TUFFITES FROM THE VARIEGATED SHALE FORMATION OF THE SKOLE UNIT

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Abstract: The Variegated Shale Formation in the Polish part of the Skole Unit contains four horizons of tuffites and dispersed pyroclastic material. All the tuffites are bentonitized and consist mainly of the mixed-layer illite/smectite, with a small amount of terrigenic and pyrogenic material: quartz, K-feldspar, plagioclase, muscovite, biotite and glauconite, plus rare calcite, ilmenite, magnetite, zircon, apatite, tourmaline, rutile, staurolite, garnet, and secondary anatase. Genetically, the tuffites are associated with dacitic-andesitic volcanism of the island arc type.

Key words: Skole Unit, variegated shales, bentonitized tuffite, Paleocene

INTRODUCTION

Sediments of the Polish part of the Skole Unit belong to a single stratigraphic succession, spanning a range of Lower Cretaceous–Upper Miocene. The thickness of this succession varies from 3.5 to 5.5 km. The strata were finally deformed in Burdigalian during the Styrian phase. Variegated Shale Formation represent a thin part of this succession (Rajchel 1990) lying upon the Ropianka Fm (Upper Cretaceous to Lower Paleocene) and are covered by the Hieroglyphic Fm (the upper part of Lower Eocene to the lower part of Oligocene).

GEOLOGICAL SETTING

The Variegated Shale Formation /VSF/ (Upper Paleogene–Lower Eocene) occurs over the whole area of the Skole Unit in the Polish part of the Outer Carpathians. The thickness of this complex in the axial part of the Skole Unit ranges from 130 m in the east up to 190 m in the west and it thins near the margins of the basin. This formation comprises the complex of red clayey and muddy shales with interbeds of green shales, lenses of lithosomes of various sandstones, cohesive gravitation flows, layers of limestones and horizons of bentonitized tuffites. The VSF contains also Mn and Fe oxide microconcretions as well as Mn, Fe, Mg and Ca oxide and carbonate concretions, with rare-occurring rancieite. The major component of shales of the VSF is represented by Ca-dioctahedral smectite (60-90%), which is accompanied by subordinate kaolinite, clinoptilolite, glauconite and quartz, and an admixture of muscovite, biotite and chlorite (Muszyński *et al*. 1979, Franus *et al*. 1999).

The VSF was formed below the CCD and represents deposits of a deep-sea basin from lower bathial and abyssal (hemipelagic) zones (Olszewska 1984). The formation depth of the VSF was about 3.4-3.7 km in an environment with high oxidation potential within the sediment being formed (Leszczyński & Uchman 1991, Franus & Rajchel 1999). Local fluctuations of this potential are marked by interbeds of green, noncalcareous shales, and also by sporadically occurring Fe, Cu and Pb sulphides (Franus & Rajchel 1999).

At the border with Ropianka Fm the VSF contains lithosomes of the Boguszówka Sandstone Mbr. The material of this sandstone is similar to that of the sandstones from the Wola Korzeniecka Mbr at the top of the Ropianka Fm (Kotlarczyk 1978). In the middle and upper part of the VSF there are individual, separated lenses of lithosomes of the Kosztowa Sandstone of different composition. The top of the VSF is occupied by the characteristic lithosom of the Chmielnik Striped Sandstone Mbr with silica cement and abundant glauconite. The material of all these sandstones was derived from various alimentation centres (Rajchel 1990).

The Paleocene strata of the VSF (mainly Żohatyn Variegated Shale Mbr) are composed of dark-red, muddy and clayey shales. This part contain often large lenses of black clayey and muddy cohesive gravitation flows (Babica Clays), rich in exotics. All the material to these flows was derived from the northern margin of the Skole basin. At the bottom part of this formation there is a regional correlation horizon (Rajchel & Myszkowska 1998a, b) of allodapic limestones (Bircza Lithothamnium Limestone Bed), whose algal material was also derived from the northern margin of the Skole basin. The phosphorite concretions occurring in the Paleocene part of the VSF along the southern boundary of the Skole Unit and in the lying to the south Sub-Silesian and Silesian units indicate possible upwellings in this part of the Carpathian basin.

The Lower Eocene strata of the VSF consist of bright-red cinnabar and green clayey shales. They form the characteristic horizon of the Trójca Red Shale Mbr about 20-30 m thick, which contains up to 30% of clinoptilolite (Wieser 1994, Bąk *et al*. 1997), a mineral of a potential economic importance. This member contains significant amounts of dispersed pyroclastic material. Morphology of zircons and chemical composition of claystons links the Trójca Red Shale Mbr with eruptions of dacite-andesite volcanoes. This horizon marks an apogee of radiolarian proliferation (above 60 species) in the VSF (Barwicz-Piskorz & Rajchel 2002).

BENTONITIZED TUFFITES

The VSF contains also several small layers of bentonitized tuffites. Their thickness is up to 5 cm, and the colour of these layers (creamy, yellowish, greenish or pink) contrasts with that of the surrounding rocks. The tuffites were found in the Skole Unit in several localities at Bircza, Olszany, Bartkówka, Futoma, Hyżne and Siedliska (Rajchel 1994, 1990, Kotlarczyk 1966, Koszarski & Koszarski 1985), and in the Szklary IG-1 borehole (Wieser 1969). All these localities belong to four horizons of bentonitized tuffites. On the basis of foraminiferal microfauna, ages of the tuffites of each site have been established and correlated with the stratigraphic position of the tuffites described from the Skole Unit and the other units in the Carpathians (Morgiel & Szymakowska 1978, Rajchel 1994).

Advanced bentonitization is common in all the tuffites from the VSF and they contain a relatively high admixture of the terrigenic material. Microscopic and X-ray investigations have revealed that fine-grained smectite is the major component of these tuffite, being accompanied by quartz, K-feldspar, plagioclase, muscovite, biotite and glauconite, rare calcite, ilmenite, magnetite, zircon, apatite, tourmaline, rutile, staurolite, garnet, and secondary anatase.

TUFFITES FROM THE UPPER PALEOCENE

The Upper Paleocene tuffites occur in two horizons, the lower (several sites) within the Boguszówka Sandstone Mbr and Żohatyn Variegated Shale Mbr, and the upper (one site) in the middle part of the Żohatyn Variegated Shale Mbr. They are light creamy and form small layers from 1 mm to 5 cm within dirty red shales of these members. The tuffites of the lower horizon show numerous features of the primary, not redeposited pyroclastic material, and rest several metres above the bottom of the VSF. These tuffites contain the highest amount of pyroclasts and reveal in hand specimens graded bedding, underlined by accumulations of biotite flakes. The lower tuffite horizon has been identified in Olszany (site 1, one layer), Leszczawa (site 2, one layers) and Bartkówka (site 3, two layers), and previously was described in Bircza (13 very thin, closely situated laminae; Kotlarczyk 1966). The upper tuffite horizon was found only in Futoma (Rajchel 1994). Compared with the lower one, it is characterized by a low amount of the clastic material and the presence of X-rayed anatase, the mineral absent in the lower horizon.

As the X-ray analyses indicate, disordered mixed layer illite/smectite with the amount of illite layers varying from 2 to 20% is the major mineral component of the tuffites from the three mentioned sites of the lower horizon. The interlayers of the smectites in question are occupied by bivalent cations Ca^{2+} and Mg^{2+}, and only in the case of one sample from Bartkówka (site 3) by monovalent Na^{+}. The tuffites do not contain kaolinite, what makes their important identification feature, as kaolinite, although in subordinate amounts, is always present in the surrounding clay rocks.

The tuffites of both the Upper Paleocene horizons contain glauconite and muscovite distinguished under the microscope, less frequent feldspars with signs of advance weathering, and dispersed, angular quartz with the grain diameter up to 0.15 mm. Only in single cases has the latter mineral the optical features of pyrogenic quartz. Voclanic glass has not been found, either in thin sections or in grain mounts, the latter prepared after leaching of the tuffite samples in hot, weak solution of hydrochloric acid.

The fraction of heavy minerals of the tuffites studied is similar to the heavy minerals in the surrounding rocks. In the tuffites from the lower horizon heavy minerals make up only 0.2-0.5%. Dominating minerals (usually 75 vol.% of the heavy fraction) include mainly opaques, ilmenite and rare magnetite, identified under the scanning microscope, while zircon and apatite are the main transparent minerals. They occur mostly as rounded grains, which indicates their terrigenic origin. The list of heavy minerals is completed by tourmaline, rutile, staurolite and garnets of typical terrigenic origin.

CLOSING REMARKS

Despite new information published all the time on the tuffite occurrences within the Outer Carpathians, only some of these rocks form reliable correlation horizons and even if they do so, the horizons are of a limited, local range. Insignificant lithological differences make correlation of the tuffites difficult (Sikora *et al*. 1969). The attempt of their correlation with zircon typologies has been unsuccessful because of the terrigenic origin of most its grains minerals (Wieser 1985). The mineral composition of the tuffites and of the dispersed pyroclastic material indicate their origin to be linked with dacite-andesite volcanism of the island arc type.

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