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Carbon and oxygen isotope curves for the Oxfordian of Central Poland

ABSTRACT: Delta-13-carbon and delta-18-oxygen values are recorded in brachiopod shell material covering the almost complete succession of the epicontinental Oxfordian in Central Poland. A positive intercorrelation of the carbon and oxygen isotope curves is recognized. The high carbon isotopic ratio suggests the Oxfordian was a time of overfed ocean conditions in the study area, when put in terms of the overfed-to-hungry ocean fluctuation model. In the Upper Oxfordian, precisely in the Bimammatum and the lower Planula Zones, a distinct discrepancy in the magnitude of the carbon and oxygen isotopic shifts is correlated with two invasions of the Boreal fauna, and hence possible inflows of less saline waters from the hydrochemically distinctive Boreal Realm.

INTRODUCTION

The Upper Jurassic sponge megafacies is widespread on the outer northern shelf of the Tethys in Europe, including Central Poland (KUTEK, MATYJA & WIERZBOWSKI 1984). Consequently, the Oxfordian fauna of the sponge megafacies in Central Poland is representative of the Submediterranean province (*see* Text-fig. 1). In the Upper Oxfordian, however, two invasions of the Boreal fauna have also been recorded (MATYJA & WIERZBOWSKI 1988). These invasions have left no distinctive lithological characteristics in the stratigraphic column. One may expect, that the paleoceanographic changes that made possible the Boreal invasions must have had some environmental, physico-chemical correlates. Such correlates, in turn, are most likely to affect also the carbon and oxygen stable isotope relationships in the ocean (*cf.* SCHOPF 1980, HOEFS 1981). Therefore, the authors have undertaken to establish and analyze the carbon and oxygen isotope curves for the Oxfordian of Central Poland, as recorded in samples derived from the sponge megafacies, in the hope this analysis would contribute to elucidation of the paleoceanographic conditions and thus would shed some new light on the depositional environment at that time.

MATERIAL AND METHODS

Stable carbon and oxygen isotopic relations, as expressed in the standard delta-13-carbon and delta-18-oxygen notation, reflect the condition of a carbonate system and the nature of the kinetic fractionation processes that go on in the environment. Because of the rapidity of carbon circulation in the ocean/atmosphere system (HOLLAND *& al.* 1986), changes in the global carbon cycle must affect all local environments. Therefore, each local geologic record of delta-13-carbon is the net result of global and local processes. The smaller the local reservoir of carbon, the larger the role of local proccesses in determining the local carbon isotope curve during the appropriate time interval.

Since the Oxfordian appears to have been rather quiescent in terms of the global carbon cycle (HOEFS 1981, HOLSER 1984), the potential for application of the geological record of delta-13-carbon in Central Poland for interpretation of the paleoceanographic conditions in the northwest Tethys is substiantial.

Unfortunately, there is always a possibility of diagenetic biases introduced to the sample material, which obscure the real patterns. The authors here deliberately disregard this possibility. Under the study was exclusively

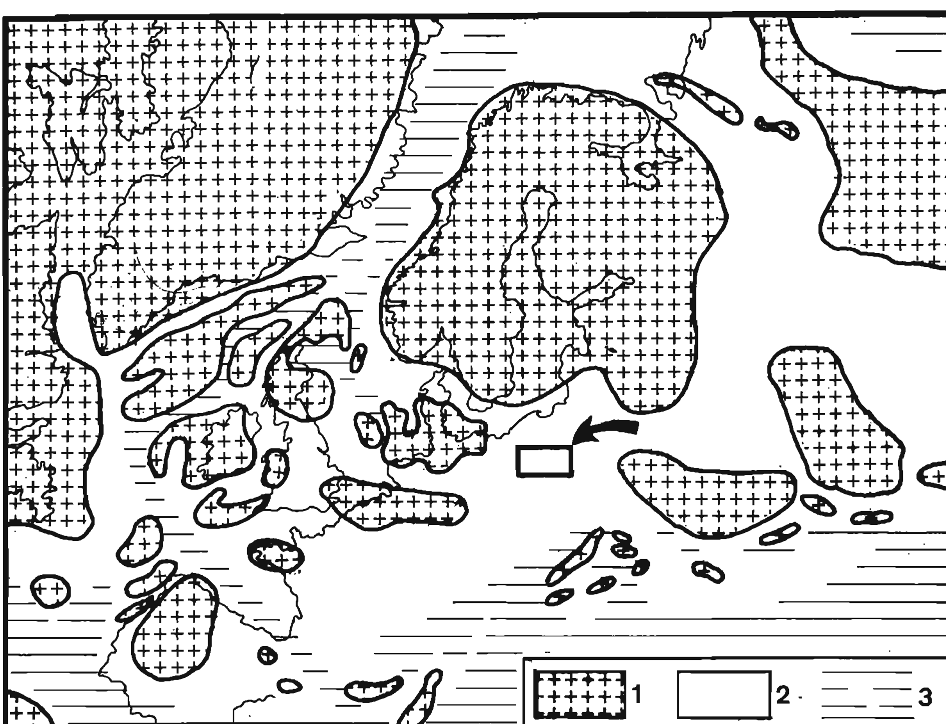

Fig. 1. Oxfordian paleogeography (*after* ZIEGLER 1987; *simplified and modified*); the study area is indicated by an arrow
1 — land areas, 2 — shallow-water areas, 3 — deep-water areas

well-preserved brachiopod (in fact solely terebratulid) shell material, while it had been demonstrated by LOWENSTAM (1961), VEIZER & FRITZ (1976), and AL-AASM & VEIZER (1982) that the brachiopod shell low-magnesium calcite is among those carbonate materials which are the least vulnerable to diagenetic alterations.

The brachiopod samples analyzed come from a number of localities in Central Poland (*see* Text-fig. 2), correlated by means of ammonite biostratigraphy (*cf.* KUTEK, MATYJA & WIERZBOWSKI 1984) to form a composite section covering almost the entire Oxfordian and the lowermost Kimmeridgian (*see* Text-fig. 3). The sample material was treated by pure phosphoric acid and studied by mass spectrometry of the resulting carbon dioxide; the standard error of single measurements is less than 0.8 permil. The results are expressed in delta notation relative to the *PDB* standard, using the *NBS-19* reference sample.

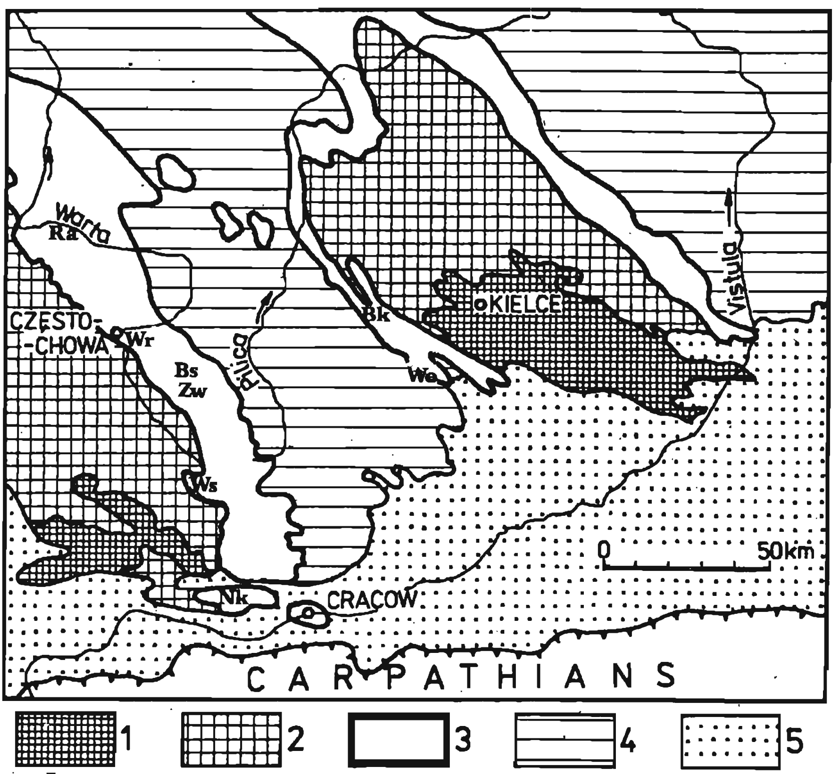

Fig. 2. Geological map of Central Poland (*after* ZNOSKO 1968)

1 — Paleozoic, **2** — Triassic through Middle Jurassic, **3** — Upper Jurassic, **4** — Cretaceous, **5** — Tertiary (Middle Miocene) of the Fore-Carpathian Depression

Sampling localities (for stratigraphic location of samples *see* Text-fig. 3): **Ra** — Raciszyn (sample *31*), **Wr** — Wrzosowa (sample *9*), **Bs** — Biskupice (sample *36*), **Zw** — Zawada (samples *32, 33, 34*), **Ws** — Wysoka (sample *3*), **Nk** — Nowa Krystyna (samples *13,26,30*), **Wo** — Wolica (samples *14,15*), **Bk** — Bukowa (sample *42*)

RESULTS

The presented results (Text-fig. 3) display a very strong positive intercorrelation of the carbon and oxygen isotope curves. It may appear surprising because a clearcut negative correlation is well documented for the Cenozoic (*e.g.* RUDDIMAN & *al.* 1989). On the other hand, however, a strong positive correlation between delta-13-carbon and delta-18-oxygen in the oceanic carbonate system occurs at all major isotopic shifts in the Phanerozoic, that is, the Permian-Triassic (GRUSZCZYŃSKI & *al.* 1989, 1990), Precambrian-Cambrian (HSÜ & *al.* 1985, Fig. 2; MAGARITZ & *al.* 1986, Fig. 1; AHARON & *al.* 1987, Table 1), and Cenomanian-Turonian transitions (JARVIS & *al.* 1988, Fig. 26); where the carbon isotope curve falls dramatically down, the oxygen curve does the same.

Moreover, there is a strong positive correlation between carbon and oxygen curves also during the well documented secular increase in the carbon isotopic ratio in the oceanic carbonate system during the Paleozoic (POPP & *al.* 1986). Thus, in spite of the impression derived from observations made in Cenozoic, the intercorrelation of the carbon and oxygen curves appears to be the rule rather than an exception. The apparent commonness of this phenomenon speaks also against the possibility that the presented results reflect a diagenetic effect rather than reality.

In the Upper Oxfordian of Central Poland, however, there appears a distinct discrepancy in the scale of the carbon and oxygen isotope shifts. The oxygen curve falls dramatically (by 4.5 permil), while the carbon drop is rather mild (by approximately 2 permil) compared to what happens below in the stratigraphic column (*see* Text-fig. 3). A discrepancy of the reverse type occurs in the Lower

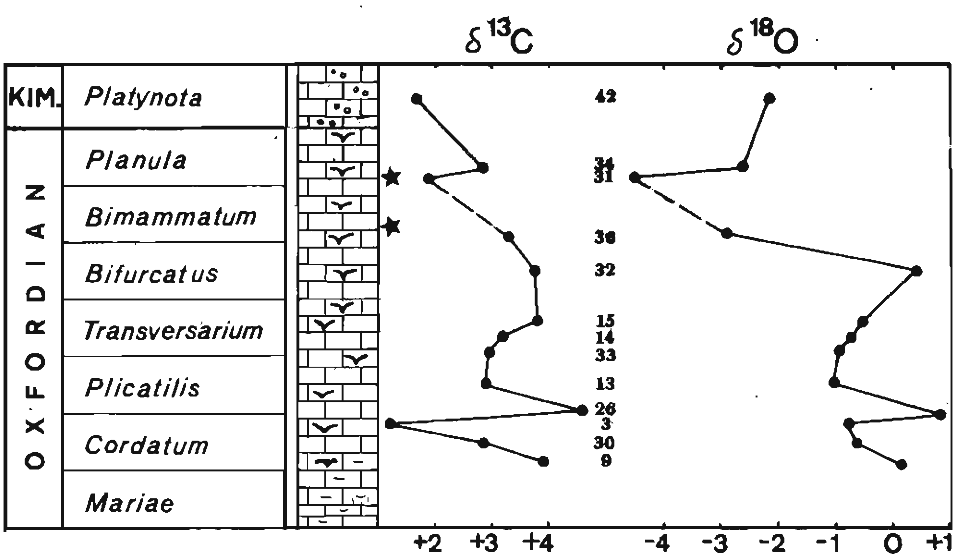

Fig. 3. Carbon and oxygen stable isotope curves (in standard notation, scale in permil) for the Oxfordian through lowermost Kimmeridgian in Central Poland; stars mark the invasions of the Boreal fauna (*cf.* MATYJA & WIERZBOWSKI 1988); for sample location *see* Text-fig. 2

Oxfordian (*see* samples No. *9, 30, 3*) where the carbon curve drops by some 3 permil, while the oxygen drop is much smaller (by 1 permil). All these observed interrelations call for an explanation.

INTERPRETATION OF DATA

The standard explanation for oxygen isotope fluctuations in the oceanic carbonate system refers to temperature and/or ice-volume effects (UREY & *al.* 1951; EPSTEIN & *al.* 1951, 1953; SHACKLETON 1977; MATTHEWS & POORE 1982). This explanation is implausible for the obtained oxygen curve, however, because (*i*) there was no ice-sheet in the Oxfordian (HALLAM 1985), and (*ii*) oxygen isotopic ratio drop in the Upper Oxfordian would translate into 20 degree Celsius increase in temperature (*cf.* CRAIG 1965), *i.e.*, up to the protein denaturation limit, which seems unacceptable.

For the carbon isotope curve, in turn, the standard explanations refer to (*i*) changes in burial partitioning between inorganic and organic carbon (BROECKER 1970) and (*ii*) dramatic increase in organic carbon influx from land due to regression and soil erosion (SHACKLETON 1977). Both these explanations, however, fail in the case of the presented carbon curve for the Oxfordian (*see* Text-fig. 3), since neither of them directly applies to a positive intercorrelation of the carbon and oxygen curves.

It is the paleoceanographic model of overfed-to-hungry ocean fluctuation (MAŁKOWSKI, GRUSZCZYŃSKI, HOFFMAN & HAŁAS 1989; HOFFMAN, GRUSZCZYŃSKI & MAŁKOWSKI 1990, 1991) that can provide a satisfactory explanation for the observed correlation. In overfed (that is, stagnant and stratified) ocean, the upper box has high delta-13-carbon and high delta-18-oxygen values, while the lower box has low delta-13-carbon and low delta-18-oxygen values. A temporary and perhaps local mixing should therefore lead to covariant fluctuations in both the carbon and oxygen isotopic curves.

In fact, the generally high delta-13-carbon values in the Jurassic (HOLSER 1984, JENKYNS 1988) suggest that this was a time of predominantly stagnant ocean. Hence, the local mixing scenario may work and explain the covariation of the carbon and oxygen isotopic curves observed in Polish records. It cannot, however, unequivocally explain the discrepancies between carbon and oxygen curves found in the Lower and Upper Oxfordian of Central Poland (*cf.* Text-fig. 3). The lower discrepancy in the Cordatum Chron, with carbon curve falling much more distinctly than oxygen curve, may be attributed to increased local mixing of water masses, because ocean stratification is expected to have a particularly pronounced effect on carbon isotope differentiation between the lower and upper oceanic boxes (HOFFMAN, GRUSZCZYŃSKI & MAŁKOWSKI 1991).

This mechanism cannot account for the much larger drop in the oxygen curve than in the carbon one, as observed in the Upper Oxfordian Bimammatum and lower Planula Zones. In fact, this discrepancy between the two isotopic curves can best be explained by rapid influx of isotopically light oxygen from outside the local environment; such influx could be most likely due to a considerable inflow of fresh or at least less saline waters. One might suggest that the northwestern shelf of the Tethys got at that time under the influence of another oceanic province, where more brackish conditions had developed.

In fact, the paleobiogeographic data on the Upper Oxfordian ammonite fauna of Central Poland strongly corroborate the hypothesis that the waters from the Boreal province invaded the Tethyan shelf at that time (MATYJA & WIERZBOWSKI 1988). There also are good reasons to believe that these waters were less saline (HALLAM 1971) — perhaps, due to lower temperatures and larger riverine inflow to the rather restricted Boreal reservoir (*cf.* BARRON & *al.* 1981, ZIEGLER 1987). This independent evidence thus lends support to the presented interpretation of the carbon and oxygen isotopic data.

CONCLUSIONS

The interpretation of the carbon and oxygen isotope curves in the Oxfordian of Central Poland reflects temporary and perhaps local fluctuations in the rate of mixing of the generally stagnant and stratified ocean. The major drop in the oxygen curve in the Upper Oxfordian, which occurred coevally with two invasions of the Boreal fauna, reflects a substantial inflow of less saline waters from the Boreal Realm.

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KRZYWE IZOTOPOWE WĘGLA I TLENU W OKSFORDZIE POLSKI ŚRODKOWEJ

(Streszczenie)

Analiza odchylenia izotopowego węgla ($\delta^{13}C$) i tlenu ($\delta^{18}O$) w skorupkach ramienionogów z sekwencji obejmującej niemal cały oksford epikontynentalnych facji w Polsce środkowej (*patrz* fig. 1–2) wykazuje mocną dodatnią korelację krzywych izotopowych węgla i tlenu (*patrz* fig. 3). Wysokie wartości odchylenia izotopowego węgla sugerują, że — jeśli przyjmie się model „sytego" i „głodnego" oceanu, proponowany poprzednio przez współautorów (MAŁKOWSKI *& al.* 1989) — w oksfordzie panowały na tym obszarze warunki sytego, tj. stratyfikowanego i stosunkowo stagnującego oceanu. Lokalne wahania stopnia wymieszania wód oceanicznych prowadzą w takich warunkach do dodatniej korelacji krzywych izotopowych węgla i tlenu. W górnym oksfordzie występuje jednak wyraźna rozbieżność stopnia zmian obydwu krzywych, przy czym — wbrew przewidywaniom modelu — wartości odchylenia izotopowego tlenu spadają o wiele bardziej drastycznie, niż to się dzieje w przypadku węgla. Najbardziej prawdopodobnego wyjaśnienia dostarcza hipoteza o dopływie w tym okresie mniej słonych wód z obszaru borealnego. Hipoteza ta znajduje potwierdzenie w danych paleontologicznych, świadczących o wystąpieniu w górnym oksfordzie dwóch inwazji amonitowych faun borealnych na obszar submedyterański w Polsce (*patrz* MATYJA & WIERZBOWSKI 1988).
