

GEOLOGICAL FRAMEWORK OF THE VOLHYN COPPER FIELDS WITH A REVIEW OF THE VOLHYN FLOOD BASALT PROVINCE (WESTERN MARGIN OF THE EAST-EUROPEAN CRATON)

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Abstract: Geological structure of the Volhyn Flood Basalt Province has been described. Hydrothermally altered and partly eroded Vendian lava flows and intraflow pyroclastics occur upon an area of about 350,000 km² in Belarus, Poland, the Ukraine, and Moldova. They host important native Cu mineralization. The Vendian volcanism developed during four volcanic phases, producing lava and pyroclastics within the Tornquist rift system along the Teisseyre-Tornquist margin. During the last two phases, the Vendian rift was tectonically parted with crust melting. The major volcanic activity occurred in the part superimposed on the deepest part of the older Late Riphean mid-Baltica rift system, which developed across the Tornquist rift. The rifting finished with opening of the Tornquist Ocean. Actually, the Palaeozoic, Mesozoic, and (or) Cainozoic beds cover the trappean volcanic plateau. The Ratne and Rafalovka-Berestovets copper fields are situated in the central part of the Lukow-Ratne swell and along western border of the Ukrainian Shield, respectively. The ore-bearing basalts were partly eroded since the Devonian until the Late Cretaceous.

Key words: East-European Craton, Volhyn, Vendian, Tornquist rifting, flood basalts.

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INTRODUCTION

The Volhyn trapp formations are situated in the western margin of the East-European Craton and present the extraordinary Deccan-size flood basalt province that originated during the Vendian “rejuvenation” of this margin. The flood basalts strike along a distance of 1,150 km from the Mazury High in Poland to the North-Moldovian Monocline in Moldova, following the ancient rift system (Nikishin *et al.*, 1996; Hartz & Torsvik, 2002). Superpositions of the volcanic systems and long-time eruptions resulted in a complex of deposited lava flows, tuffs, and tuffites. These rocks are exposed only at some places along the western borders of Ukrainian Shield and in the Dnister River valley (Fig. 1), whereas at other places they are covered by younger deposits, up to 4,000 m thick.

Małkowski (1929, 1931) published the first data about occurrences of native copper in the Volhyn basalts. He found some small (< 1 kg in weight) nuggets in the bottom of the basalt flow in the village Velykiy Midsk. For the next years, until 1939, the Polish Geological Institute developed prospecting works for copper in the zone Rafalovka-Bere-

stovets (Wojciechowski, 1939; Małkowski, 1951), however, no economic copper concentrations were found. Since 1963 till recent, the Ukrainian Geological Survey periodically resumed the searching, promoted with occasional finding of copper mineralization and nuggets in the basalt open pits (Dovge Pole, Rafalovka, etc.). Of the works, keeping by the Ukrainian State Geological Survey now, prospecting for copper deposits in the Volhyn trappean formations is one of the topical objectives (Pryhodko *et al.*, 1993; Białowolska *et al.*, 2002). Two fields, both at depths of 10–500 m are in prospecting for copper: Ratne and Rafalovka-Berestovets (Fig. 1). The Zhyrychi copper deposit has been found in the Ratne field (Pryhodko *et al.*, 1993). However, because of complicated geological structure, the shape of the economic ore bodies is still obscure. Nevertheless, the numerous finds of high-grade (5–16%) Cu ore make the area potentially economic.

The purpose of this paper is to review geological setting of the perspective fields as a part of the ancient Volhyn Flood Basalt Province. We believe that this work will cor-

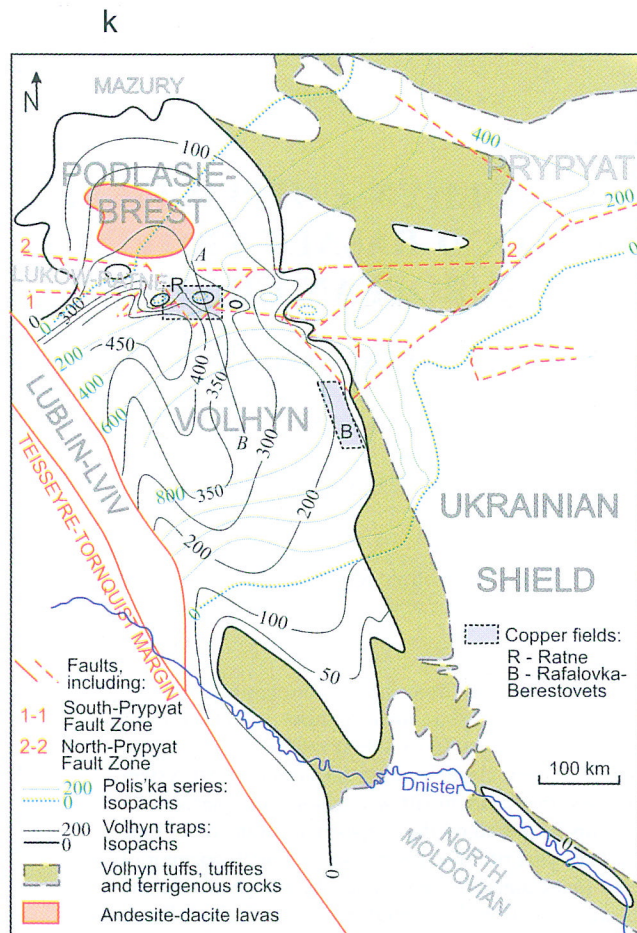


Fig. 1. Sketch map of the Volhyn flood basalt formations superimposed on the Upper Riphean strata

rect a concept about geological structure of the region, and improve the directions of the ore prospecting.

PRESENT-DAY TECTONIC SETTING

The younger tectonic units divide the ancient flood basalt province. Recently, the volcanic traps have been found in the boreholes in the north-eastern part of the North Moldovian monocline, in the Volhyn Depression, and the Lukow-Ratne Swell, in the eastern part of the Podlasie-Brest Depression, and in the southern slope of the Mazury High (Fig. 1).

Cu-bearing bodies of the Rafalovka-Berestovets field are found within the narrow 300 km² zone of the basalt formations, which settles close to the surface in the north-eastern margin of the Volhyn Depression, along the western slope of the Ukrainian Shield. The basalt flows strike along with the 580 Ma swarm of gabbro-dolerite dikes (Semenenko, 1968). These rocks are cutting the Precambrian crystalline rocks, Riphean red-beds, and Volhyn volcanogenic suite. The swarm, 8–10 km wide, strikes NW about 70 km along the marginal fault zone close to the border of the Ukrainian Shield. Westward, in the Volhyn Depression, the trapps dip monoclinaly and are thrown down by 3.5–4 km along some regional faults obscured by the younger beds.

The Ratne field is situated in the Ratne High, one of the horst-type highs of the Lukow-Ratne Swell. The swell strikes 350 km E–W in the East-European Craton, from the Ukrainian Shield to the Slavatytsky High in Poland (Semenenko, 1968; Sokołowski, 1970; Garetsky, 1981, 1990; Fig. 1). The adjoining blocks between the highs were downfaulted by submeridional faults. Along the South-Prypyat Fault Zone, the swell abuts on the Volhyn Depression, and southwestwards – on the Lublin-L'viv Basin. Along the South-Prypyat faults, the Precambrian beds are downfaulted by 300, 400, 650, 800 and 1,450 m against the Dubrovitsa, Hoteslov, Ratne, Hotyslav, and Wishnitsa Highs, respectively. Along the Sarna fault, the Dubrovitsa High borders upon the Ukrainian Shield. The area of flood basalts in the Lukow-Ratne Swell reaches 1,200 km².

The swell is poorly recognised structurally. Numerous faults cut the Precambrian beds. Close to the eastern (Dubrovitsa and Hoteslov) highs, the basement is stepwise displaced southwards down by some latitudinal faults. In the Dubrovitsa High, the volcanogenic beds have been found only in the southwestern part. Numerous sublatitudinal faults cut the Hoteslov High. The Precambrian surface of this high is dome-like: in the northern slope the beds dip from 3 to 4° to the north, and in the southern slope – from 6 to 8° to the south. Because of the pre-Cretaceous erosion, the Early Proterozoic basement crops out in the Ratne and Hotyslav palaeohighs, where it recently settles below the Upper Cretaceous beds. Generally, the heavily faulted Upper Proterozoic beds dip 10–15° to the SE and, inbetween the southern faults the dip is even steeper.

Semenenko (1968) and Garetsky (1990) designated the North-Prypyat Fault Zone as the northern border of the Lukow-Ratne High. The vertical displacement of the Precambrian beds down this zone increases from 150 to 300 m westwards, but at some places between the Dubrovitsa and Hotyslav Highs the beds are shifted up, and dip flatly to the north up to the southern faults of the Podlasie-Brest Depression.

REVIEW OF STRATIGRAPHY

The copper fields are located on the tectonically prominent structures, which were periodically eroded between the Early Cambrian and Late Cretaceous. Consequently, in the studied area the sedimentary cover comprises Precambrian, Cambrian, Ordovician and Silurian rocks that are covered by the Upper Cretaceous beds, which, in turn, are locally overlapped by Cainozoic strata (Figs 2, 3). The most complete stratigraphic logs have been found in the boreholes in the western parts of the Podlasie-Brest and Volhyn Depressions, and in the Lublin-L'viv Low (Fig. 2).

The Upper Riphean strata, called Polis'ka series, 170–850 m thick, covers Lower Proterozoic crystalline rocks, which mostly consist of 1.2 Ga gneisses and granitoids containing numerous syenite and 1–1.1 Ga gabbro intrusions (Semenenko, 1968; Velikanov & Korenchuk, 1997). The sedimentary rocks are developed as red-bed sandstones and siltstones intercalated with clays, and comprise four successive sedimentary cycles (Garetsky (Ed.), 1981). The field-

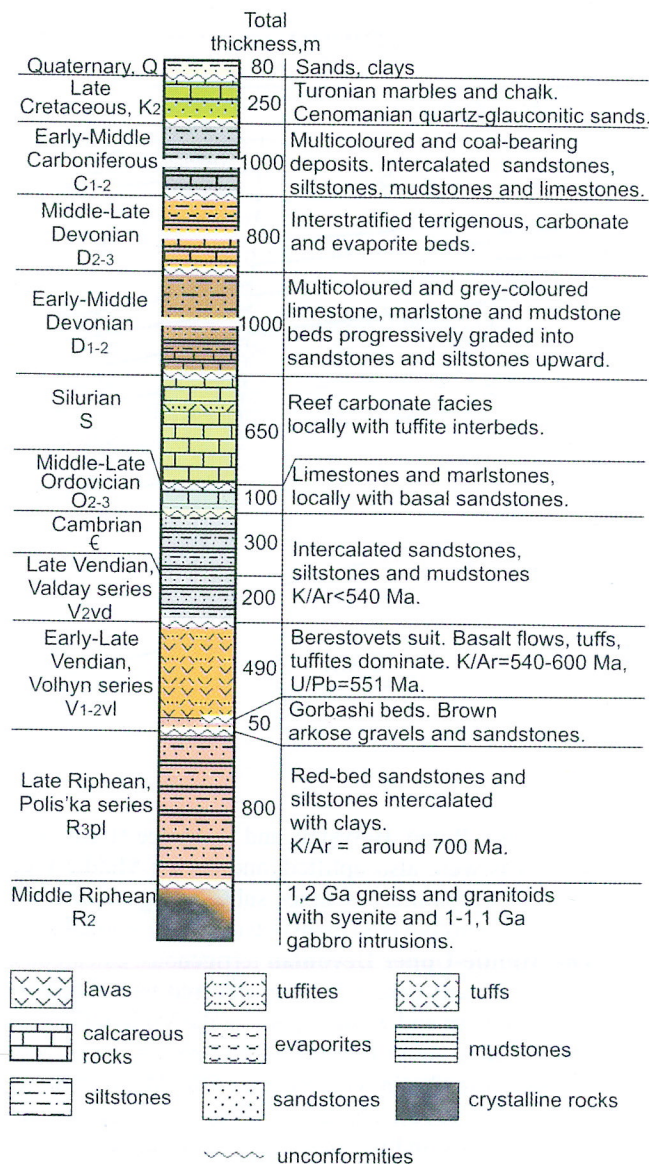


Fig. 2. Stratigraphic log of the Volhynian copper fields and adjacent areas

spar and mica of these sandstones have been K-Ar dated at 770–700 Ma (Semenenko, 1968; Krashennikova, 1987). The uppermost beds of the strata contain tillites.

The Upper Riphean strata filled the mid-Baltica rift system (Nikishin *et al.*, 1996), striking from NW and W to E across the present-day Volhyn Depression, Lukow-Ratne Swell, eastern margins of the Podlasie-Brest Depression and Belarus High, Prypyat and Orsha Depressions and Klinovsky High. Northeastwards, across the present-day Velizhsky High, this system abuts on the Mid-Russian – Valday aulakogen. The thickest, about 800 m, red-bed strata have been found in the central part of the Volhyn Depression (Fig. 1). In the Lukow-Ratne Swell, their thickness varies from 0 to 300 m on the highs and from 250 to 550 m in the adjacent lows. In the Podlasie-Brest Depression and farther east in the central part of the mid-Baltica, the thickness of these strata reaches 400–450 m.

The Lower Vendian brown and grey-brownish arkose

gravelstones and sandstones (Gorbashi beds of the Volhyn Series), 0–50 m thick, overlap the Upper Riphean strata or older crystalline rocks in the outskirts of the already ceased mid-Baltica rift. The clasts are composed of quartz, feldspar, plagioclase, and red sandstones.

The Lower through Upper Vendian flood basalt formations (Berestovets Suite of the Volhyn Series) represent the trappian effusive and pyroclastic deposits which conformably cover the above-described Gorbashi beds, overlap the Upper Riphean strata, and locally rest on the Lower Proterozoic crystalline rocks. Coeval dikes and sills of gabbro-dolerites everywhere cut and intercalate with the Upper Riphean strata and the Volhyn volcanogenic beds. Among pyroclastics, tuffites dominate. They contain many rounded 0.5–30 mm clasts of both basalts and tuffs. Tuffs and tuffites are mostly red, brownish, green-brownish, green or multi-coloured. They are hydrothermally affected by epidotization, chloritization, zeolitization, and hematitization. Everywhere basalts include layers of sintered red ashes.

The basalts exposed in the quarries are often columnar or massive. At some places, top massive basalts, 2–3 m thick, are represented by pillow lava flows. Both the colour and structure of the basalts and tuffs testifies to the continental and shallow-marine volcanic environments, characterized by intensive weathering and coastal erosion of the volcanogenic formations.

The thickness of the flood basalt formations reaches 350–450 m in the Volhyn Depression, the central part of the Lukow-Ratne Swell, and the southern part of the Podlasie-Brest Depression (Fig. 1). In these areas, the traps usually comprise 5–13 basalt flows which are intercalated with tuffs, tuffites, and terrigenous beds. Towards the marginal parts of the basalt province, the volcanogenic formations thin out, but in some places were eroded. Farther eastwards, along the mid-Baltica rift and in the southern margin of the Volhyn Depression, tuffites and terrigenous beds (Fig. 1) laterally displace the trappian formations.

The zircons of the uppermost tuffs have been dated at 551 ± 4 Ma by U/Pb ratio (Compston *et al.*, 1995). The K/Ar chronometry shows 600–500 Ma for the Volhyn flood basalts and 660–500 Ma for gabbro-dolerite dikes and sills, although the most common dates range 540–600 Ma (Semenenko, 1968; Krashennikova, 1987; Velikanov & Korenchuk, 1997). The last figures estimate the age of the flood basalt plateau. Some older and younger age estimations (Krashennikova, 1987; Velikanov & Korenchuk, 1997) relate to the hydrothermally altered rocks.

The Upper Vendian (Valday Series) and Cambrian beds unconformably cover the Volhyn volcanogenic formations as cyclically interbedded layers of sandstone, siltstone, and mudstone. The total thickness of the deposits ranges from 300–500 m at the western margins of the Podlasie-Brest and Volhyn Depressions up to 1,500 m in the North Moldovian Monocline. It suggests that the deposition occurred in an opened rift. The boundary between the Vendian and Cambrian beds is ascertained in the top of the so-called Laminarian Horizon, which includes carbon laminae comprised in grey and green-grey claystones.

Semenenko (1968) and Krashennikova (1987), basing on K/Ar ratio, dated feldspar and mica of siltstones and