Paleotemperatures in the Skole nappe (Outer Carpathians)
inferred from diagenetic evolution of illite/smectite;
the pilot results

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Abstract

A considerable difference in the degree of illite/smectite (I/S) diagenesis has been recorded in the surface samples of claystones from the Polish and Ukrainian part of the Skole nappe. While in Poland highly smectitic I/S has been found, in the Ukrainian part of the Skole nappe highly illitic, ordered interstratifications dominate. Assuming similar heat flow, these results imply little erosion of the Polish segment of the Skole nappe, and advanced erosion of the Ukrainian segment.

Keywords: illite/smectite, diagenesis, Skole nappe, paleotemperatures

Introduction

Illite/smectite (I/S) is a mixed-layer clay mineral which abundantly occurs in soils and sedimentary rocks, accounting for about 30 % of the total mass of the Earth's sedimentary cover. Mixed-layer I/S is a product of progressive conversion of smectite to illite (a process referred to as smectite illitization), a diagenetic reaction which is induced by the increase of temperature most often related to deep burial of argillaceous sediments. These features make I/S a useful mineral indicator of diagenetic evolution of sedimentary basins. X-ray diffraction studies have shown that during diagenesis the percentage of smectite in mixed-layer crystals decreases at the expense of illite and the degree of structure ordering increases from random (R = 0) to progressively higher ordered (R > 0) interstratifications (R stands for Reichweite – an index of ordering). The degree of diagenesis is usually expressed as % smectite (% S) in mixed-layer crystallites and the type of ordering (R). Illitization of claystones seems to be controlled primarily by temperature. The data from the East Slovak Basin (Sucha et al., 1993) indicate that the measurable illitization of randomly interstratified (R = 0) clays composed of 70–90 %S, begins at about 80 °C. In the temperature range from 110 to 120 °C, with mixed-layer crystals containing about 35 %S, a transition from random to ordered interstratification (R = 1) takes place. R > 1 ordering appears at temperature of about 165 °C. Similar scenario is known also from other basins (e.g. Jennings and Thompson, 1986). The above scheme allows us to utilize I/S as a paleothermometer i.e. to establish the highest paleotemperatures which have affected the basin. One may also calculate the approximate thickness of the pile of sediments eroded after the time of maximum paleotemperatures, provided that the evolution of geothermal gradient in the basin is known (Środoń, 1995). This approach has been used to study the Skole nappe.

Geological setting

The Skole nappe extends from eastern Poland through Ukraine to the Romanian Carpathians in Moldova. In Poland, the Skole nappe is the outermost nappe of the Outer Carpathians which overthrusts the Stebniak and Zglobeice Units, and the unfolded Miocene strata of the Carpathian Foredeep (Fig. 1). The Polish part of the Skole nappe has been subdivided into inner and outer parts which differ in style of tectonic deformation (Książkiewicz, 1972). The rocks of the outer part are folded in tight, asymmetric folds and numerous slices. In the inner part, open folds are common. In Ukraine, the Skole nappe overthrusts the folds of Borysław-Pokucie Unit which separates it from the Sambor Unit and the unfolded Miocene strata of the Carpathian Foredeep. In the Ukrainian part of the studied region the Skole nappe is composed of several slices (Fig. 1).

Materials and methods

The studies of I/S diagenesis were performed on 29 surface samples of claystones collected both in the Polish and Ukrainian parts of the Skole nappe. The samples were collected from the strata that range in age from the Miocene to late Cretaceous. The sample sites are shown...
in Fig. 1A and B. In Poland, the majority of the investigated samples come from the outer part of the Skole nappe. In Ukraine, samples were collected along the Opor river. The section is located perpendicular to thrusts and axes of the map-scale folds.

Illitization of smectite has been studied in the clay fraction (<0.2 μm) of by X-ray diffraction. Sedimentary preparations were analyzed in air-dried and glycolated slates by the Philips diffractometer equipped with Cu tube and graphite monochromator and scanned from 2 to 37 °2θ with 0.02°2θ step and counting time 5s/step at 45 mA and 60 kV. The percentage of smectite (%S) in mixed-layer crystals and degree of ordering were identified by XRD techniques of Środoń (1984).

Results and conclusions

In the Polish part of the Skole nappe, surface samples contain highly smectitic I/S (71–95 %S) characterised by random interstratification. This would imply that the rocks have never been subjected to elevated temperatures (probably less than 80 °C). The lack of measurable diagenesis of I/S in the Polish part of the Skole nappe corresponds to the low degree of diagenesis traced in the boreholes down to about 2000 m in the Miocene strata of the Polish segment of the Carpathian Foredeep (Dudek, 1999). In the Ukrainian part of the Skole nappe, the diagenesis of I/S in the surface samples is much more advanced. I/S in those samples contains 20 % smectite layers on average, and is characterised by R > 1 ordering. According to the scheme presented in the introduction, the high degree of diagenesis would suggest that the rocks were subjected to the elevated temperatures, probably exceeding 160 °C, which could be attained by deep burial.

In conclusion, the presented diversity in the degree of diagenesis between the two areas suggests no or little erosion in the Polish part of the Skole nappe, and extensive erosion in Ukraine, assuming that the two regions have been characterised by similar heat flow. Another explanation of this diversity may be the totally different heat flow in the two studied areas.

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References