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DIAGENETIC MINERALS AS TEMPERATURE INDICATORS IN THE BURIAL HISTORY OF THE ROTLIEGEND SANDSTONES

INTRODUCTION

Presented study results concern the Upper Rotliegend sandstones from the Szczecinek – Bydgoszcz zone, which are at present incorporated to the Drawa and Noteć subgroups (Hoffmann i in., 1997; Pokorski, Wagner, 2001). The majority of the studies have been conducted in the Polish Geological Institute using different analitical methods (CL, SEM, EDS ISIS, XRD, fluid inclusions). The stable isotope determinations of light elements were performed in other scientific centres as: the isotope laboratory at the University of New Mexico (USA) and the Mass-spectrometry Laboratory of the Institute of Physics at the University in Lublin.

Studies of the autigenic minerals were one of the aims of the research. These minerals may point to the values of the paleotemperatures in the diagenetic history of the sandstones.

DIAGENETIC MINERALS IN SANDSTONES

The sandstone lithofacies is the main and the most common lithofacies in the Rotliegend sandstones. The following rock types have been distinguished: quartz, arkosic, subarkosic, lithic and sublithic arenites and wackes.

Apart from the grain fabric (mono- and polycrystalline quartz, feldspars, lithoclasts, micas, accessory minerals) authigenic minerals in the cements have been distinguished in the Rotliegend sandstones. They correspond to iron oxides and hydroxides, clay minerals, carbonates, sulphates and quartz. Some of these minerals may be concerned as the indicators of the paleotemperatures.

Iron oxides and hydroxides mostly occur as the overgrowths around the detrital grains. Iron was probably transported as ions in the solution, being bound in the iron hydroxide which is the hematite precursor (Walker, 1967). Such processes could have occurred in the oxidation environment, either in hot, desert climate or due to the progressing burial. The minimum temperature ofdehydratation and hydroxide transformation into hematite is about 40^0 C (Mücke, 1994).

Chlorites, kaolinite, dickite and illite have been distigiuished among the clayminerals. Mixed-layered illite/smectite occurs sporadically with them.

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Chlorites observed in the scanning microscope mostly occur as tables, plates, which form aggregates or as thin overgrowths around the detrital grains. X-ray studies have shown that the overgrowth forms are mostly built of the magnesium-rich chlorites. They could have crystallized in the temperature range of 90 – 120^{0}C. Such values Aagaard et al. (2000) have got due to the synthesis of chlorite similar to that present in the sandstones from the Norwegian oil fields at the depth of about 3000 m as well as due to the observations of the natural chlorite overgrowths from the same deposits.

Kaolinite and dickite mostly occur as platels aggregates which fill the porous space of the rocks. Due to the X-ray structural studies, it is possible to say that kaolinite is a main component of the fraction < 2 μm and 2 – 10 μm in the samples, the depth of which is lower than 4000 m. In two samples below 4000 m (borehole Wilcze IG1), dickite has been noticed in the clay fraction, the presence of which points to the diagenetic temperature of the sandstones over 100^{0}C (Ehrenberg i in. 1993).

As it results from the conducted studies, illite is the most common mineral in the clay cements of the Rotliegend sandstones (Kuberska, 2000, 2001). Lamellae of illite, arranged in a cellar manner and thin fibres, often described as filaments, are one of the occurrence forms of illite. The filaments are concerned as the authigenic components crystallizing in the temperatures over 70^{0}C (Wilson, Pittman, 1977; Small, 1993).

A presence of the mixed-layered minerals I/S of illite content exceeding 90% has been stated in some samples. The order expressed in terms of Reichweite equals to $R \geq 3$. Assuming that the illitization of smectite results only from the heating of the orogen, according to the Hoffman and Hower model points to the paleotemperatures over 180^{0}C (Horton, 1985).

Calcite and dolomite are the most common carbonates in the cements, ankerite being rare. Two calcite varieties have been distinguished due to CL and EDS ISIS analyses. They are: pure calcite (early diagenetic) and Mn-calcite (formed mostly in mesodiagenesis).

The homogenisation temperatures of fluid inclusions in the calcite and dolomite cements are from 80^{o}C to 101^{o}C (the approximate minimum trapping temperatures). The determinations of $\delta^{18}O$ in the carbonate cements (pure calcite, Mn-calcite, dolomite) allowed an estimation of the approximate crystallization temperatures according to the formula of Epstein et al. (1953) and Friedman and O`Neil (1977) with respect to a differentiation in the isotopic composition of the porous waters. The pure calcite might have crystallized in the temperatures from some to above 30^{o}C, taking an average $\delta^{18}O_{SMOW}$ for water equal to -5‰, Mn-calcite – from about 20^{0}C to over 75^{0}C ($\delta^{18}O_{SMOW}$ = 0‰), while the dolomite – either from 60^{o}C to about 100^{o}C ($\delta^{18}O_{SMOW}$ = +1‰) or from 32^{o}C to 60^{o}C (for $\delta^{18}O_{SMOW}$ = -5‰).

The anhydrite is a common cement component of the Rotliegend rocks. Assuming that the early anhydrites evaporated from the playa solutions, this early cement could have crystallized at about 50^{o}C. The later mesodiagenetic ones precipitated probably from the mixed, continental – marine solutions. Their crystallization temperature was about 115°C due to the interpretation of the results of the $\delta^{18}O$ determinations.

RECAPITULATION

Three main diagenetic stages have been distinguished in the burial history of the deposits: eo-, meso- and telodiagenesis due to the conducted studies and observations of the diagenetic minerals in the cements in the Rotliegend sandstones.

The following conclusions may be presented due to the analysis of the crystallization temperatures of the minerals:

the processes of the eodiagenesis occurred in the temperature not exceeding 50°C under the influence of the meteoric waters; the overgrowth cements (clayish, clayish-iron, calcite) and the early porous cements (calcite, dolomite, anhydrite and kaolinite) have formed at this stage;

the processes of the mesodiagenesis, occurred in temperatures close to 100°C as it results from the isotopic and fluid inclusion studies. The late diagenetic anhydrite points to the temperature of 115°C, while dickite – to about 120–130°C. The mesodiagenetic changes occurred under the influence of the continental – marine waters.

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