The 'Inoceramus' azerbaydjanensis fauna (Bivalvia) and its value for chronostatigraphic calibration of the European Campanian (Upper Cretaceous)

by Ireneusz WALASZCZYK, William A. COBBAN, Christopher J. WOOD & Adrian KIN


Abstract

The ‘Inoceramus’ azerbaydjanensis group which comprises the species ‘I.’ azerbaydjanensis Aliev, 1939 and ‘I.’ vorhelmensis (Walaszczyk, 1997), is widely distributed throughout the Euramerican biogeographic region. Its evolutionary history and, as a consequence, its taxonomic position remains unclear; morphological features which recall those of the genus Cordiceramus Heinz, 1932, may easily have resulted from convergent evolution. Both species are found in the lowermost mid-Campanian Baculites obtusus and Baculites maclearni zones in the US Western Interior, and in the Patagiosites stobaet/Galeola basiplana and Galerites vulgaris/Galeola basiplana zones in northern Europe. Biostratigraphic correlation of the potential maximum range of their occurrences in both these regions enables geochronologic calibration of the lower part of the traditional European upper Campanian. The dating of the Nostoceras polyplocum ammonite Zone is critically reviewed in the light of this correlation.

Keywords: Bivalvia, Inoceramidae, Campanian, Europe, US Western Interior, trans-Atlantic correlation.

Introduction

Late early and early late Campanian inoceramid bivalve faunas of the Euramerican biogeographic region are dominated by ‘cataceramids’, for which the stratigraphic record is rather crude and whose evolutionary history is poorly understood. The associated ‘platyceramids’ and ‘cordiceramids’ are rare, and usually are assigned to long-ranging lineages, generally assumed to go mostly back well into the Santonian. Hence, the apparently sudden appearance in the earliest late Campanian of forms referred herein to the group of ‘Inoceramus’ azerbaydjanensis Aliev, 1939, which comprises that species and ‘I.’ vorhelmensis (Walaszczyk, 1997), is of considerable biostratigraphic significance. Although the origin of this group and its stratigraphic range in other areas still raise a number of questions, the distinctive morphology, very narrow vertical range and occurrence throughout the entire Euramerican biogeographic region allow it to be used in trans-Atlantic correlations and, consequently, in the geochronologic calibration of the European Campanian, which remains highly controversial. The present paper summarises the main taxonomic and biogeographic views on ‘I.’ azerbaydjanensis and ‘I.’ vorhelmensis as currently recognised, and focuses on their geochronologic importance and inferences for the European Campanian. North American records of this
group are well known and have been published in detail (Cobban & Scott, 1964; Cobban & Kennedy, 1993; Kauffman et al. 1994; Walaszczyk et al., 2001). European data are based on newly collected material from sections in southern Poland (Nida Trough), part of which has recently been published by Jagt et al. (2004).

**Taxonomic and biogeographic remarks on the ‘I.’ azerbaydjanensis fauna**

What is referred to herein as the ‘I.’ azerbaydjanensis group are Cordiceramus-like forms appearing in the early late (or early mid- in the US tripartite subdivision of the stage) Campanian of the Euramerican biogeographic region and possibly in the East African province (in Kauffman’s 1973 biogeographic subdivision). Two species are recognised within this group, namely ‘I.’ azerbaydjanensis (see Aliev, 1939, 1954; Dobrov & Pavlova, 1959; Cobban & Scott, 1964; Kotsubinsky, 1974; Masslennikova, 1982; Cobban & Kennedy, 1993; Walaszczyk, 1997; Walaszczyk et al., 2001) and ‘I.’ vorhelmensis (see Walaszczyk, 1997; Walaszczyk et al., 2001). ‘Inoceramus’ tausiensis Aliev, 1954 shares all the characteristics of ‘I.’ azerbaydjanensis, falls into its range of variation, and thus should be synonymised with it (Cobban & Kennedy, 1993; Walaszczyk et al., 2001). ‘Inoceramus’ tausiensis Aliev, 1954 shares all the characteristics of ‘I.’ azerbaydjanensis, falls into its range of variation, and thus should be synonymised with it (Cobban & Kennedy, 1993; Walaszczyk et al., 2001). ‘Inoceramus’ tausiensis Aliev, 1954 shares all the characteristics of ‘I.’ azerbaydjanensis, falls into its range of variation, and thus should be synonymised with it (Cobban & Kennedy, 1993; Walaszczyk et al., 2001).

The distinction between ‘I.’ azerbaydjanensis and ‘I.’ vorhelmensis is purely typological and is based on the assumption of progressive development of their ‘Cordiceramus’ characters. In contrast to ‘I.’ vorhelmensis (see Fig. 1B, C, E-G), ‘I.’ azerbaydjanensis (see Fig. 1A, D, H) possesses a more distinct and stronger axial sulcus (i.e., the radial sulcus parallel to the growth axis), a more or less well-developed ‘Schalenkante 1’ (sensu Seitz, 1961) along the anterior margin of the valve and an anterior sulcus. This might suggest a simple evolutionary lineage and ancestor/successor relationships between both species. In addition, transitional morphotypes between ‘I.’ vorhelmensis and Cataceramus beckumensis (Giers, 1964), the youngest member of the Cataceramus copetdagensis-C. dariensis-C. beckumensis lineage can be found, which may suggest evolutionary relationships between these two (Walaszczyk, 1997). If this interpretation is correct, ‘I.’ azerbaydjanensis and ‘I.’ vorhelmensis would be descendants of the Cataceramus clade and their Cordiceramus-like architecture would result from convergent evolution. Taxonomically, both taxa could then be referred either to the genus Cataceramus or, alternatively, to a new genus. Another possibility is that both forms are descendants of a Cordiceramus clade, which is very poorly represented in the late early Campanian. The third possibility is that this fauna immigrated during the early late Campanian from another biogeographic region. A potential area could be e.g., the East African province, where ‘corderamids’ predominate in the lower and lower upper Campanian (Walaszczyk et al., work in progress). In fact, a form which may belong to the ‘I.’ azerbaydjanensis group is known to occur there (see Walaszczyk et al., 2001). In the two last-named options, both species would represent the genus Cordiceramus, as suggested by their morphological characteristics. Considering its uncertain evolutionary history, both species are herein referred to ‘Inoceramus’ sensu lato.

**Biostratigraphy of the ‘I.’ azerbaydjanensis group**

**North America**

In North America, the ‘I.’ azerbaydjanensis group is known from Texas and the US Western Interior. In Texas, it occurs in the Wolfe City Sand, which is correlated with the Baculites maclearni Zone of the Western Interior (Cobban & Kennedy, 1993), the second oldest ammonite zone of the mid-Campanian, in the tripartite American subdivision of the stage (Fig. 2). Records from the US Western Interior are all dated as Baculites obtusus and B. maclearni zones (Cobban & Scott, 1964; Walaszczyk et al., 2001), although the precise range of this species within the zones is unknown.

**Europe and western Asia**

In Europe and western Asia, the ‘I.’ azerbaydjanensis group is widely known primarily from regions along the southern margin of the eastern European craton. ‘Inoceramus’ azerbaydjanensis was first described by Aliev (1939) from the Lesser Caucasus, originally from beds considered by him to be of Turonian age, but revised subsequently to Campanian (Aliev, 1954). No type specimen was selected, but one of the original specimens illustrated was subsequently designated lectotype by Aliev (1954). Specimens referred to this species recorded from the northern Great Caucasus
‘Inoceramus’ azerbaydjanensis and calibration of the European Campanian

Fig. 1 – ‘Inoceramus’ azerbaydjanensis fauna from Busko Zdrój, Nida Trough (southern Poland), lower upper Campanian. A, D, H. ‘Inoceramus’ azerbaydjanensis ALIEV, 1939; A – FGUW ZI/35/148; D – FGUW ZI/35/151; H – FGUW ZI/35/155. B, C, E-G. ‘Inoceramus’ vorhelmensis (WALASZCZYK, 1997); B – FGUW ZI/35/149; C – FGUW ZI/35/150; E – FGUW ZI/35/152; F – FGUW ZI/35/153; G – FGUW ZI/35/154. I. ‘Inoceramus’ ellipticus (GIERS, 1964), FGUW ZI/35/156. With the exception of A and D, which are × 0.9, all other specimens are natural size. All material is housed in the Museum of the Faculty of Geology of the University of Warsaw (FGUW).

by DOBROV & PAVLOVA (1959) were dated as early Campanian. In more recent studies, the species is considered to be late early or early late Campanian in age, and records include the Crimea, Ukraine (ATABEKIAN, 1997), the Pericaspian Depression (MASSLENNIKOVA, 1982), Donbass (KOTSURINSKY, 1974), the Great Caucasus (PERGAMENT & SMIRNOV, 1972) and other areas (ALIEV, 1979). KUZNETZOV (1968; see also ALIEV et al., 1971) recorded the species from the upper upper Campanian of Tuarkyr, Russia. Based on dating of the North American and Central European (Westphalia, Germany; Nida Trough, southern Poland) material, the actual range of the species in regions south of the Russian Craton is here assumed to be early late Campanian. Differences between the various authors are here regarded to have resulted from variable bio-
Fig. 2 - Intercorrelation of the US Western Interior ammonite zonation (after COBBAN, 1994) and the European ammonite/belemnite/echinoid zonation as based on inoceramids (in part after WALASZCZYK et al., 2001; WALASZCZYK, 2004), and mixed rhythmicity and radiometric dates (after NIEBUHR, 2004, 2005); grey area in the left-hand and median columns shows the potential maximum range of the 'Inoceramus' azerbaydjanensis group; the grey area in the right-hand column indicates the uncertainty interval in positioning of the base of the Nostoceras polyplocum Zone. The middle Campanian radiometric dates on the left-hand side are calculated dates. In the central column, the base of the European N. polyplocum Zone is indirectly correlated with the base of the B. asperiformis Zone.

<table>
<thead>
<tr>
<th>Stage and substage</th>
<th>US Western Interior ammonite zonation</th>
<th>Inoceramid-based calibration of the European zonation</th>
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<td>UPPER</td>
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<td>79.8 Baculites maclearni</td>
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<td>conica / mucronata</td>
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<td>80.5 Baculites sp. (weak flank ribs)</td>
<td>conica/mucronata</td>
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<td></td>
<td>80.5 Baculites sp. (smooth)</td>
<td>gracilis/mucronata</td>
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chronostratigraphic concepts applied to the Campanian. This assumption is confirmed by early late Campanian records of 'I. azerbaydjanensis' from Mangyshlak (western Kazakhstan), where Campanian zones were correlated with the German succession on the basis of belemnites (NAIDIN et al., 1984). The species was found in the lower part of their lowermost upper Campanian zone characterised by the belemnite Belenmitella mucronata mucronata (VON SCHLOTHEIM, 1813) and the ammonites Patagiosites cf. stobaei (NILSSON, 1827), Hoplitoplacen ticeras coesfeldiense (SCHLÜTER, 1867) and Trachyclypeatites spiniger (SCHLÜTER, 1872). This biostratigraphically well-constrained record from Mangyshlak demonstrates clearly that the restricted early late Campanian date for occurrences of the 'I. azerbaydjanensis' group in the Euramerican biogeographic region can be applied at least as far as western Asia. Nevertheless, as the possibility that the 'I. azerbaydjanensis' group has a longer stratigraphic range in other parts of Asia cannot be completely excluded, the stratigraphic horizons of all the published records need to be investigated further.

In central and western Europe, 'I. vorhelmensis' is quite well documented from Westphalia, Germany (WALASZCZYK, 1997), albeit its precise stratigraphic range is unknown, and it can only be broadly referred to the Patagiosites stobaei/Galeola basiplana and Galerites vulgaris/Galeola basiplana zones of the refined zonal scheme of the Campanian used in northern Germany (see WALASZCZYK, 1997). 'Inoceramus azerbaydjanensis' in Germany is known only from a single ('aff.') record, also from Westphalia.
Inoceramus 'azerbaydijmenensis and calibration of the European Campanian (Walaszczyk, 1997), referred to approximately the same interval. Two Campanian sections in the Nida Trough in southern Poland (see Fig. 3) are therefore of great importance, because there 'I. 'azerbaydijmenensis is now on record from the Busko Zdrój composite section in the northeastern part of the trough (see Machalski et al., 2004) and from Rzeżuśnia in the southwest (Jagt et al., 2004). The Nida (= Miechów) Trough is the southeasterly portion of the Szczecin-Lódź-Nida (= Miechów) Synclinorium, one of the major Alpine tectonic units in extra-Carpathian Poland (Pożarski, 1977). The Busko Zdrój and Rzeżuśnia sections represent the northeasterly and southwesterly margins of this trough respectively.

1. Busko Zdrój section

This composite section comprises four temporary exposures in the town of Busko Zdrój, situated in the northern limb of the Nida Trough (Fig. 3; see also Machalski et al., 2004). The Campanian in the area is represented by a continuous succession of siliceous marls (opokas) and marls, apparently without stratigraphic gaps, and reaching a total estimated thickness of c. 300 m. The early late Campanian succession is quite fossiliferous, yielding heteromorph and non-heteromorph ammonites, belemnites, echinoids and inoceramid and non-inoceramid bivalves.

Based on ammonite evidence, the Busko Zdrój
composite section was dated as *Galeola basiplana/Trachyscaphites spiniger* and *Galerites roemeri* zones (as defined in the Lägerdorf-Kronsmoor area, northern Germany) and as *Patagosites stobaei/Galeola basiplana*, *Galerites vulgaris/Galeola basiplana* and *Galerites vulgaris/Micraster stolleyi* zones (as defined in the Lehrte West Syncline, northern Germany; see Machalski et al., 2004, fig. 2).

2. Rzezusnia section

This is exposed at a working quarry near Rzezusnia, north of Kraków. The succession comprises c. 30 m of opokas with marly layers and siliceous concretions in the middle part (see Jagt et al., 2004, fig. 2), correlated with the *Patagosites stobaei/Galeola basiplana* and *Galerites vulgaris/Galeola basiplana* zones (Jagt et al., 2004). Inoceramids of the *azerbaydjanensis* group occur in the middle part of the section, characterised by a series of siliceous concretions.

**Correlations**

**Biostratigraphic correlation**

Inoceramids from the Busko Zdrój composite section, recorded here for the first time, and those from Rzezusnia, enable dating of the *I. azerbaydjanensis* group with reference to the early late Campanian belemnite/echinoid/ammonite zonal scheme used in northern Germany. Although, on the basis of ammonites, the Busko Zdrój section was dated as equivalent to the *Patagosites stobaei/Galeola basiplana* and *Galerites vulgaris/Galeola basiplana* zones (Machalski et al., 2004), it is significant that, out of four exposures of this composite section, *I. azerbaydjanensis* is known from only one, namely from section 1 (see Fig. 3). The presence in section 1 of the ammonite *Pachydiscus cf. subrobustus* Seunes, 1892 suggests correlation with the Vorhelmer Schichten of Westphalia, which are considered to equate with the *Galerites vulgaris/Galeola basiplana* Zone (see Kaplan et al., 1996). Similarly, in the Rzezusnia section, dated as equivalent to the *Patagosites stobaei/Galeola basiplana* and *Galerites vulgaris/Galeola basiplana* zones (Jagt et al., 2004), the *I. azerbaydjanensis* group is known exclusively from the middle part of the succession. Based on sections in Texas (Cobban & Scott, 1964; Cobban & Kennedy, 1993) and on the US Western Interior succession (Cobban & Scott 1964; Walaszczyk et al., 2001), *I. azerbaydjanensis* is confined to the lowermost mid-Campanian (in the tripartite US subdivision of the stage) *Baculites obtusus* and *B. maclearni* zones (Fig. 2).

For the purpose of the correlation as proposed herein, the possible maximum range of the *I. azerbaydjanensis* group in the US (*B. obtusus-B. maclearni* zones) and in Europe (*Patagosites stobaei/Galeola basiplana* and *Galerites vulgaris/Galeola basiplana* zones) is taken. It must be emphasised, however, that neither in the US Western Interior nor in the European sections is the actual range of the group known. Moreover, records from the Polish sections suggest that its stratigraphical range there may be extremely limited.

**Implications for calibrating the European Campanian**

Our *I. azerbaydjanensis*-based trans-Atlantic correlation has important implications for the inter-correlation of the European and the US Western Interior zonal schemes for the mid-Campanian. Correlations of this interval published so far differ quite considerably (compare e.g., Hardenbol et al., 1998; Ogg et al., 2004) and, in the recent discussion on the base of the *Nostoceras polyplocum* Zone (and location of the mid-/upper Campanian boundary in Europe; see Niebuhr, 2004), differences amount to 3-4 myr.

**The base of the European upper Campanian**

This is defined as the lower boundary of the *Echinocorys conica/Belemnitella mucronata* Zone, a level regarded to be coeval with the base of the *Baculites obtusus* Zone (see e.g., McArthur et al., 1993; Ogg et al., 2004), which defines the base of the mid-Campanian in the US Western Interior ammonite succession (Cobban, 1994). If we correlate the possible maximum range of *I. azerbaydjanensis* in North America and in Europe (*B. obtusus-B. maclearni* zones and *stobaei/basiplana-vulgaris/basiplana* zones, respectively), the base of the traditional European upper Campanian correlates with a level below the base of the *B. obtusus* Zone, somewhere within the upper lower Campanian of the US Western Interior succession (Fig. 2).

**Campanian calibration and substage division**

At the Second Symposium on the Cretaceous Stage Boundaries (Brussels, 1995), it was agreed that the Campanian should be divided into three substages, of approximately equal duration (see Hancock & Gale, 1996). A tripartite Campanian subdivision has long been used in the US Western Interior, with the FADs of *B. obtusus* and *Didymoceras nebrascense* defining the bases of the mid- and upper Campanian respectively (see Cobban, 1994 and references therein), and
with a subequal duration of the substages. There are no good absolute dates available for the European Campanian, and the geochronologic calibration is usually based on biostratigraphic correlation to the North American succession. Ammonites, the key index group for the Upper Cretaceous, cannot be fully used in view of the highly endemic nature of the US Western Interior ammonite faunas. It has recently been demonstrated that inoceramids have a high trans-Atlantic correlation potential (WALASZCZYK et al., 2001, 2002a; WALASZCZYK, 2004) but, until now, in the upper rather than the lower part of the stage (WALASZCZYK et al., 2000b; ODIN & WALASZCZYK, 2003). The biostratigraphic correlation based on the ‘I.’ azerbaydjanensis group as suggested herein is thus of considerable importance.

For the purpose of the present paper, the most recent radiometric dates by OBRADOVICH (in COBBAN et al., 2006) for the US Western Interior succession are used. In the interval concerned, two direct dates are available: 80.58 ± 0.55 Ma for the lower part of the B. obtusus Zone and 75.84 ± 0.26 Ma for the Baculites scotti Zone (Fig. 2). The ages for the intermediate zones were obtained by an even subdivision of the resulting interval by the number of zones (albeit the actual durations of particular zones may differ quite considerably – see e.g., McARTHUR et al., 1993). Accordingly, the calculated radiometric date for the base of the B. maclearni Zone is 79.8 Ma, and for the base of the Baculites asperiformis Zone, 79.2 Ma. Consequently, the lower and upper boundaries of the maximum potential range of the ‘I.’ azerbaydjanensis group would be 80.5 and 79.2 Ma, respectively (Fig. 2). As the FAD of Nostoceras polylocum in Texas is assumed to correlate with the Baculites asperiformis Zone in the US Western Interior (KENNEDY & COBBAN, 2001), it follows that the base of the N. polylocum Zone in Europe could be as old as 79.2 Ma.

Correlation of the N. polylocum Zone with the US Western Interior succession and its interpretation in terms of radiometric dates has lately led to very divergent views (see NIEBUHR, 2004). As stated above, based on direct correlation of the first occurrences of this ammonite species in Europe and North America (COBBAN in OGG et al., 2004), the base of the European N. polylocum Zone corresponds to the base of the Western Interior Baculites asperiformis Zone, i.e. quite low in the mid-Campanian (Fig. 2). Very different conclusions were reached, however, by NIEBUHR (2004, 2005), on the basis of analyses of Campanian marl-limestone rhythmites in the Lehrte West Syncline (northern Germany). Assuming the FAD of the belemnite Belemnitella mucronata to be at c. 80 Ma and calculating (by analysing rhythmicity) the duration of the interval between this level and the first occurrence of N. polylocum (amounting to c. 5.3 myr), she dated the FAD of N. polylocum at c. 75 Ma (Fig. 2). In radiometric ages, this level would thus correspond to the Didymoceras nebrascense-Exiteloceras jenneyi zones interval of the US Western Interior succession (see COBBAN et al., 2006; Fig. 2 here), which represents the lowermost upper Campanian in the North American sense. Consequently, NIEBUHR proposed the FAD of N. polylocum as a good potential marker for the base of the upper Campanian. The occurrences of N. polylocum in Texas, in an interval equivalent to the Western Interior Baculites asperiformis Zone, she interpreted as a much earlier appearance of the species in North America. The difference in radiometric ages (79.2 and 75 Ma) between these two correlations is approximately 4 myr.

The correlation suggested herein, as based on records of ‘I.’ azerbaydjanensis, corroborates previous inoceramid-based conclusions (e.g., WALASZCZYK, 2004) and an isochronous FAD of N. polylocum throughout the entire Euramerican biogeographic region. The N. polylocum Zone would thus be entirely within the middle Campanian, and the mid-/upper Campanian boundary would be above it.

Discussion

The ‘Inoceramus’ azerbaydjanensis group corroborates previous inoceramid-based correlations between the European and US Western Interior Campanian (WALASZCZYK et al., 2001; WALASZCZYK, 2004), according to which the base of the European Nostoceras polylocum Zone may equate with a level as low as the Baculites asperiformis Zone in the US Western Interior scheme. Also, it suggests that N. polylocum appeared approximately synchronously all over the Euramerican biogeographic region. Such a correlation contradicts the rhythmicity-based dates (NIEBUHR, 2004, 2005), tied to the assumed radiometric age of c. 80 Ma for the lower/upper Campanian boundary, which suggest an interval of approximately 5 myr between the base of the European upper Campanian and the FAD of N. polylocum. If the US radiometric dates are accepted there would simply be not enough time for that. Although every element of the correlation discussed (e.g., US Western Interior radiometric dates; rhythmicity-based dates, and inoceramid and ammonite synchronous appearances) may be questioned and further work is needed, it...
appears for now that the correlation based on the ‘I.’ azerbaydjanensis group is the most parsimonious.

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Ireneusz Walaszczyk
Faculty of Geology
University of Warsaw
Al. Zwirki i Wigury, 93
PL 02-089 Warszawa, Poland
E-mail: i.walaszczyk@uw.edu.pl