the caldera fault. Their effusive and explosive products, including ignimbrites, filled up also

radially oriented valleys on outer slopes of the stratovolcano. At the same time fissure eruptions gave rise to extensive effusive complexes.

The formation of minor andesitic stratovolcanoes Vtáčnik, Remata and Flochová was linked with volcanic centers situated along marginal faults of the Kremnica graben. A larger pyroxene andesite stratovolcano Poľana in the NE part of the region covered completely the former caldera and graben. In a similar way andesite stratovolcanic complexes covered Badenian formations and volcanotectonic grabens of the Javorie stratovolcano.

Middle - Late Sarmatian

Volcanic activity of the Javorie and Štiavnica stratovolcanoes continued on their outer slopes by effusive activity of pyroxene and leucocratic andesites. Explosive and effusive activity of amphibole-pyroxene and pyroxene andesites created two minor volcanoes SE of the Kremnica stratovolcano. Volcanic activity was accompanied by asymmetric subsidence in the Upper Nitra, Turiec, Žiar, Bátovce and Zvolen depressions, compensated by accumulation of volcanisedimentary rocks.

Late Sarmatian - Early Pannonian

The most distinct block movement with vertical displacement up to 3000 m took place along N-S and NNE-SSW faults system in the central part of the region. Within the Štiavnica caldera an asymmetric uplift of the resurgent horst took place, leading to the exposure of basement rocks and subvolcanic intrusions in its western part. At the same time horsts west of Pukanec and west of Kremnica were also uplifted. The uplift of horsts was regionally compensated by the conspicuous subsidence of the Žiar graben as well as a less conspicuous subsidence in the Turiec graben at the North and Bátovce graben at the South. Marginal faults of horsts and grabens were used extensively for the ascent of rhyolitic magma to the surface. While uplifted blocks host rhyolite dykes, a rhyolite dome/flow complex and related pyroclastic and epiclastic rocks accumulated at the southern and south-eastern parts of the Žiar graben.

Pannonian - Pontian

In the Pannonian to Pontian time subsidence and limnic sedimentation continued in the Bátovce, Žiar and Turiec grabens. A renewed subsidence took place also in the Upper Nitra depression and Slatina depression at the northern margin of the Javorie stratovolcano.

The fluvial, limnic and lacustrine sedimentation involved a large proportion of nonvolcanic material brought into the region by rivers. Volcanic activity at this time interval was sporadic, represented by calc-alkali basalts and basaltic andesites, with centers along the N-S trending marginal faults of the Kremnica graben. The first showings of the alkali basalt volcanism took place close to the end of this time interval at Ostrá Lúka, Devičie and Banská Štiavnica.

Conclusions

Evolution of the horst/graben system and contemporaneous dominantly andesitic volcanic activity took place in the hinterland of the evolving Tertiary Carpathian arc. An intimate relationship among both processes implies a common cause, which we see in the back arc extension related to the subduction rollback and contemporaneous upraise of asthenospheric mantle (Lexa and Konečný, 1998). Changing orientation of horsts and grabens with time corresponds to the observed changes in the orientation of the principal stress axis due to a gradual collision of the ALCAPA block with the European Platform margin (Nemčok et al., 1993). While during the early stages regional processes controlled evolution of the grabens as well as localisation of volcanic centers, during the later stages there was significant also a magmatic control in evolution of calderas as well as volcanotectonic horsts and grabens (due to the evolution of shallow magma chambers).

References

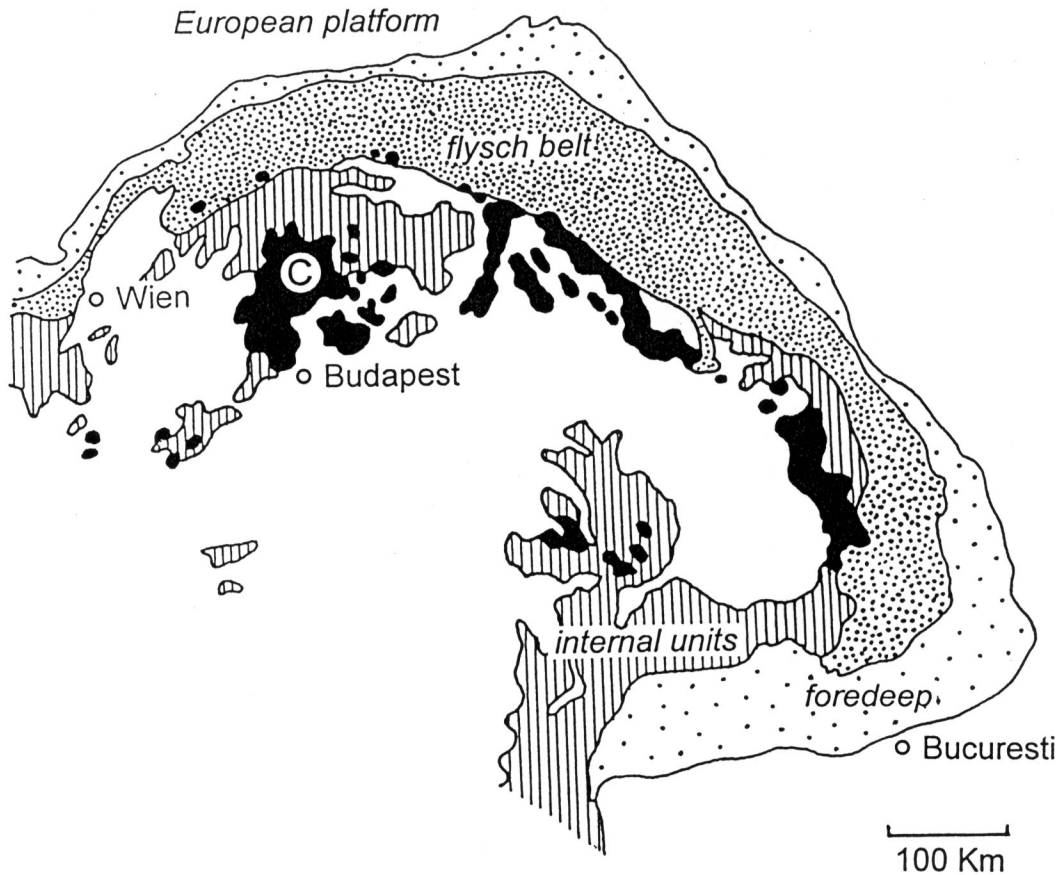
- Konečný, V., Šefara, J., Zbořil, L., 1975: Investigation of deep structures in the basement of Central Slovakia young volcanic region and their classification with respect to Neogene volcanism. Proceeding of the Xth Congress CBGA, 3, GÚDŠ, Bratislava, pp. 209-227.
- Konečný, V., Lexa, J., Šefara, J., 1978: Vzťah vulkanizmu k morfológickým štruktúram predvulkanického podložia (Relation of volcanism to basement morphotectonic structures). Open file report, GS SR, Bratislava.
- Konečný, V., Lexa, J., Hojstřichová, V., 1995: The Central Slovakia Neogene volcanic field: a review. *Acta Vulcanologica* (Pisa), 7: 63-78.
- Lexa, J. and Konečný, V., 1998: Geodynamic aspects of the Neogene to Quaternary volcanism, in Rakús, M. ed., *Geodynamic development of the Western Carpathians: Geological Survey of Slovak Republic*, Bratislava, pp. 219-240.
- Nemčok, M., Hók, J., Kováč, P., Marko, F., Madarás, J. and Bezák, V. 1993: Tektonika Západných Karpát v terciéri (Tectonics of Western Carpathians during Tertiary). In: Rakús, M. and Vozár, J. eds.: *Geodynamický model a hlbinná stavba Západných Karpát*. Geologický ústav D. Štúra, Bratislava, pp. 263-268.

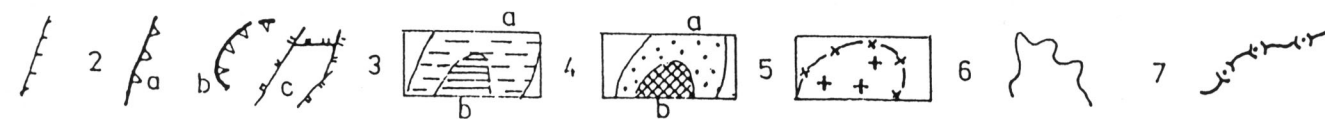
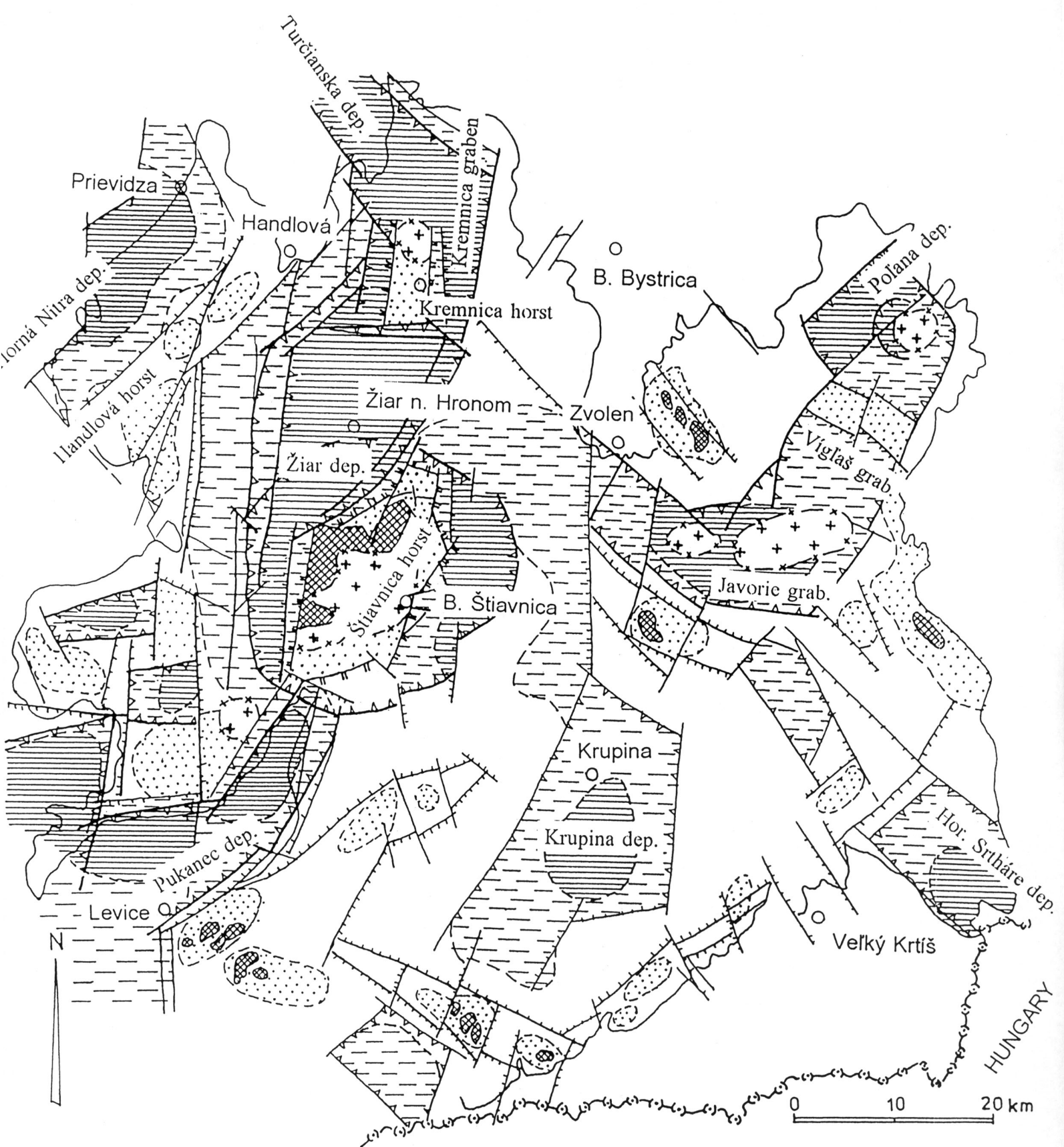
Fig. 1. Position of the Central Slovakia Volcanic field (C) among the Neogene to Quaternary volcanics (black) of the Carpatho-Pannonian region.

Fig. 2. Structure of the pre-volcanic basement in the area of CSVF (Konečný et al., 1995). 1 - faults limiting uplifted and subsided blocks, 2 - faults limiting: a - graben, b - caldera, c - volcano-tectonic horsts, 3 - depressions: a - shallow part, b - deep part, 4 - elevations: a - upper part, b - outcropping basement, 5 - geophysical indications of subvolcanic intrusive complexes, 6 - extent of volcanics, 7 - state boundary.

Fig. 3. Structural scheme of the Central Slovakia Volcanic Field. *Pannonian to Quaternary*: 1 - sediments of intravolcanic depressions; 2 - products of the alkali basalt volcanism, a - necks, b - cinder cones, c - lava flows; *Pannonian*: 3 - lava flows and sills of aphanitic calc-alkali basalts / basaltic andesites (a) and pyroxene andesites (b); 4 - stratovolcano of porphyritic calc-alkali basalts / basaltic andesites, a - volcanic cone, b - effusive complex; *Middle to Late Sarmatian*: 5 - rhyolite domes / dome flows (a), dykes (b) and pyroclastic and epiclastic rocks (c) of the Jastrabá formation; *Early to Middle Sarmatian*: 6 - andesite stratovolcanoes, a - effusive cones, b - stratovolcanic cones, c - stratovolcanic complex of the proximal zone, d - epiclastic volcanic breccias of the proximal zone, e - epiclastic volcanic breccias and conglomerates of the proximal/distal zone, f - epiclastic volcanic conglomerates and sandstones of the distal zone, g - tuffaceous sediments; 7 - andesite necks (a) and dykes (b); 8 - andesite extrusive domes (a) and diorite porphyry intrusions (b); 9 - rhyodacite domes / dome flows (a) and related pumice tuffs and reworked tuffs (b) of the Strelníky formation; *Late Badenian*: 10 - basaltic andesite / andesite effusive complexes with hyaloclastites and phreatomagmatic pyroclastic rocks filling grabens; 11 - dome/flow complexes and related breccias of intermediate to acid andesites filling grabens and caldera; *Early to Middle Badenian*: 12 - andesite stratovolcanoes: a - propylitized complex of the central zone, b - stratovolcanic complex of the proximal zone, c - epiclastic volcanic breccias of the proximal/distal zone, epiclastic volcanic conglomerates and sandstones of the distal zone; 13 - andesite pyroclastic volcanoes, a - pyroclastic cones, pyroclastic complexes of the proximal zone, c - epiclastic volcanic breccias and conglomerates of the proximal/distal zone; 14 - andesite necks (a), quartz-diorite porphyry sills (b) and dykes (c), andesite dykes (d); 15 - subvolcanic intrusions, a - granodiorite, b - granodiorite porphyry, c - diorite and diorite porphyry; *Early Badenian*: 16 - extrusive domes (a) and related breccias (b) of garnet-bearing

andesites in the terrestrial environment; 17 - andesite extrusive domes (a) and volcanoclastic rocks of the Vinica formation; 18 - *pre-volcanic basement*: a - Early Miocene sediments, b - older rocks, 19 - *faults*: a - marginal faults of volcanotectonic grabens, b - marginal faults of the caldera, c - marginal faults of volcanotectonic horsts, d - other faults; 20 - state boundary.





KREMNICA volc. complex

