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Remarks on thermal maturity level in the subsurface of the Upper Silesian Coal Basin

ABSTRACT: The thermal maturity data presented by BROCHWICZ-LEWIŃSKI & *al.* (1986) from the subsurface of the Upper Silesian Coal Basin, southern Poland are discussed. The supposed low maturity level (60–70°C) in Cambrian rocks, based on acritarch color; is inconsistent with the maturity trends inferred by other indices of organic metamorphism (coal rank, vitrinite reflectance, conodont CAI), most probably because of decolorization of acritarchs due to secondary oxidation. The broad spectrum of maturity data (BEŁKA 1993 *and* KOTAS & *al.* 1983) shows that the Cambrian in the southern part of Upper Silesia must be slightly supramature. The validity of particular organic maturation indices is briefly outlined.

INTRODUCTION

BROCHWICZ-LEWIŃSKI & *al.* (1986) found acritarchs in the Cambrian clastic deposits covering the basement of the Upper Silesian Coal Basin. The acritarchs were collected from two boreholes that pierced the whole Paleozoic sequence in the southern part of Upper Silesia (*see* Text-fig. 1). Apart from the biostratigraphic evidence, these microfossils have also been applied for evaluating the thermal maturity level. Based on acritarch color, BROCHWICZ-LEWIŃSKI & *al.* (1986) recognized a very low level of organic maturation, corresponding to the vitrinite reflectance value (R_0) of 0.33%, in the borehole "Andrychów 3" at the depth of 2235 m. Subsequently, they used this estimation as argument to support the assumed extraneous character (suspect terrane) of the Upper Silesian Massif.

In the present paper the acritarch color data of BROCHWICZ-LEWIŃSKI & *al.* (1986) are discussed as they are in all respects inconsistent with the broad spectrum of different maturity data (coal rank, vitrinite reflectance, conodont CAI) known from the Devonian and Carboniferous strata of Upper Silesia. Moreover, the data show considerable sample bias.

VALIDITY OF ORGANIC MATURATION INDICES

Optical techniques are the most popular methods which have been in use since several years for assessing the thermal maturity of organic material contained in sedimentary sequences. They include indices based on optical properties of organic matter, such as its reflectance and fluorescence (for review *see* HÉROUX & *al.* 1979 *and* HOFFKNECHT 1991). Another group of indices is based directly on the sequential change in color of conodonts, amorphous kerogen, or various organic-walled microfossils (*e.g.* spores, acritarchs, chitinozoans, dinocysts, pollen), which is related to the progressive and irreversible alteration of organic matter.

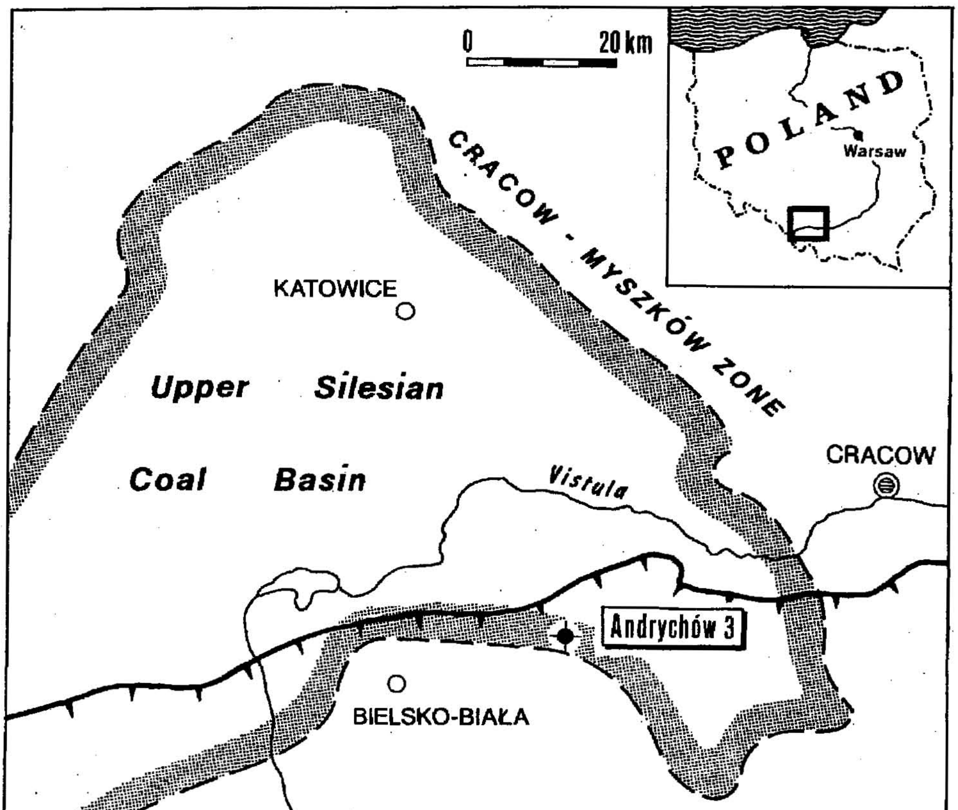

Fig. 1. Schematic map of Upper Silesia in southern Poland with location of the "Andrychów 3" borehole from which Cambrian acritarchs were analyzed by BROCHWICZ-LEWIŃSKI & *al.* (1986) for evaluating the thermal maturity level. The boundary of the Upper Silesian Coal Basin and the Carpathian overthrust are indicated

All these maturation indices, however, offer an indirect approach to temperature reconstruction through a calibration scale (TISSOT & *al.* 1987). Because none of the measured parameters can be directly converted to paleotemperature, it is difficult to prove the significance and validity of particular indices. Therefore, it is also not possible to convert precisely one of these indices into another, not only because of problems of inter-laboratory comparison of data (DEMBICKI 1984).

In practice, there are advantages and disadvantages in the application of any maturity parameters. Vitrinite reflectance, for example, which is generally considered to be the best method, cannot be used in strata older than the Late Silurian as they are devoid of land plants. Additionally, the composition of "vitrinite" macerals and thus their reflectance is clearly dependent on the marine or lacustrine origin of organic matter (DURAND & *al.* 1986). Conodont color alteration index (CAI) is applicable only to the marine Paleozoic and Triassic rocks. The advantage of this method, however, is due to the abundance of conodonts in a variety of sediments, including those in which vitrinite or graptolites are absent. The procedure is moreover very simple and inexpensive (EPSTEIN & *al.* 1977). The organic carbon present within conodont elements is certainly less subjected to oxidation due to weathering or diagenesis than is the organic matter dispersed in the host rocks (BEŁKA 1993).

Palynomorphs are good thermal indicators, especially in the low-temperature range (below 150°C) of organic diagenesis, but special care must be taken when applying these microfossils in maturation studies. This is because the palynomorphs are susceptible to selective loss of organic matter particles during host-rock diagenesis or when oxidative techniques are used for their preparation. As a consequence the color change observed do not often correspond with the real maturation level. In addition, the monitoring of palynomorphs color is subjective and may cause an inaccurate calibration. Another problem is that the particular groups of palynomorphs, i.e. spores, pollen, acritarchs, chitinozoans, exhibit different and poorly known chemical structures of organic matter, whereas the color depends on kerogen type and thickness of particle inspected. Therefore, each group of palynomorh grains require separate thermal calibration. The general correlation of spore color changes, for instance, to other maturity parameters is rather well established, but in the past various spore coloration scales were developed. Recently, COLLINS (1990) has proposed a Spore Color Index (SCI) 1-10 scale as a standard in order to solve the problem of inter-laboratory correlation. For other palynomorphs, there are as yet no universally accepted scales. Acritarchs may provide a valuable maturation index. The comparative studies showed, however, that a major color change occurs in acritarchs in the late mature zone. In practice, to test the validity of acritarchs color as a maturation index, a calibration against another known organic indicator is required (LEGALL & *al.* 1981) as well as a large set of samples to eliminate the oxidized material. Otherwise the estimated thermal maturity level is usually too low.

DISCUSSION

The Cambrian acritarchs used as a geothermometer in Upper Silesia by BROCHWICZ-LEWIŃSKI & *al.* (1986) were found in the borehole "Andrychów 3". The samples were taken from the mudstone and sandstone complex occurring at the depth between 2223 m and 2269 m. In this very short core interval, the acritarchs varied in color from light yellow to brown. The paleotemperature estimations were made for two samples only. As noted by BROCHWICZ-LEWIŃSKI & *al.* (1986), the first and stratigraphic youngest sample at the depth of 2222.9–2223.9 m contained light brown palynomorphs. Their coloration has been interpreted as indicative for a temperature of about 140°C. In the sample lying 12 meters below, however, the acritarchs were light-yellow in color corresponding approximately to the temperature of 60–70°C. In the remaining samples the coloration of acritarchs varied from yellow to brown.

It is in fact a curious case that BROCHWICZ-LEWIŃSKI & *al.* (1986) have paid no attention to the irregular variation in acritarch color within the only 46 m thick Cambrian complex. Even the discrepancy of the paleotemperatures values estimated side by side in the core have neither been explained nor discussed. On the contrary, they surprisingly assumed the lower temperature (60–70°C) to represent the maturity level of the Cambrian sequence. It is true that the thermal alteration of organic matter is irreversible and causes the darkening of organic tissues but, as already mentioned above, this is not valid in every case for the color changes observed in palynomorphs because of clearing effects (decolorization) due to the secondary oxidation.

BROCHWICZ-LEWIŃSKI & *al.* (1986) appear to have overlooked (or ignored?) some earlier papers dealing with organic maturation in the Upper Silesian Coal Basin and in particular the large set of coal quality data and vitrinite measurements (KOTAS & *al.* 1983). The coal quality field reflecting the maturity level of organic matter contained in the coal seams has been defined over large areas of the basin and mapped down to 1000 m below the surface. This maturity pattern has recently been confirmed by the conodont CAI analysis in the carbonate complexes underlying the Late Carboniferous coal measures (BEŁKA 1993). From all these data, it is evident that in the area of Andrychów the Carboniferous strata occurring at the top of the Paleozoic sequence are thermally mature in respect to oil generation (*see* Text-fig. 2). The base of the "oil window" zone, which is usually correlated with the maximum temperatures of 140–150°C, appears to occur at depth of 1800 to 1900 m. Thus, when extrapolating the maturation trend downwards, the Cambrian sequence pierced at depths of 2220 to 2350 m must be slightly supramature. It seems, therefore, that the brown coloration of Cambrian palynomorphs obtained from the borehole "Andrychów 3" reflect the real level of thermal

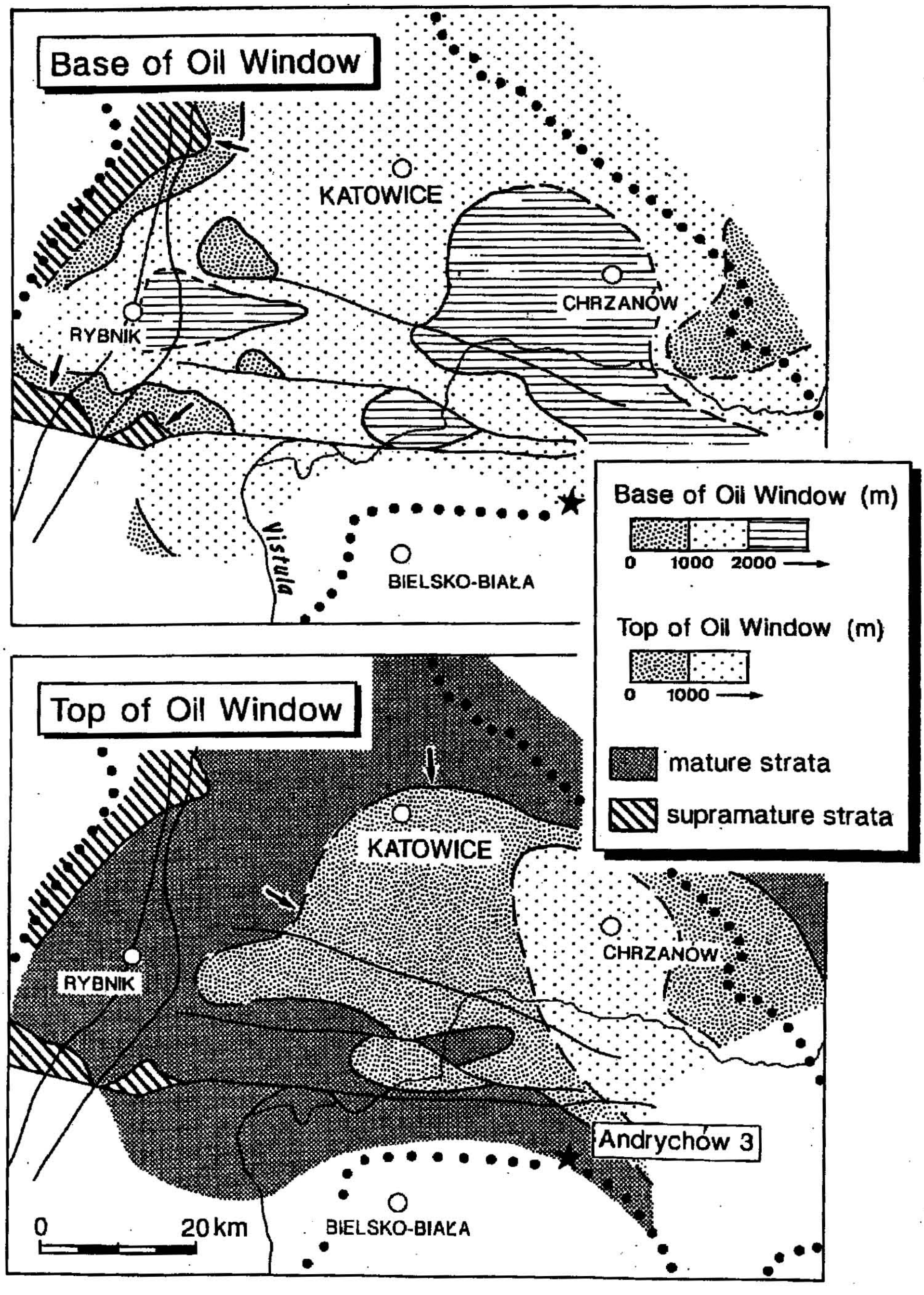

Fig. 2. Maps of the Upper Silesian Coal Basin showing thermal maturity zones in respect to oil generation for the top of Paleozoic sequence. Depth of the base and of the top of the "oil window" zone is additionally mapped. The thermal maturity zones occur independently of depth and stratigraphy. Maturation pattern compiled chiefly from coal quality maps of KOTAS & *al.* (1983) and combined with conodont CAI data (BEŁKA 1993) and mostly unpublished vitrinite reflectance measurements. Oil window defined as between 0.55% and 1.35% R_{omax}. The base and the top of the oil window zone are separately arrowed. Asterisked is the location of the "Andrychów 3" borehole

alteration attained most probably after Variscan inversion of the basin (*cf.* BEŁKA 1993).

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UWAGI O DOJRZAŁOŚCI TERMICZNEJ SKAŁ W PODŁOŻU GÓRNOŚLĄSKIEGO ZAGŁĘBIA WĘGLOWEGO

(Streszczenie)

Przedmiotem niniejszej pracy jest dyskusja oceny dojrzałości termicznej osadów kambru w podłożu Górnośląskiego Zagłębia Węglowego (*patrz* fig. 1) przedstawionej przez BROCHWICZA-LEWIŃSKIEGO i in. (1986). Autorzy ci użyli barwy akrytarchów jako miary stopnia podgrzania osadów. Dojrzałość termiczną osadów kambryjskich oszacowali jako niską (maksymalne podgrzanie do 60–70°C) i wykorzystali to jako argument wskazujący na pierwotne położenie Masywu Górnośląskiego z dala od jego współczesnej pozycji tektonicznej. Powyższa interpretacja opiera się jednak wyłącznie na wynikach pojedynczej próby. BROCHWICZ-LEWIŃSKI i in. (1986) zignorowali zarówno stosunkowo dużą zmienność barw akrytarchów stwierdzoną w obrębie krótkiego odcinka rdzenia, jak też niezwykle obszerne dane o dojrzałości termicznej osadów karbonu GZW (KOTAS i in. 1983). Dane te, potwierdzone i uzupełnione przez badania barw konodontów (BEŁKA 1993) wskazują, że w okolicy wiercenia Andrychów-3, skąd pochodziły kambryjskie akrytarchy, osady kambru sa lekko przegrzane (*supramature*) i znajdują się już poniżej strefy generacji płynnych węglowodorów. Przegrzanie to nastąpiło najprawdopodobniej w czasie późnowaryscyjskiej inwersji basenu górnośląskiego (*patrz* fig. 2).

W pracy naszkicowano krótko również wady i zalety poszczególnych metod stosowanych w paleotermometrii skał osadowych, a szczególności zwrócono uwagę na podatność akrytarchów na odbarwienie wskutek wtórnego utlenienia materii organicznej.