MAGNETIC ANOMALIES SOURCES OF THE TERTIARY AND QUATERNARY VOLCANISM OF THE WESTERN CARPATHIANS ON THE TERRITORY OF THE SLOVAK REPUBLIC

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Abstract: Magnetic map of Slovakia was compiled in the year 2001 in the frame of the project „Atlas of geophysical maps and profiles“. All relevant magnetic anomalies were quantitatively interpreted and modelled (Kubeš et al., 2001) using an unified methodology. This approach enabled a more objective interpretation of areal distribution of magnetic inhomogeneities on the territory of Slovakia and to compile the map of magnetic anomalies sources of Tertiary and Quaternary volcanism.

The maps of magnetic anomalies sources contain data on the interpreted thickness of the volcanic complex. At those sources, which do not crop out to the surface, the depths of their uppermost rims are presented.

Geological interpretation of the magnetic anomalies source contains data on the body type, its age, lithostratigraphic division and lithological-petrographical characteristic. In some cases data on hydrothermal alterations of individual rock types are presented.

Key words: neovolcanites, magnetometry, Slovakia

Introduction

Magnetic map provides a manifold magnetic image of Slovakia (Fig.1). It reflects a complicated geological setting of the Western Carpathians. The values of magnetic field on the territory of the Slovak Republic ranging from 1000 nT to +1100 nT.

The most distinct changes in the magnetic field were identified at sites of morphological elevations, built mainly of products of Tertiary and partially also Quaternary volcanism.

In the central part of Slovakia this is valid mainly for mountain ranges Pohronský Inovec and Štiavnické vrchy, Vtáčnik, Kremnické vrchy, Poľana, Javorie and Krupinská planina Plateau. In the eastern Slovakia neovolcanic mountains dominate – Slanské vrchy and Vihorlatské vrchy. Anomalous effects of the products of Tertiary volcanism were identified

also in the Žiarska kotlina Basin. Relatively significant magnetic effects were observed in the wider surrounds of Pohronská Polhora, Pokorádzska tabuľa Table and in the East Slovakian Lowland.

In the area of the Cerová vrchovina Upland distinctly observable are mainly the anomalous effects of the Quaternary volcanism products.

In the Podunajská nížina Lowland, boreholes and magnetic measurements have proved for the presence of the Tertiary volcanism products. Neovolcanic rocks occur at relatively great depths and this is why their magnetic manifestation is less distinct. The only exceptions are Burda Mts.

Sources of magnetic anomalies of the Tertiary and Quaternary volcanism

Neogene–Quaternary volcanism of the Middle, South and Eastern Slovakia is a compound of a wider extensive volcanic areal situated on the inner part of the Carpathian Arc and in the area of the Pannonian Basin. The volcanism was connected with a subduction of Oligocene–Miocene flysch basins and with back–arc extension processes (Lexa and Konečný, 1998).

In the extensional processes regime and diapirism of the uppermost mantle Neogene andesite volcanism of the Middle Slovakia developed during Badenian–Sarmatian, closely linked with the evolution of horst–graben structures both from temporal and spatial point of view. At the ascent of magmatic masses towards the surface and at distribution of intrusive bodies, mainly fault systems on the rims of grabens and horsts were utilised. Subsidence of grabens and horsts was compensated by syngenetic deposition of volcano–sedimentary rocks in the sea even brackish–limnic environment (Konečný, Lexa, Šimon and Dublan, 2001).

In the area of thinner crust, the Neogene volcanism of the East Slovakia shows a closer spatial relation with subduction processes. The volcanism is linked with fault systems on the margins of the East Slovakian Basin, which formed, by pull-apart process.

The dominating type of volcanic structures are andesite stratovolcanoes made of alternating lava flows, pyroclastics and epiclastics. In the central volcanic zones the subvolcanic intrusions of diorites, granodiorites and diorite to granodiorite porphyries are exposed due to erosion, accompanied by aureoles of hydrothermal alterations penetrating the surrounding environment.

In the structure of stratovolcanoes pyroxenic andesites prevail (± amphibole ± biotite). The rocks of andesite-dacite composition are rather rare and even in lesser portion rhyodacites

and rhyolites linked with fault systems courses occur. Besides the stratovolcanoes extrusive bodies of more acid andesites to dacites and andesites with garnet are present.

The alkali basalt volcanism concentrated prevailingly in the area of the South Slovakia (Lučenská kotlina Basin, Cerová vrchovina Upland) is represented by isolated relics of lava flows and lava blankets, by maars, diatremes and necks.

Magnetic properties of rocks and paleomagnetism

In the frame of regional geophysical research of Slovak neovolcanites a study of magnetic properties of rocks on samples from natural outcrops and boreholes, was carried out. The laboratory values of magnetic susceptibility KAPA and remanent magnetic polarisation (RMP) were determined.

The statistical processing of measured data (Husák and Stránska in Ibrmajer et al., 1989) gave the result, that the magnetic properties of the main types of neovolcanites show a wide range of KAPA and RNP values. The KAPA values range from 0 to $94.137.10^{-6}$ (SI). The RMP values vary from 0 to 61 896 nT. This immense dispersion was determined for similar petrographic types.

Despite a great variability of the tested parameters values the fundamental rule on a direct dependence of magnetic parameters on rocks basicity is valid. From the average values, calculated for main types of neovolcanic rocks (rhyolite – andesite – basalt) it appears, that the magnitude of the KAPA and RMP parameters increase with basicity. Furthermore, it has been found out, that secondary alterations by which the volcanic rocks, mainly those of central volcanic zones, are affected, distinctly influence the magnetic parameters values. In many cases they lead to a distinct decrease of values, so former highly magnetic rocks may become very low magnetic or even the non-magnetic ones.

The results of paleomagnetic studies proved the existence of magnetic rocks with normal (NRMP) and reverse (RRMP) magnetic polarisation in practically every neovolcanic mountains of Slovakia. The reverse magnetised rocks show intense magnetic anomalies with amplitude reaching -1000 nT.

The presence of intermediary to basic volcanic rocks with normal and reverse magnetic polarisation reflects the alterations of the polarity of the magnetic pole of Earth during its geological history (Cox in Harland et al., 1989, Berggren et al., 1995).

From the magnetostratigraphic scales compiled it follows, that during Miocene and Pliocene a whole range of inversions with variable time intervals occurred. During the Upper Badenian and Pannonian the periods of normal polarity prevailed, while during Middle and

Upper Sarmatian (to Pannonian) the reverse polarity prevailed. The Lower and Middle Sarmatian characterised the period of equal portion of both polarities. The longest period of the reverse polarity was determined for Middle Badenian.

The overall character of the magnetic field in the neovolcanic rocks was influenced mainly by magnetic properties of rocks (rock complexes) and the presence of products with normal and reverse magnetic polarity.

Štiavnické vrchy Mts. and Vtáčnik Mts.

Regarding the distribution of the Tertiary and Quaternary volcanism products throughout the entire territory of Slovakia, our contribution is focused on Central Slovakia Volcanic Region, namely the volcanic mountains of Štiavnické vrchy and Vtáčnik.

The region is situated in the western part of a discontinuous belt of neovolcanites at the Inner side of Carpathian Arc. It is represented by areal type of andesite volcanism (Lexa and Konečný, 1998). The volcanic activity of the andesite volcanism took part from 16,5 Ma (Lower Badenian) to 8,5 Ma (Pannonian). This period is characterised by alternations of the magnetic field polarity in relatively short time intervals. The changes of the Earth's magnetic field polarity are proved also by the results of aeromagnetic mapping, which testified the presence of magnetic anomalies of various areal sizes with an amplitude ranging from -1 000 to + 1 100 nT.

Štiavnické vrchy Mts.

The widespread Štiavnica Stratovolcano of the Badenian-Sarmatian age is characterized by evolution of the caldera, the intrusive complex and lastly by the evolution of the horst structure. The volcanic rocks with NRMP (positive anomalies) show their maximum occurrence in the central part of the Štiavnické vrchy Mts. In the central part of the Štiavnica Stratovolcano the subvolcanic intrusive granodiorite and diorite complex is exposed by the erosion within the horst structure. In the SE part sillies and dikes of quartzitic-diorite porphyries and stock intrusions of granodiorite porphyries (Banisko and Zlatno intrusive complexes). Tatiarsky and Belujský intrusive complexes also belong to this magnetic structure. They are built of stock intrusions of granodiorite, diorite to andesite porphyries. NE, S and SW part of the Štiavnica Stratovolcano is characterized by the presence of rocks with the NRMP as well as the reverse (RRMP) magnetic polarisation. The alternations of the magnetic field polarity prove for a longer evolution of the Štiavnica Stratovolcano within the time interval Middle Badenian – Lower Pannonian. The anomalies in the area of Pukanec-

Bátovce and Čajkov Basins with continuation towards SW prove for the presence of volcanic rocks below the younger Upper Sarmatian to Pannonian non–magnetic sediments of various thicknesses (100-300 m). A distinct accumulation of rocks with NRMP and RRMP creates a conspicuous magnetic structure of the SW–NE direction of a length around 60 km and an average width of about 30 km.

Vtáčnik Mts.

A wide extent with relatively small thickness reach the products of the andesite volcanism with NRMP in the SE part of the Štiavnica Stratovolcano.

Intense alternation of volcanic rocks of both polarities is typical for the volcanic mountains of Vtáčnik. In the southern part a smaller volcano Markov vrch is situated and northward is the Vtáčnik Stratovolcano with explosive–effusive products (Šimon in Kubeš et al., 2001). Furthermore, in the area of Vtáčnik scattered extrusions of hypersthene–amphibole andesites of the Plešivec Formation occur. The relics of the above stratovolcanoes create magnetic structures, oriented in the SW–NE direction.

On the magnetic maps, the Tertiary and Quaternary volcanism products are displayed as positive and negative anomalies of various amplitudes. The anomalies values are mostly influenced by the extent, thickness and magnetic properties of individual types of rocks (andesites, rhyolites and rhyodacites, intrusions).

Conclusion

Based on the interpretation of the magnetic field anomalies and the recent geological knowledge, approximate thicknesses of non–altered volcanic complexes have been estimated, reaching in some volcanic mountains more than 1000m. The greatest thicknesses are linked with the closest surround of central volcanic zones, represented by the regions of volcanic slopes. The increased values reaching up to ± 1000 nT correspond to lava flows and coarse pyroclastics rocs accumulations. In the distal zones of stratovolcanoes prevailingly coarse– to fine–grained epiclastic rocks with scattered lava flows are deposited, corresponding to ± 300 nT values. The more external zones with prevailing redeposited pyroclastics and epiclastics (tuffs, sandstones, conglomerates) give values up to + 100 nT. The complex character of the magnetic field was identified within central volcanic zones. The older complexes of the central volcanic zones underwent in major cases the hydrothermal alterations, which led to the decrease of their magnetic parameters. These complexes comprise intrusions of granodiorites,

granodiorite porphyries, diorites, diorite porphyries, quartzitic-diorite porphyries to monzodiorites.

The characteristic feature of the central volcanic zones of stratovolcanoes is the different polarity of magnetic anomalies when comparing with the polarity of the mantle rocks.

The presence of the volcanic rocks with normal and reverse magnetic polarity has to be put in to the context of the Earth's magnetic field alternations, which polarity had changed in the period of the Lower Badenian in relatively short time intervals. This fact proves for forming of intrusive complexes in the period of different magnetic polarity when comparing with the polarity of mantle rocks.

References

Berggren Wiliam, A., Kent Denis, V., Swischer Care, C. and Aubry M. P. 1995: A revised Cenozoic geochronology and chronostratigraphy. In: Berggren et al., geochronology Time Scales and Global Stratigraphic Correlation. SEPM, spec. publ. 54.

Harland Brian, W., Armstrong Richard, L., Cox Allen, V., Craig Lorratine, E., Smith Alan, G., and Smith David, 6. 1989: A geological time scale. Cambridge University Press.

Husák, L., Stránska, M. 1989: Magnetická charakteristika hornín Západných Karpát (Magnetic characterisation of the rocks of the Western Carpathians, in Czech). In: J. Ibrmajer and M. Suk: Geofyzikální obraz ČSSR, Československá akademie věd, Praha, 1989. 354s.

Konečný, V., Lexa, J., Šimon, L. and Dublan, L. 2001: Neogénny vulkanizmus stredného Slovenska (Neogene volcanism of the Central Slovakia, in Slovak). Mineralia Slovaca 33, 3, s. 159-178.

Kubeš, P., Filo, M., Gluch, A., Hrušecký, I., Kucharič, Ľ., Ujpál, Z., Bezák, V., Dublan, Š., Elečko, M., Határ, J., Hraško, Ľ., Ivanička, J., Janočko, J., Kaličiak, M., Kohút, M., Konečný, V., Mello, J., Polák, M., Potfaj, M., Šimon, L. and Vozár, J. 2001: Atlas geofyzikálnych máp a profilov SR (Atlas of geophysical maps and profiles, in Slovak) (in press). Štátny geologický ústav Dionýza Štúra, Bratislava.

Lexa, J., Konečný, V. 1998: Geodynamic aspect of the Neogene to Quaternary volcanism. In: Rakús, M. (ED.) Geodynamic development of the Western Carpathians. Bratislava. Geological Survey of the Slovak Republic, 219-240.

MAGNETIC MAP OF THE SLOVAK REPUBLIC

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