Petrological studies, isotopic and fluid inclusion relations in the Miocene sandstones in the Polish segment of the Carpathian Foredeep

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The study concerns the Sarmatian, deltaic sandstones from the eastern part of the Carpathian Foredeep basin. Samples from five boreholes: Chalupki Debnianskie 1, Jodlowka 18, Kupno 2, Nowosielce 3 and Pruchnik 22 have been studied. The following research methods were applied in rock observations: polarizing microscope (dyeing analysis, cathodoluminescence studies – CL, fluid inclusion studies - FI), scanning electron microscope (SEM) investigations and energy dispersive spectrometer studies (EDS ISIS), X-ray diffraction analyses (XRD) and isotopic analysis.

Petrographically, these sandstones are medium- to very fine-grained – sublithic and subarkosic arenites and wackes. The main component of the sandstone grain framework is quartz (19.7 – 70.6 vol. %) with predominance of mono- to policrystalline quartz. Feldspars (1.7 – 12.3 vol. %) are often represented by potassium feldspar and rare by acid plagioclase, which in CL have blue and green luminescence, respectively. Among lithoclasts (0 – 18.3 vol. %) fragments of carbonate rocks are predominating over clastic rocks, granitoids, volcanic rocks and quartz-mica schists. Micas (0 – 14.0 vol. %) are represented mainly by muscovite, sporadically by biotite. Among bioclasts (0 – 3.3 vol. %) shells of foraminifers, bivalves and brachiopods and fragments of echinoderms and bryozoans have been identified. Glauconite (about 1 vol. %) forms oval-shaped grains of different size. Heavy minerals are rare. Porosity of the sandstones is often of about 30% (primary and secondary porosity).

In the sandstones cement, matrix composed of mud quartz and detrital clay flakes was described, being locally impregnated by iron hydroxides, organic matter and pyrite. XRD analyses show mainly the presence of smectite, illite and chlorite. Booklets of kaolinite vermiform crystals and Mg/Fe-chlorite rims on quartz grains have been observed in SEM investigations. Authigenic quartz mostly forms thin overgrowths on quartz grains or singular, euhedral prisms in the pore space of rocks. Carbonate cements are represented by common calcite (micrite and spar) and subordinate dolomite/ankerite and siderite. The chemical composition of calcite is: 92.7 – 98.8% mol. $CaCO_3$, 0 – 4.6% mol. $FeCO_3$, 0 – 1.8% mol. $MgCO_3$ and 0 – 2.5% mol. $MnCO_3$. Calcite becomes purple in Evamy's solution and is characterized by red-orange and orange-yellow colours in CL. Fluid inclusions observed in the calcite cement in the Pruchnik 22 borehole are distinctly one phase. They are of two types – transparent (L1) and dark (L2). Their size oscillates from < 1 μm to small (1 – 2 μm). Some of them do not show any characteristic feature in the heating-freezing mode. The inclusions do not create a bubble when freeze, however, their one phase character points to low temperatures of the cement formation – below 50°C. The eutectic temperatures of about (-39°C) point to the $NaCl$-$CaCl_2$-$MgCl_2$-H_2O system, that means they characterize chemical system of dissolved ions of Cl-, Ca_2+, Mg_2+,Na+ and Fe_2+, while the ice melting temperature of -9.6°C proves the fluid salinity of 13.52 % NaCl eq. The δ18O data from calcite vary from -8.61 to -5.51‰PDB. They show that calcite precipitated from pore water which was a mixture of marine and meteoric waters. The δ13C values are in the interval of -5.72 to -1.71‰PDB and suggest inorganic origin of carbon. Dolomite/ankerite very often forms rhombohedrons. Some of crystals show zonation. The chemical composition of dolomite minerals is: 52.4 – 61.4% mol. $CaCO_3$, 18.1 – 44.3% mol. $MgCO_3$, 0 – 21.0% mol. $FeCO_3$ and 0 – 1.6% mol. $MnCO_3$. Microcrystalline siderite occurs as scattered crystals in sandstones. Siderite varies widely in composition, being enriched in magnesium and represents sideroplesite.