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Thermal evolution of the Ordovician in the western margin of the East-European Platform: CAI and R_O data

Maria NEHRING-LEFELD, Zdzisław MODLIŃSKI, Elżbieta SWADOWSKA

Zakład Geologii Regionalnej i Naftowej, Państwowy Instytut Geologiczny, 00-975 Warszawa, ul. Rakowiecka 4

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Values of colour alteration index of conodonts (CAI), based on collections from Ordovician strata of 40 boreholes, have been established for the area of the pre-Vendian Platform in northeastern Poland and adjacent southwestern areas of younger consolidation. Changes of the CAI are shown on maps. Six zones of similar CAI values are distinguished. Their presumed ranges beyond the boundaries of Poland are outlined basing on data from the adjacent countries. A spatial distribution of paleotemperatures was achieved in this way yielding new data which may serve to interpret the thermal history of the Early Palaeozoic deposits in the western slope of the East-European Platform. The changes of CAI are correlated with the results of vitrinite reflectance measurements (R_o) from selected profiles.

INTRODUCTION

Conodont alteration index (CAI) has been analyzed from the Ordovician strata known from numerous outcrops and boreholes situated along the western margin of the East-European Platform. The Ordovician sediments containing conodonts from Norway through Sweden, Denmark, boreholes in the Baltic Sea, Poland, Lithuania, Estonia, Belarus and Ukraine were taken into account. From the south-west toward south-east the following structural units have been distinguished within the pre-Vendian Platform: the Peri-Baltic Syneclise (PBS), the Mazury–Suwałki Elevation (MSE), the Podlasie Depression (PD), the Łuków–Wisznica Horst (ŁWH), the Włodawa Depression (WD), the Kumów Elevation (KE) and the Terebin Depression (TD) (J. Znosko, 1970; A. M. Żelichowski, 1974). The profiles used in this work come from the depressed structural units in which the Ordovician deposits are preserved (Fig. 1). These are calcareous-marly-clayey sediments about 100 m thick. They represent almost all Ordovician stages from Arenig up to Ashgill. Tremadoc sediments occur locally only.

Determination of the CAI on the basis of collection sampled in 40 boreholes allowed to present its changes on the map. Majority of these are deep boreholes of Polish Geological Institute. Beside that two boreholes were used drilled by the "Górnictwo Naftowe" Company (Pilzno 40, Uszkowce 1) and the data from the PP "Petrobaltic" Company drilling from the B3 structure.

Ordovician samples were also analyzed from Denmark (Bornholm Island) and Sweden (Scania and Öland Island) as well as from outcrops and drillings from Estonia, Lithuania, Belarus and Western Ukraine. The analysis of CAI values in the Scandinavian countries and in Ukraine has been based partly on published data (S. M. Bergström, 1980; D. M. Drygant, 1993).

The CAI values were compared with the results of vitrinite reflectance measurements (R_O) yielded from the Ordovician sediments of selected profiles (Fig. 3). They were then analyzed against the background of the present Ordovician structural pattern.

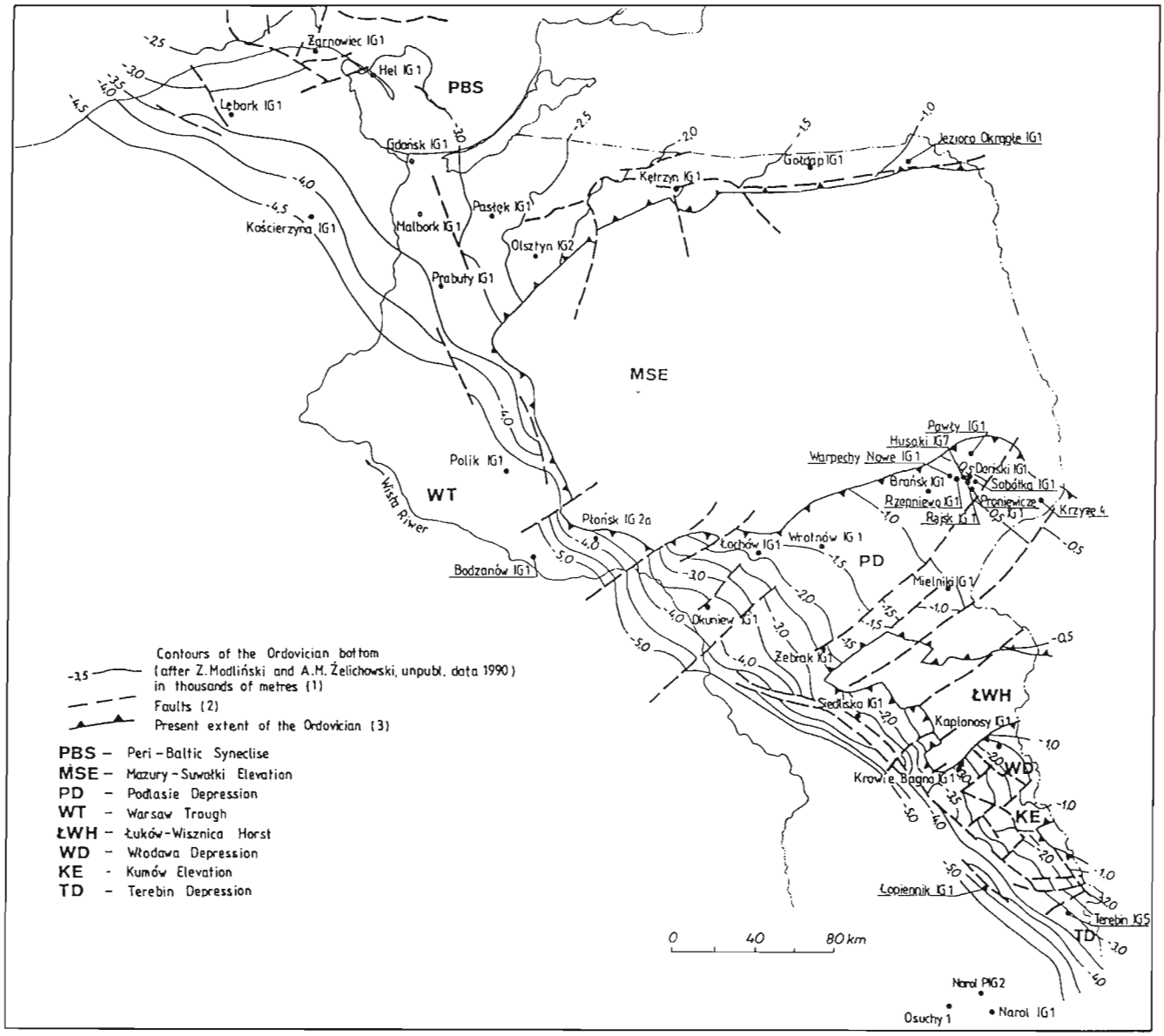

Fig. 1. Structural scheme of the Ordovician bottom (plotted on the basis of top Cambrian contour map — Z. Modliński, A. M. Żelichowski, 1990, unpubl. data) and location of boreholes

Szkic strukturalny spągu ordowiku (zestawiono na podstawie mapy strukturalnej kambru Z. Modlińskiego, A. M. Żelichowskiego, 1990, materiały niepublikowane) i lokalizacja otworów wiertniczych

1 — izohipsy spągu ordowiku w km, 2 — ważniejsze strefy uskokowe, 3 — obecny zasięg osadów ordowiku

INVESTIGATION METHODS OF CAI AND CHARACTERISTICS OF THE PALAEONTOLOGIC MATERIAL

In order to evaluate CAI the conodont collections were used coming from 135 rock samples taken from boreholes in Poland (Fig. 1) and from 48 samples coming from the adjacent countries. The frequency of conodonts in the particular collection varied greatly — from a few up to several hundreds of specimens in a sample. This palaeontological material contains about 10 000 specimens. The greatest frequency of conodonts is in the Lower Ordovician sediments. In cases of greater abundance the CAI values were established on the basis of 5–10 selected specimens treated as representative. The Munsell colour scale was used in colour determinations.

The method of CAI determination and its use were comprehensively described by A. G. Epstein *et al.* (1977) and V. A. Rejebian *et al.* (1987). In Poland it has been first applied by Z. Bełka (1990). The description of the method and its usage in the sedimentary basin analysis has been discussed by M. Narkiewicz and M. Nehring-Lefeld (1993).

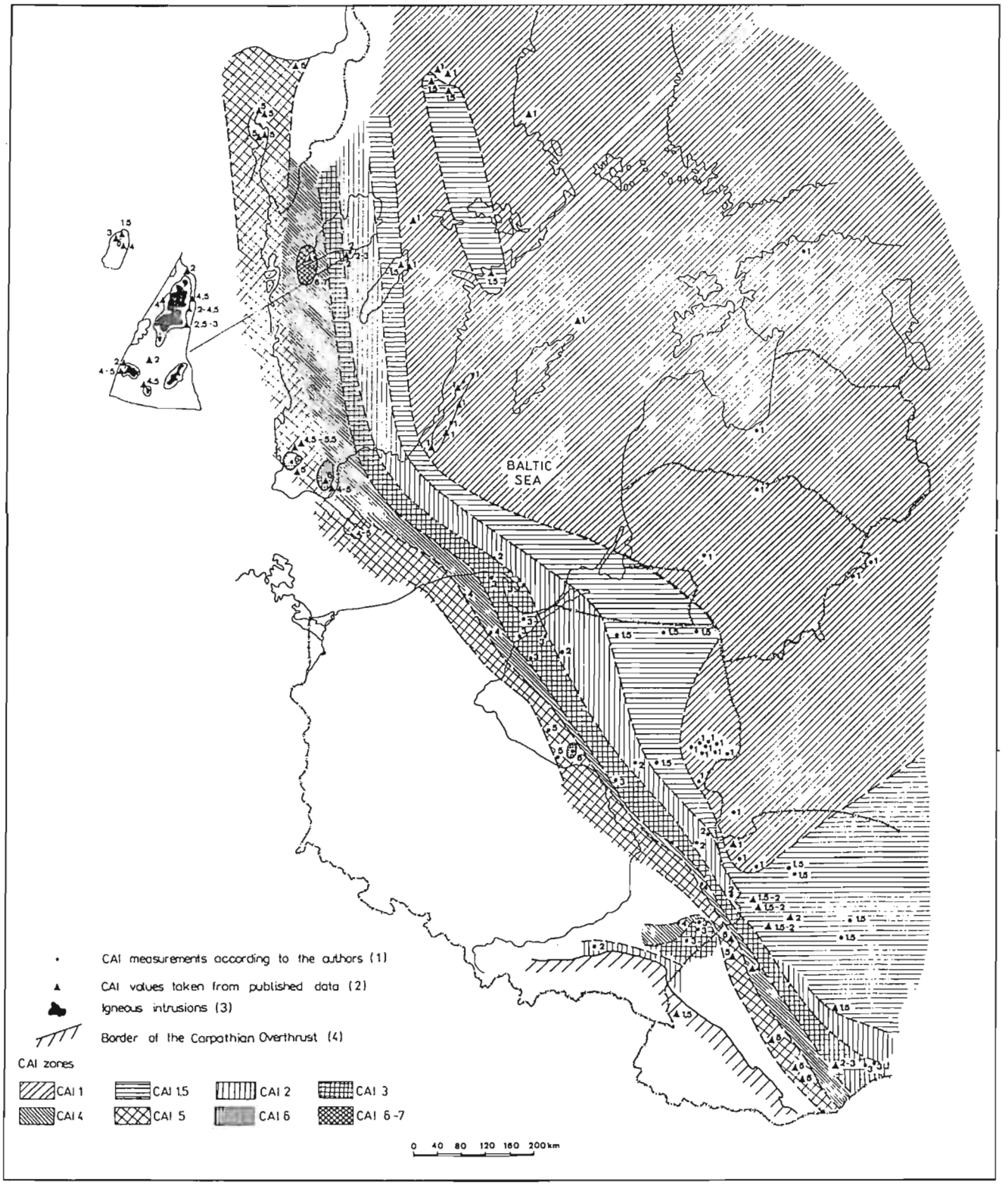

Fig. 2. Variability of CAI values in the western part of the East-European Platform and the Baltic Shield

Zmienność wskaźnika CAI w zachodniej części platformy wschodnioeuropejskiej i na tarczy bałtyckiej

1 — oznaczenia CAI wykonane przez autorów, 2 — oznaczenia CAI pochodzące z prac publikowanych, 3 — intruzje skał magmowych, 4 — granica nasunięcia karpackiego

VARIABILITY OF CAI IN THE WESTERN SLOPE OF THE EAST-EUROPEAN PLATFORM

On the basis of analysis of CAI values a map has been constructed (Fig. 2) of areas of similar values. Zonal arrangement of the CAI values and their increase from ENE toward WSW is observed. Six zones were distinguished of diversified width. In the east the zones are broader but they narrow markedly toward marginal, more depressed parts of the platform located near deep fractures of the Teisseyre-Tornquist zone. In the Ukraine, Poland and the Baltic Sea these zones run NNW–SSE whereas in Sweden their trend is close to meridional.

CAI 1 AND CAI 1.5 ZONES

In the area of Poland the CAI 1 zone has been distinguished within the eastern part of the Podlasie Depression only. The CAI 1.5 zone runs west of the CAI 1 zone and includes eastern part of the Peri-Baltic Syneclise, central part of the Podlasie Depression and a part of the Lublin area (Fig. 2).

Beyond the area of Poland both these zones cover vast regions in the western part of the East-European Platform. They are documented in the northwestern part of Ukraine (D. M. Drygant, 1993), in Belarus, Lithuania, Estonia and Sweden (S. M. Bergström, 1980). The observed CAI values 1 and 1.5 show (according to A. G. Epstein *et al.*, 1977) that the Ordovician sediments of these zones might have been heated up to temperatures of 50–90°C.

CAI 2 ZONE

The CAI 2 zone has been defined on the basis of conodonts from the Olsztyn IG 2 and Łochów IG 2 boreholes (for location see Figs. 1 and 2) as well as from the borehole drilled in the Baltic Sea (B3 structure). This zone is broadest in the eastern area of the continental part of the Peri-Baltic Syneclise and then narrows northward. It is well documented in Västergötland in Sweden (S. M. Bergström, 1980). In opposite direction it is again narrow in Western Ukraine.

On the basis of CAI indexes (A. G. Epstein *et al.*, 1977) the Ordovician sediments of that area were heated up to 60–140°C. It should be mentioned here that in the same area in Sweden some samples reveal very high CAI values 4–5 and even 6–7 (S. M. Bergström, 1980; see Fig. 2). Such high values are a result of influence of local igneous intrusions. In some areas in Västergötland there occur intrusions of Permian dolerites which have heated the adjacent sediments up to very high temperatures. The CAI 4–5 values are ascribed to temperatures of 190–480°C and CAI 6–7 — respectively — 360–720°C (A. G. Epstein *et al.*, 1977; V. A. Rejebian *et al.*, 1987).

CAI 3 ZONE

This zone is well documented by conodonts from the Peri-Baltic Syneclise and western part of the Podlasie Depression. It makes a narrow belt that broadens slightly in the Peri-Baltic Syneclise and narrows again in the Lublin area. In the north it is marked in Sweden in Västergötland (S. M. Bergström, 1980) and in the south-east — in Western Ukraine: the conodonts of CAI values 2–3 and 3 were found there in the Ordovician and Silurian sediments (vicinity of Chernovtsy — D. M. Drygant, 1993) as well as in outcrops near Kamenets Podol'skiy and Kitajgorod (the Tarnava River gorge).

This value of CAI suggests paleotemperatures of 110–140°C.

CAI 4 ZONE

The conodonts upon which the CAI 4 values has been determined come from western part of the Peri-Baltic Syneclise and southeastern part of the Lublin area. It is a narrow belt running NNW–SSE parallel to the CAI 3 zone. The zone is narrowest below the Warsaw Trough and in the Lublin area. It was marked on the basis of few data but its course is established by the adjacent zones.

This zone extends northward through the Baltic Sea to southern Sweden which is shown by data from the Ordovician sediments in Bornholm and Scania. The situation in Scania, however, is complicated by igneous intrusions that have caused local thermal anomalies. For example, in southeastern Scania the samples taken from the Ordovician close to an intrusion showed CAI = 6 whereas the samples taken in a distance of a few metres only off that site show CAI values 4–5 (S. M. Bergström, 1980).

This zone continues southeastward in Western Ukraine (D. M. Drygant, 1993). A CAI value of 4 allows to presume that the sediments of that zone were heated up to temperatures of 190–300°C.

CAI 5 ZONE

This zone is well documented in two boreholes only: Polik IG 1 and Bodzanów IG 1. Its continuation toward north-west and south-east may only be presumed on the basis of CAI values found in the Ordovician in Sweden and Norway (S. M. Bergström, 1980) and Western Ukraine (D. M. Drygant, 1993). In the latter area this zone was documented in boreholes located in the western part of the Lvov Depression up to the Rava Ruskaya Fault as well as in the southern part beneath the Carpathian Foredeep.

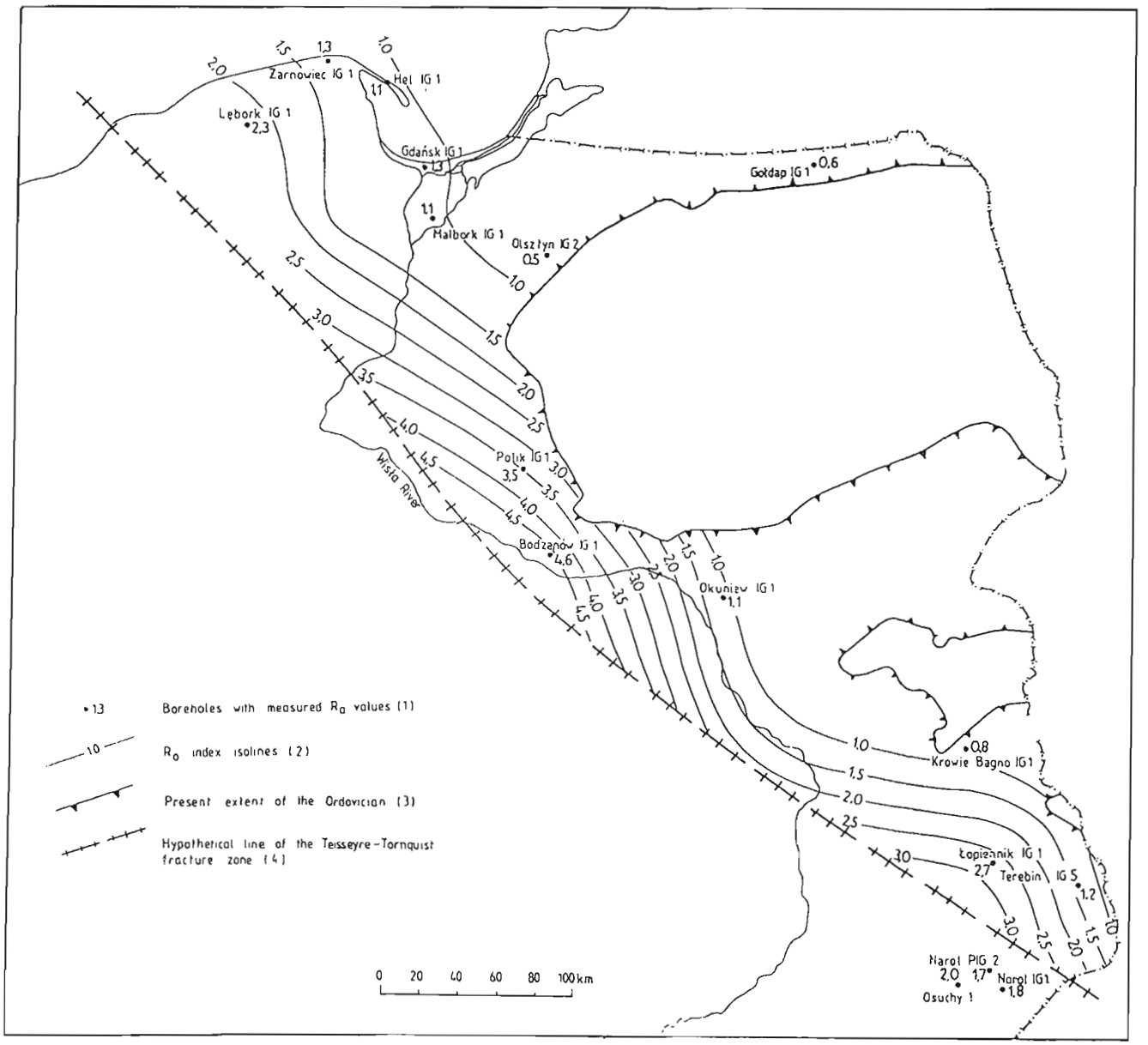

Fig. 3. R_o values in the Ordovician sediments from northeastern and eastern Poland

Mapa wartości wskaźnika R_o w osadach ordowiku NE i E Polski

1 — otwory wiertnicze z wyznaczoną wartością R_o, 2 — izolinie wskaźnika R_o, 3 — obecny zasięg osadów ordowiku, 4 — hipotetyczny przebieg rozłamów strefy Teisseyre'a–Tornquista

The CAI 5 index corresponds to temperature range 300–480°C (V. A. Rejebian *et al.*, 1987).

AREA OF ANOMALOUS CAI 6 VALUES

Below the Warsaw Trough a local anomaly of CAI 6 has been marked within the CAI 5 zone (Fig. 2). It was based on conodonts from the Płońsk IG 2a borehole. It allows to presume that the sediments containing those conodonts were heated up to temperature 360–550°C (V. A. Rejebian *et al.*, 1987). The cause of overheating is most probably the syenite intrusion pierced at Płońsk above the Ordovician rocks (M. Juskowiakowa, O. Juskowiak, 1974).

AREA OF VARIABLE CAI 2–4 VALUES IN SOUTHERN LUBLIN AREA AND THE CARPATHIAN FOREDEEP

This area is situated southwestward of the deep fractures of the Teisseyre-Tornquist zone beyond the limits of the pre-Vendian Platform. The CAI values were defined here in Ordovician sediments in profiles of four boreholes (Fig. 2). No correlation was noted between the present depth of the Ordovician sediments and the CAI values in those profiles.

This is an area of younger consolidation (Caledonian?) in which the Early Palaeozoic sediments are strongly tectonised and more or less depressed. This is reflected by considerable variability of the observed paleotemperatures that vary from 110 to 300°C.

VARIABILITY OF VITRINITE REFLECTANCE INDEX (R_o) IN THE ORDOVICIAN SEDIMENTS

Investigations of reflectance of organic matter have been made in 16 boreholes located in the Peri-Baltic Syneclise, the Łeba Elevation, the Warsaw Trough, the western part of the Podlasie Depression and the Lublin area.

Alteration degree of rather scarce organic substance in the Ordovician sediments determined on the basis of reflectance ability by vitrinite-similar macerals and bituminite is subject to considerable changes, that are distinct in regional scale. It is illustrated on the map of reflectance index R_o (arithmetic median) in the particular boreholes (Fig. 3). The changes of the degree of organic matter alteration reveal distinct correlation with depth of the Ordovician sediments despite the fact that locally are many deviations from this rule (Fig. 4).

The subsequent stages of alteration of organic matter and generation phases of oil and gas have been distinguished on the basis of R_o index values (P. Robert, 1985). The dependence between R_o index and paleotemperature, important in the process of alteration of organic matter, has been determined as well. In the vast area of the eastern part of the Peri-Baltic Syneclise the alteration degree of organic matter is subject to minor changes. It is in immature state or at the start of ability to generate hydrocarbons (R_o — 0.46–0.60%). The diagenetic processes of sediments in which organic matter occurs proceeded in temperatures from 50 up to 60°C. Remarkable is great difference in present depth at which the analyzed Ordovician sediments occur i.e. about 1000 m (compare Fig. 3 with Fig. 1).

In the adjacent areas of the central part of the Peri-Baltic Syneclise and the Łeba Elevation an increasing trend of the degree of organic matter alteration toward SW is noted, according to deepening of the rock sequences. The R_o index distribution is rather regular. Its isolines run parallel and its value increases from 1 up to 1.5%. The organic matter reaches maturity stage corresponding to the main phase of generation of oil (R_o from 1.1 up to 1.20%). Then it enters the main phase of generation of wet gases (R_o from 1.21 up to 1.43%) under temperatures changing from 60 up to 140°C. This image is somewhat disturbed by anomalous degree of metamorphism of organic matter in the Lębork IG 1 borehole located in the western part of the Łeba Elevation in which the R_o index is 2.30%. This proves alteration degree corresponding to a phase of generation of dry gases and pointing to high temperatures from 190 up to 300°C.

Intensity and rather regular changes of the organic matter reflectance are well illustrated by isolines of reflectance index R_o within a relatively narrow zone stretching along the margin of the pre-Vendian Platform (Fig. 3). These isolines are more or less parallel to the platform margin and their values increase toward SW from 1.0 up to 4.5%. Increase of organic matter alteration with depth from the stage of the main phase of generation of liquid hydrocarbons (R_o = 1.1%) to the stage of dry gases (R_o = 4.6%) is associated with rather quick and regular subsidence increasing toward SW i.e. toward the margin of the pre-Vendian Platform as well as with influence of temperatures from 60 to 480°C.

Similar but less distinct trend visible in the Lublin area (Fig. 3). WNW–ESE isoline direction in the northern part of the Włodawa Depression changes to more southerly one in the eastern part of the Terebin Depression with simultaneous increase of values from 1.0 up to 2.5% toward SW. The alteration degree increases there with depth of sediments.

These values show that the sediments reached an early phase of generation of oil up to the phase of generation of dry gases in temperatures changing respectively from about 90 up to about 300°C.

In the southern part of the Lublin area, beyond the limits of the pre-Vendian Platform the organic matter alteration degree is high. It changes little and does not show correlation with depth of the Ordovician sediments. In the boreholes Narol IG 1 and Narol PIG 2 (Fig. 3) the R_o value is, regardless of the depth, from 0.72 up to 1.90%. It shows an alteration corresponding to the main phase of generation of wet gases and a temperature at maximum from 110 up to 200°C. A distinct anomaly is to be noted in the Osuchy 1 borehole in which, at smaller depth, the R_o index is from 1.95 up to 2.15% pointing to an initial stage of generation of dry gases and a temperature of 190–300°C.

COMPARISON OF PALEOTEMPERATURES ON THE BASIS OF CAI AND R_o

The CAI values have been compared with the results of R_o measurements in the Ordovician from selected profiles. In some cases it allowed to confine the temperature ranges. Within the zones CAI = 1 and CAI = 1.5 the temperatures were defined on the basis of conodont studies. Only in the Gołdap IG 1 profile the R_o measurements have shown similar values. A comparison of results of CAI and R_o data within the zone CAI = 2 in the Lublin area (Terebin IG 5) has confirmed temperatures 60–140°C which has made them more reliable but did not allow to narrow their ranges. On the other hand

the results of measurements from the Olsztyn IG 2 and Krowie Bagno IG 1 boreholes do narrow the temperature range to 60–90°C.

Comparison of CAI and R_o data from the Żarnowiec IG 1, Hel IG 1, Gdańsk IG 1 and Malbork IG 1 boreholes located within the CAI 3 zone (Fig. 2) allows to presume that the temperatures might have vary within 110–140°C.

Within the zone CAI 4 (Lębork IG 1, Łopiennik IG 1) both methods point to the temperatures of the order 190–300°C.

The Ordovician sediments pierced in the Polik IG 1 and Bodzanów IG 1 boreholes located in the CAI 5 zone — again according to both methods — might have undergone temperatures 300–480°C.

In the southern part of the Lublin area and in the Carpathian Foreland the CAI and R_o measurements in the profiles of the Narol IG 1 and Narol PIG 2 allow to reckon that the Ordovician sediments were subjected to temperatures 110–200°C whereas in Osuchy 1 borehole — to temperatures 190–300°C.

EVALUATION OF DEPTH OF THE ORDOVICIAN SEDIMENTS BASED ON ANALYSIS OF CAI

The interpretation of CAI distribution allows also to draw conclusions as to the amount of subsidence. On the basis of paleotemperature analysis interpreted after the CAI values it is possible to evaluate the probable primary depth of the sediments that at present crop out or are found in boreholes at various depths. The results of investigations in the Appalachian basin (A. G. Epstein *et al.*, 1977) are of primary importance here: this area is ideal for testing the conodonts because of preserved full sequence of Palaeozoic sediments which allows to correlate precisely the CAI isolines with overburden thickness. The primary depth of sediments may have been defined taking for granted that geothermal gradient was similar to the present-day one i.e. about 33 m/1°C. A similar geothermal gradient — about 30m/1°C — was assumed by A. Witkowski (1989) in his analysis of depth for the Peri-Baltic Syneclise.

Taking into account the experience of those researches it may be assumed that the CAI 1 in the areas of western part of the East-European Platform suggests overburden thickness down to about 1200 m. Such a value was encountered mainly in the Podlasie Depression. The CAI 1.5 values have been found in Western Ukraine (the Volhynia Elevation), western part of the Podlasie Depression, in the eastern part of the Peri-Baltic Syneclise and in the Baltic Shield (Sweden — Silian district, Narke, Södermanland (Tvären), Ostergötland). In the latter area the Ordovician strata occur on the surface but they must have been deeply buried in the past. The overburden was probably composed of Silurian, Devonian and presumably the Carboniferous which formations were then removed at least in part. The data from the Appalachian region show that the CAI = 1.5 values correspond to a depth down to 2400 m. Such might have been the thickness of the overburden that covered the Ordovician in Volhynia. They

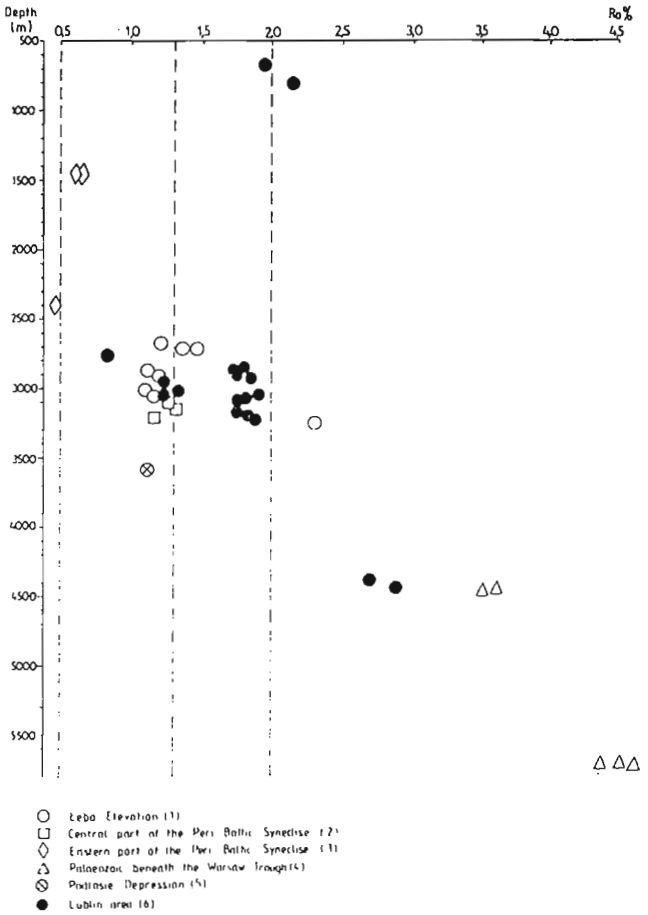

Fig. 4. Correlation of mean R_o values with depth of the Ordovician sediments

Korelacja średniego wskaźnika R_o z głębokością w osadach ordowiku
1 — wyniesienie Łeby, 2 — centralna część syneklizy perybałtyckiej, 3 — wschodnia część syneklizy perybałtyckiej, 4 — podłoże niecki warszawskiej, 5 — obniżenie podlaskie, 6 — obszar lubelski

occur at present at depths of about 200–400 m there. In Sweden the Ordovician sediments crop on the surface. So, the amount of uplift in both areas were of the order of 2000–2500 m.

In the case of CAI = 2 the maximum depth is estimated at about 3600 m. Similar values were stated in the central part of the Peri-Baltic Syneclise (Olsztyn IG 2) and in the Lublin area (Krowie Bagno IG 1, Terebin IG 5). Definitely shallower position occupy the Ordovician sediments in the eastern part of the latter area (Kaplonosy IG 1). The uplift there is caused by block tectonics. Another elevation is noted in the southern part of the Baltic Sea (the B3 structure).

The CAI = 3 values in the Appalachian region were stated at depth of about 3600–5500 m. In Poland the sediments at similar depths were found but in the westernmost part of the Podlasie Depression (Okuniew IG 1) as well as in the depressed central part of the Peri-Baltic Syneclise (Prabuty IG 1). Definitely elevated Ordovician sediments occur in the Łeba Elevation (Żarnowiec IG 1) and in the southern Lublin area (Narol IG 1, Narol PIG 2) where the overburden thickness must have been much greater than now.

In the Appalachians the CAI = 4 values correspond to depth about 7500 m and the CAI = 5 — about 9500 m, respectively. Those are much greater depths than those in Poland and in Western Ukraine with the same CAI values. Thus it can be reckoned that the Ordovician strata in the latter areas were primarily much more depressed.

CONCLUSIONS

1. A zonal pattern of CAI values is observed in the investigated part of the East-European Platform. CAI values increase from ENE toward WSW. In the east the CAI zones are broad but they definitely narrow toward the marginal, more depressed, parts of the platform.

2. In general, there is an accordance of the CAI zonal pattern with the structural plan of the bottom of the Ordovician sediments. The following deviations from this scheme are to be observed: (a) A comparison of the present Ordovician bottom with the CAI distribution shows that the Łeba Elevation must have been primarily much more depressed. This depression may have resulted from the overburden of the thick Silurian and the Devonian strata. The comparison of two maps (Figs. 1 and 2) clearly show a discordance of Ordovician isohypses and the course of CAI isolines which cross each other almost at a right angle. This discordance may pertain to some extent to the more easterly situated areas of the Peri-Baltic Syneclise i.e. the Gdańsk–Pasłęk one. (b) A concordance of the CAI isolines and the bottom contours of the Ordovician is observed in the southwestern more depressed part of the Peri-Baltic Syneclise (Kościerzyna IG 1, Prabuty IG 1 and Lębork IG 1). (c) Similar accordance was noted as well in the Warsaw Trough but there the CAI zones are narrow. A distinct anomaly was observed near Płońsk (Płońsk IG 2a). A very high CAI value results there from the existence of syenite intrusion above the Ordovician sediments (M. Juskowiakowa, O. Juskowiak, 1974). (d) A narrowing of the CAI zones occurs in the Podlasie Depression as compared to that in the Peri-Baltic Syneclise. It is even more pronounced in the southeastern part of the Lublin area. This agrees with a strong inclination of the Ordovician bottom surface toward WSW. (e) In the southeasternmost part of the Lublin area and in the Carpathian Foreland i.e. in the area beyond the pre-Vendian Platform the isolated, few CAI data do not allow to draw the isolines.

3. A comparative analysis of CAI and R_o measurements from the Ordovician sediments allowed more precise determination of probable paleotemperature ranges. The Ordovician system is representative for the Early Palaeożoic. Hence, the ranges of paleotemperatures of the Ordovician sediments are close to those under which the diagenetic processes in the latest Cambrian and in the Early Silurian took place.

4. The interpretation of CAI pattern allows to draw conclusions concerning palaeotectonics. On the basis of analysis of paleotemperatures read from the CAI values it may have been possible to evaluate the probable depth to which were depressed these Ordovician sediments which occur now at the surface (e.g. some areas in Scandinavia) or are pierced on small depths (the Podlasie Depression).

5. Analysis of CAI values makes the reconstruction of paleothermal history of an area easier thus being one of the methods for evaluation of organic matter maturity degree in sediments. The Ordovician sediments of CAI 1 and CAI 1.5 did not undergo stronger heating, thus they contain immature organic material.

The values of CAI 2 zone point to a degree of alteration of organic matter in the sediments which corresponds to the main phase of generation of liquid hydrocarbons.

The sediments classified to the CAI 3 zone are associated with the phase of generation of wet gases whereas the sediments of CAI 4 and CAI 5 zones should be associated with a higher degree of metamorphosis of organic matter i.e. of phase of generation of dry gases.

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EWOLUCJA TERMICZNA ORDOWIKU NA ZACHODNIM SKŁONIE PLATFORMY WSCHODNIOEUROPEJSKIEJ NA PODSTAWIE DANYCH CAI I R_O

Streszczenie

Ustalono wartości wskaźnika zmiany zabarwienia konodontów na podstawie kolekcji z osadów ordowiku z 40 otworów wiertniczych z prewendyjskiej platformy NE Polski oraz przylegających do niej na południowym zachodzie obszarów o młodszej konsolidacji. Badaniami objęto również próbki z osadów ordowiku Danii (Bornholm), Szwecji (Skania, Olandia), Estonii, Litwy, Białorusi i Zachodniej Ukrainy. Analiza wartości CAI w krajach skandynawskich i na Zachodniej Ukrainie została sporządzona częściowo na podstawie danych już opublikowanych (S. M. Bergström, 1980; D. M. Drygant, 1993). Dla oceny wskaźnika CAI wykorzystano kolekcje wyizolowane ze 135 próbek pobranych z otworów wiertniczych zlokalizowanych na badanym obszarze Polski (fig. 1) oraz z 48 próbek pochodzących z krajów ościennych. Ustalenie wartości tego wskaźnika pozwoliło na przedstawienie na mapie (fig. 2) zmian jego wartości w osadach ordowiku. Wyznaczono 6 stref o podobnych wartościach CAI oraz ich przypuszczalne zasięgi poza obszarem Polski. Uzyskano w ten sposób dane dla odtworzenia paleotemperatur. Ordowik jest systemem reprezentatywnym dla starszego paleozoiku, dzięki czemu zakresy paleotemperatur są bardzo zbliżone do zakresów, w których przebiegały procesy diagenetyczne, zarówno wyższego kambru, jak i dolnego syluru.

Zaobserwowano strefowe ułożenie wskaźnika CAI, którego wartości zwiększają się od ENE ku WSW. Na wschodzie obszaru są one bardzo rozległe, wyraźnie zwiększając się ku brzeżnym, bardziej pogrążonym częściom platformy. Istnieje duża zgodność rozkładu poszczególnych stref ze szkicem strukturalnym spągu ordowiku, istnieją jednakże od tego pewne odstępstwa.

Dzięki porównaniu wskaźników CAI i refleksyjności witrynitu R_o można było precyzyjniej określić przypuszczalne zakresy paleotemperatur, w jakich mogły się znajdować osady ordowiku (A. G. Epstein i in., 1977; V. A. Rejebian i in., 1987). W strefach CAI 1 i CAI 1,5 osady te mogły być podgrzewane do temperatury 50–90°C. Zróżnicowanym temperaturom podlegały osady tego wieku zachowane w strefie CAI 2. W jej części północno-zachodniej i częściowo w centralnej Lubelszczyźnie diageneza mogła przebiegać w temperaturach 60–90°C. Osady z południowej części tejże strefy podlegały temperaturom 60–140°C. Paleotemperatury w strefie CAI 3 mogły wahać się w granicach 110–140°C, w strefie CAI 4 — w granicach 190–300°C, wreszcie w strefie CAI 5 — 300–480°C. Przedgórze Karpat i najbardziej na SE wysunięta część Lubelszczyzny (strefa Biłgoraja) to obszary o młodszej konsolidacji, gdzie utwory ordowickie zostały silnie zaangażowane tektonicznie i w różny sposób wypiętrzone. Stwierdzonych tu wartości CAI nie można zatem łączyć ze strefami tego wskaźnika wyznaczonymi na platformie prewendyjskiej.

Na podstawie analizy paleotemperatur odczytanych z wartości CAI próbowano ustalić przypuszczalną głębokość, do której były pierwotnie pogrążone osady ordowiku. Dla rozważań tych wykorzystano rezultaty badań prowadzone w Appalachach (A. G. Epstein i in., 1977). Wynika z nich m.in., iż występujące obecnie na powierzchni osady ordowiku południowej Szwecji i Bornholmu, w których CAI wynosi od 1,5 do 4, musiały być pierwotnie silnie pogrążone nawet do głębokości kilku kilometrów. Również ordowik wyniesienia Łeby znajdował się pierwotnie znacznie głębiej. W obu tych obszarach wiąże się to z pierwotnie dużo większą miąższością osadów syluru i obecnością utworów dewonu.

Osady ordowiku wyniesienia wołyńskiego w Zachodniej Ukrainie, w których CAI = 1,5, a występujące na głębokości ok. 200–400 m mogły pierwotnie występować na głębokości do ok. 2400 m. Nadkład ich obejmował najprawdopodobniej osady syluru i dewonu, a być może i karbonu, które następnie zostały częściowo lub całkowicie zerodowane.

Analiza wskaźników CAI stanowi jedną z metod służących do oceny stopnia dojrzałości materii organicznej w osadach. Utwory ordowiku stref CAI 1 i CAI 1,5 nie ulegały silniejszemu podgrzaniu i tym samym zawierają niedojrzały materiał organiczny. Wartości wskaźników strefy CAI 2 wskazują na stopień przeobrażenia tego materiału, odpowiadający głównej fazie generowania ciekłych węglowodorów. Osady ordowiku zaliczone do strefy CAI 3 związane są z fazą generowania gazów mokrych, natomiast osady stref CAI 4 i CAI 5 z fazą generowania gazów suchych.