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The Turonian – Coniacian boundary in the United States Western Interior

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ABSTRACT:

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The Turonian/Coniacian boundary succession in the United States Western Interior is characterized by the same inoceramid faunas as recognized in Europe, allowing the application of the same zonal scheme in both regions; *Mytiloides scupini* and *Cremnoceramus waltersdorfensis waltersdorfensis* zones in the topmost Turonian and *Cremnoceramus deformis erectus* Zone in the lowermost Coniacian. The correlation with Europe is enhanced, moreover, by a set of boundary events recognized originally in Europe and well represented in the Western Interior: *Didymotis* I Event and *waltersdorfensis* Event in the topmost Turonian, and *erectus* I, II and ?III events in the Lower Coniacian. First "Coniacian" ammonite, *Forresteria peruana*, appears in the indisputable Turonian, in the zone of *M. scupini*, and the reference to *Forresteria* in the boundary definition should be rejected. None of the North American sections, proposed during the Brussels Symposium as the potential boundary stratotypes, i.e. Wagon Mound and Pueblo sections, appears better than the voted section of the Salzgitter-Salder. The Pueblo section is relatively complete but markedly condensed in comparison with the German one, but it may be used as a very convenient reference section for the Turonian/Coniacian boundary in the Western Interior. The Wagon Mound section was mis-interpreted in respect of its biostratigraphical position and is entirely of Late Turonian age.

INTRODUCTION

Since COBBAN & REESIDE's (1952) publication, the Turonian/Coniacian (T/C) boundary in the U.S. Western Interior was placed at the base of the *Cremnoceramus erectus* Zone (*see also* SCOTT & COBBAN 1964). It is a horizon approximating the appearance level of Coniacian ammonites, and moreover, marking a radical change within inoceramid faunas. Subsequently KAUFFMAN (1977 and *in* KAUFFMAN & *al.* 1978) introduced a markedly refined zonation for the T/C boundary interval with a series of zones distinguished by him within the traditional *C. erectus* and *C. deformis* zones. In a number of his "European papers" (KAUFFMAN 1978a, b; WIEDMANN & KAUFFMAN 1978, and *in* HERM & *al.* 1979) he showed also the applicability of his scheme to the European succession. It was a great step foreword in the knowledge of the Turonian/Coniacian boundary faunas as well as in the correlation between the European and North American Turonian/Coniacian boundary successions. The problem began, however, when very refined studies on the boundary succession were undertaken in Europe. These were initiated with Gundolf ERNST's project "*Eventstratigraphie*" in

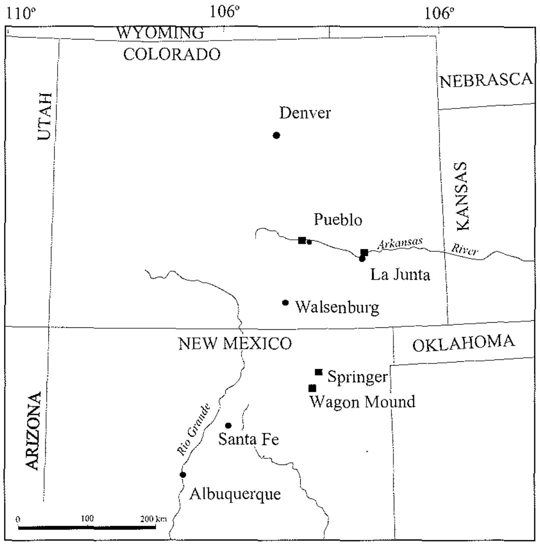


Fig. 1. Locality map for a part of the Western Interior showing the localities mentioned in the text

Germany, and publication of WOOD & *al.* (1984) on the Salzgitter-Salder section. WOOD & *al.*'s paper, as well as a series of successive reports from Europe (CECH 1989, KÜCHLER & ERNST 1989, WALASZCZYK 1992, MARCINOWSKI & *al.* 1996), revealed serious difficulties with a precise correlation of the boundary interval between Europe and North America when using KAUFFMAN'S scheme (as published e.g. in KAUFFMAN & *al.* 1993). Firstly, KAUFFMAN's biozonation was built to a large extent using inoceramid taxa left in open nomenclature and secondly, mutual vertical ranges of particular inoceramid species were, according to his scheme, markedly different from those recognized in Europe.

The main objectives of our study were: (i) the comparison of the T/C boundary interval of the Western Interior and Europe applying the same taxonomic concept to inoceramid fauna, (ii) to determine if the refined event scheme, as worked out in Europe, is recognizable in the Western Interior, (iii) to document a precise correlation between the inoceramid and ammonite schemes in the boundary interval, and finally, (iv) to evaluate the Wagon Mound section as a possible T/C boundary stratotype. The Wagon Mound section was the only other section, besides Salzgitter-Salder, formally proposed as a potential stratotype section during the Brussels Symposium on the Cretaceous Stage Boundaries (KAUFFMAN & *al.* 1996). The recent statement of condensation and/or hiatus at the Turonian/Coniacian boundary in the Salzgitter-Salder section (WALASZCZYK & WOOD, *this volume*, see also discussion in WIESE, *in press*) caused new interest in this American section.

Paleontological concepts applied here to the inoceramid faunas as well as to the biostratigraphy of the Upper Turonian and Lower Coniacian of the Western Interior as used here are published elsewhere (WALASZCZYK & COBBAN, *in press*). The interpretation of the *Cremnoceramus* clade follows that presented in WALASZCZYK & WOOD (1998). One of the main results of our taxonomic study, in reference to the Turonian/Coniacian boundary, was demonstration of the conspecifity of the basal Coniacian marker, *Cremnoceramus rotundatus* (*sensu* TRÖGER, 1967 *non* FIEGE 1930) and the North American species *Cremnoceramus erectus* (MEEK, 1877) which, consequently, becomes a basal boundary marker of the Coniacian stage.

MATERIAL AND DATA

This study is based on recent field work in the Pueblo and La Junta sections in SE Colorado, and the Springer and Wagon Mound sections in NE New Mexico (Text-fig. 1). Of great help were numerous collections from the T/C boundary interval housed in the Geological Survey, Denver. Because the Pueblo and La Junta sections have much in common in regard to the T/C boundary, the following discussion will concentrate on the Pueblo section.

Pueblo section

The Turonian – Coniacian boundary near Pueblo lies within the Fort Hays Limestone, the lower member of the Niobrara Formation (Text-fig. 2) (see SCOTT & COBBAN 1964 for description of the entire Niobrara succession in the Pueblo area). The Member is well exposed over a large area of the Rock Canyon anticline, west of Pueblo, where it caps the hills surrounding the Arkansas River Valley (Text-fig. 3a). It is represented by a 13.5 m thick succession of evenly bedded, light to medium gray, pelagic/hemipelagic limestones interbedded with thin calcareous shales (SCOTT & COBBAN 1964). The limestone-shale rhythmites as well as the higher order cyclicity, composed of 4-

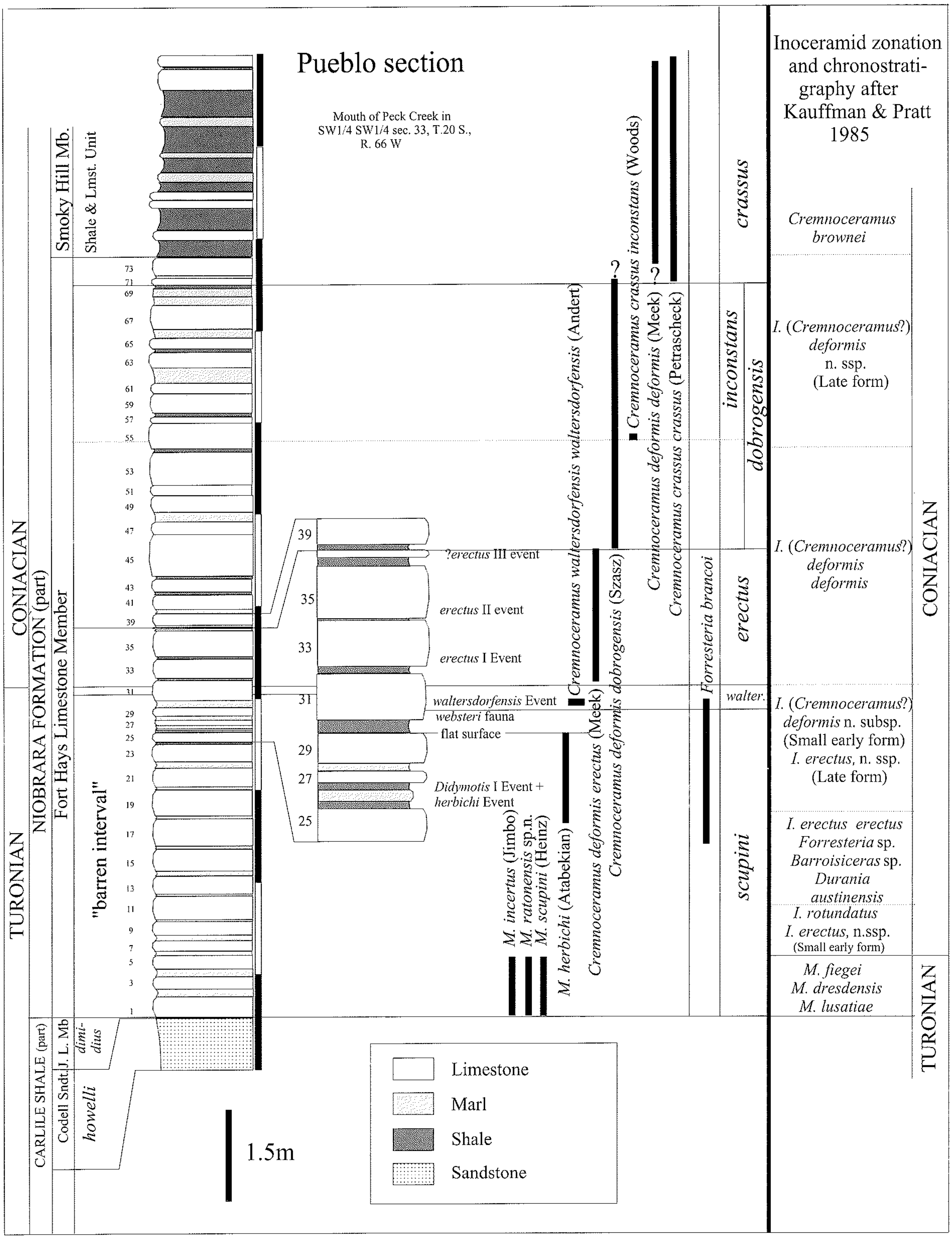


Fig. 2. Geological column, inoceramid distribution and biostratigraphy of the upper Turonian – lower Coniacian part of the Pueblo section; for comparison the zonation applied to this section by KAUFFMAN & PRATT (1985) is shown to the right; numbers on the left side of the geological column are after SCOTT & COBBAN (1964)

7 limestone-shale couplets, ascribed to climatically induced phenomena (see LAFERRIERE & *al.* 1987), are clearly recorded in the Fort Hays Member near Pueblo (Text-fig. 3b).

The Fort Hays Limestone overlies either the basal Upper Turonian shale of the Juana Lopez Member or the slightly older, Middle Turonian Codell Sandstone Member of the Carlile Shale. The associated stratigraphical gap comprises an interval from the topmost *Inoceramus dimidius* Zone, or even from the older *I. howelli* Zone to the basal *Mytiloides scupini* Zone, and represents a regionally recognized Carlile-Niobrara unconformity (see HATTIN 1975).

The basal three beds of the Fort Hays Member (beds 1, 3, 5) are fairly fossiliferous containing inoceramids represented by *Mytilodes incertus* (JIMBO), *M. ratonensis* WALASZCZYK & COBBAN, *M. scupini* (HEINZ), and *M. labiatoidiformis* (TRÖGER), an association indicative of the lower part of the *scupini* Zone (WALASZCZYK & COBBAN, *in press*). This interval is followed by an approximately 2.5 m thick succession referred to as the "barren interval" (Text-fig. 2), characterized by extremely rare fossils. It corresponds in part to the barren interval of HATTIN (1975) and KING (1972 *in* HATTIN 1975) recognized in Colorado, New Mexico and Kansas, although its upper boundary is lowered here to the first *Mytiloides* horizon below the T/C boundary. Its equivalent is also well represented in Europe (WOOD & *al.* 1984), it is an intercontinental phenomenon that had a profound impact on the inoceramid faunas. Inoceramid faunas in the overying Turonian/Coniacian boundary interval became identical to that occurring in Europe.

Inoceramids reappear in bed 25, in the uppermost *scupini* Zone, marking the base of the interval referred here to the boundary interval. They occur in abundance also higher, up to the top of the Fort Hays Member, dated as the basal *crassus* Zone (Text-fig. 2; see also WALASZCZYK & COBBAN *in press*).

The T/C boundary, defined by the FAD of *Cremnoceramus deformis erectus* MEEK [=C. *rotundatus* (*sensu* TRÖGER *non* FIEGE)] lies in the upper part of bed 31 (see Text-figs 2-3b) approximating well the boundary position as recognized by SCOTT & COBBAN (1964, text-fig. 3). Some distance below the boundary, in bed 23, were found the first ammonites of the genus *Forresteria*. The first horizon with flood occurrence of inoceramids occurs in bed 26.

Wagon Mound and Springer sections

Both sections are located in the Raton Basin in NE New Mexico, and represent the lower part of the Niobrara Formation (see SCOTT & *al.* 1986 for description of the Niobrara succession in the area). The Wagon Mound, section is situated about 0.5 km north of the town of Wagon Mound and is represented by a cut along the U.S. Interstate Highway 25. The Springer section is represented by railroad and road cuts south of the town of Springer at the southern exit from Interstate 25 to the town (see Text-fig. 6) (measured section 1 of SCOTT & *al.* 1986). Both sections represent the same succession, although the Springer section ranges stratigraphically much higher, into the lowermost Coniacian (see Text-figs 4, 6).

The lower part of the succession is very well exposed in the Wagon Mound section (Text-fig. 6b), where it is represented by the Fort Hays Limestone followed by the shale & limestone unit, the lowermost, informal unit of the Smoky Hill Member (Text-fig. 4). KAUFFMAN (1995, referring to COLLOM 1991) referred the whole succession as exposed here to the Fort Hays Limestone. However, although the basal shale & limestone unit resembles the underlying Fort Hays in having several beds of limestone but these are less resistant and more marly than those in the typical Fort Hays. The Fort Hays Member consists here of 7 limestone beds interbedded with relatively thick calcareous shales (Text-figs 4, 6b). The limestones are richly fossiliferous, although the fauna is represented mostly by inoceramids. Rarely noted are ammonites (*Prionocyclus germari*) and nautiloids (*Eutrephoceras*), and oyster bivalves (SCOTT & *al.* 1986). The fauna is relatively common in the lowermost part of the successive shale & limestone unit, but it quickly becomes sparse higher in the succession.

The entire Wagon Mound section represents the Upper Turonian *scupini* Zone, corresponding to its lower part at Pueblo, but still below the "barren interval".

The Fort Hays Limestone and ca. 12 m of the shale & limestone unit crop out in the Springer section, about 20 km north of Wagon Mound. The highest part of the succession exposed here, ranges to the basal Coniacian, where it is accessible in the highest part of the small hill east of the railroad-cut (Text-fig. 6a).

Most of the shale & limestone unit represents the "barren interval" with fauna re-appearing

Pueblo section; a – general view of the Rock Canyon Anticline area, with the yellow-colored Fort Hays Limestone capping the hills surrounding the Arkansas River valley; b – Fort Hays Limestone section in the Recreation Centre, northern side of the Arkansas River Valley (the photograph is taken in the same location as in Scott & Cobban 1964, Fig. 3) about 3 m below the top of the exposed succession. A rich fauna begins at the horizon with small-sized inoceramids (*M. scupini* and *M. herbichi* and *I. longealatus* Tröger), referred here to the basal *Mytiloides* horizon. It is followed by the *Didymotis* I Event and still higher by *waltersdorfensis* and *erectus* I events (Text-fig. 4).

The first *Cremnoceramus deformis erectus* (MEEK) was found slightly below the *erectus* I Event, which places the Turonian/Coniacian

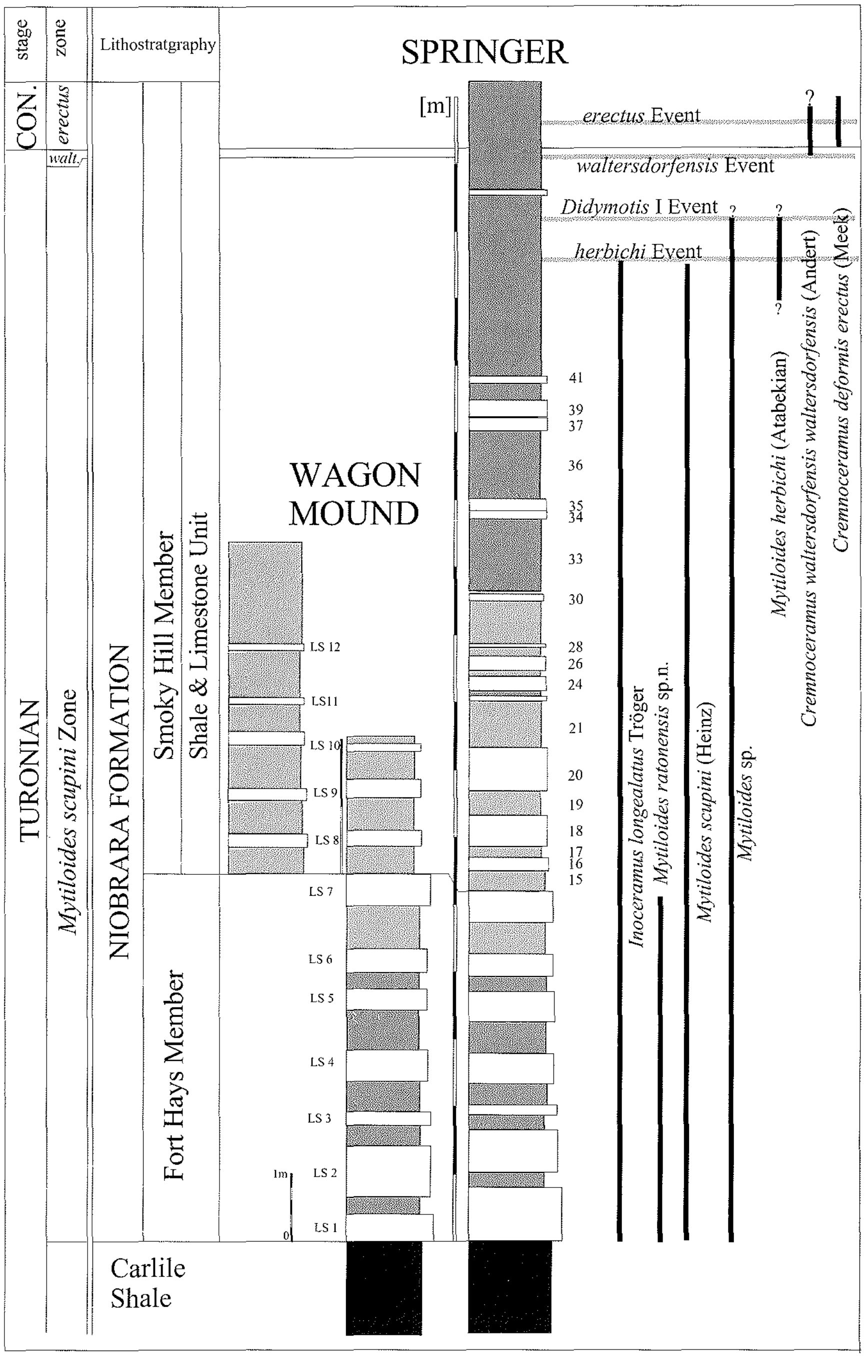


Fig. 4. Geological column, inoceramid distribution and biostratigraphy of the upper Turonian – lowermost Coniacian succession in the Springer – Wagon Mound area; numbers of the limestone beds on the left side of the Wagon Mound section (LS 1 through LS 10) are after COLLOM (1991) and KAUFFMAN (1995), and beds LS 11 and 12 are added after our own observations

boundary between the *waltersdorfensis* and *erectus* I events.

Most of the shale & limestone unit in the Springer-Wagon Mound region belongs to the Upper Turonian and represents the middle part of the *scupini* Zone ("barren interval"). The Fort Hays Member is also entirely Upper Turonian with its upper boundary lying relatively low in the *scupini* Zone and coinciding with the base of the "barren interval" (see text-fig. 4). It shows a marked diachroneity of the upper boundary of the Fort Hays Limestone between SE Colorado (Pueblo section) and NE New Mexico (Text-fig. 5).

BOUNDARY SUCCESSION

The interval close to the T/C boundary is characterized by an abundance of inoceramids concentrated in distinct horizons and being relatively rare or apparently absent in the intervals between. Their succession, composition and stratigraphical location are the same as recognized in Europe (ERNST & *al.* 1983; WOOD & *al.* 1984, WALASZCZYK & WOOD 1998) indicating their equivalency and allowing the application of the same terminology as used in the Old Continent (Text-fig. 7).

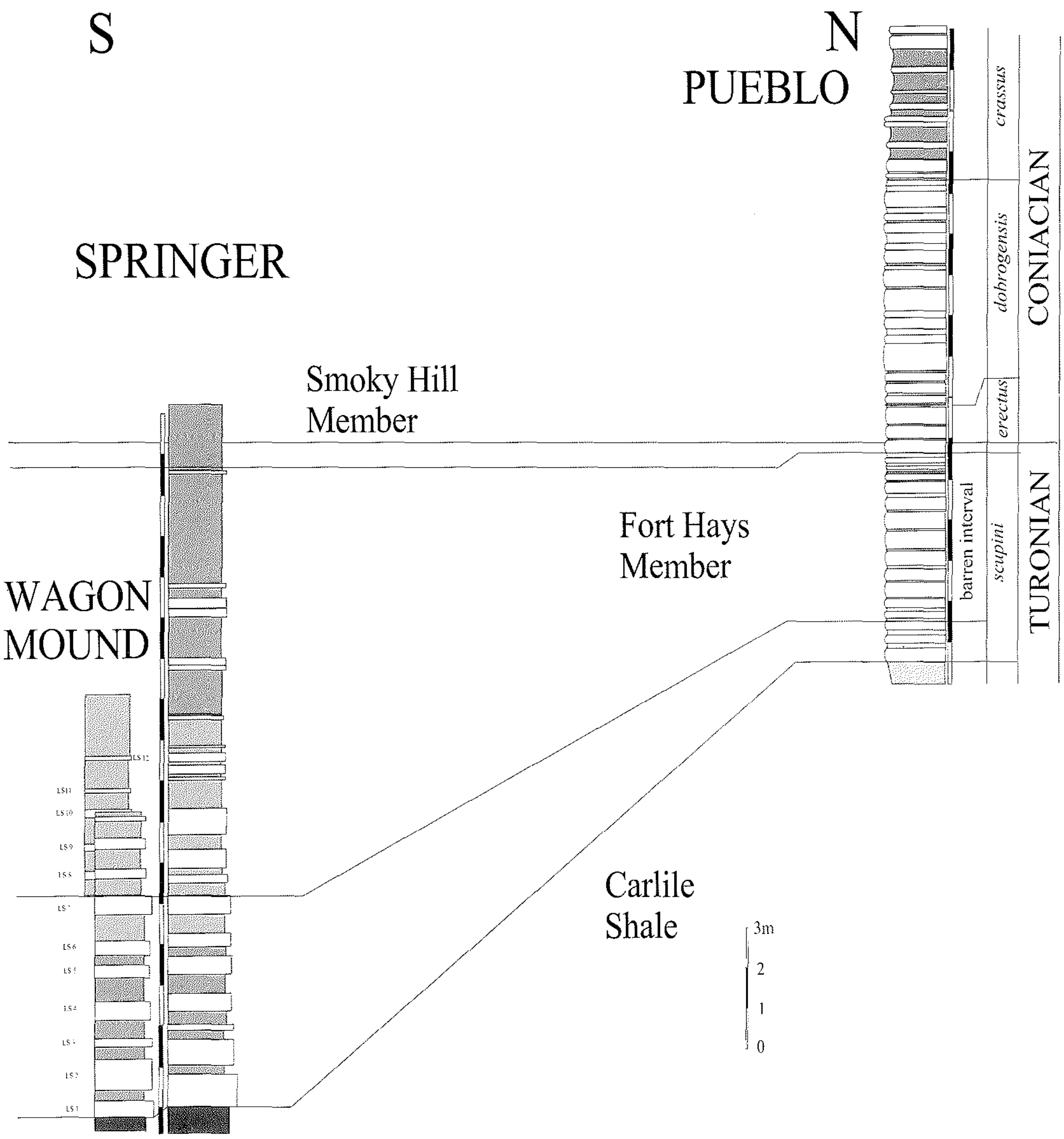
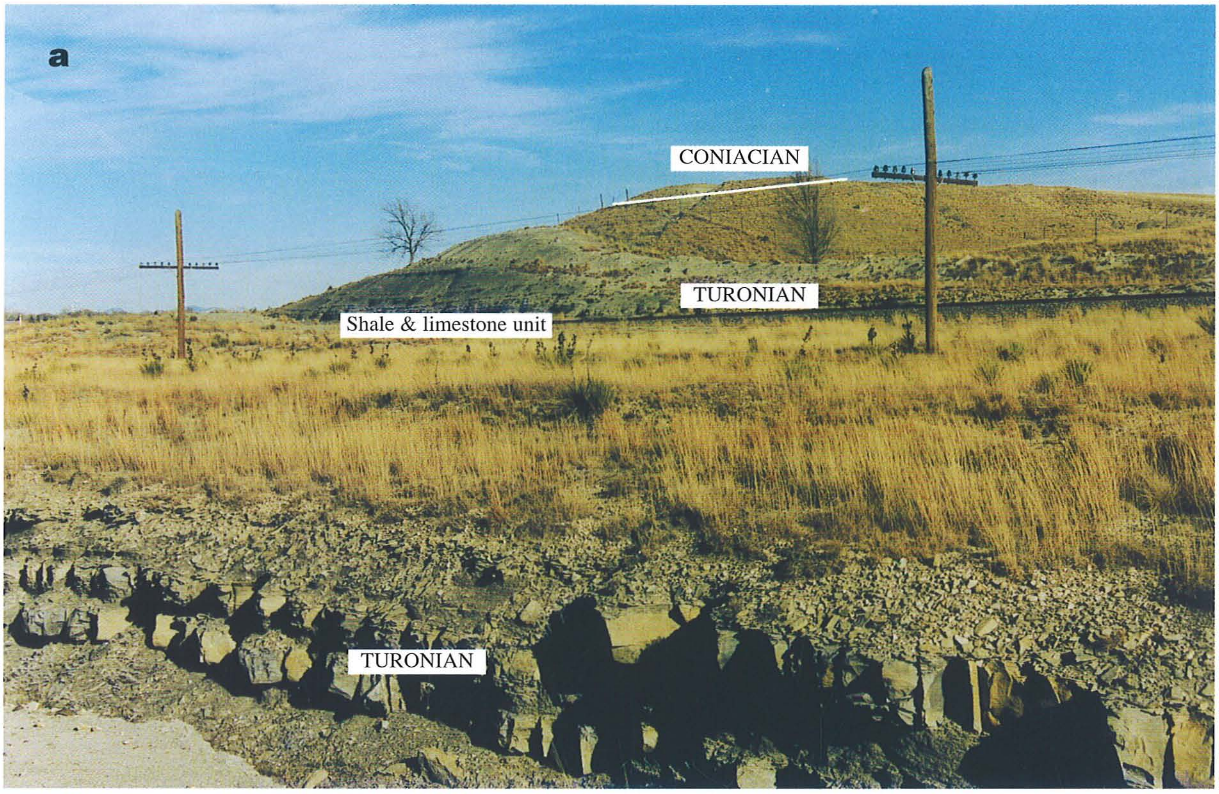
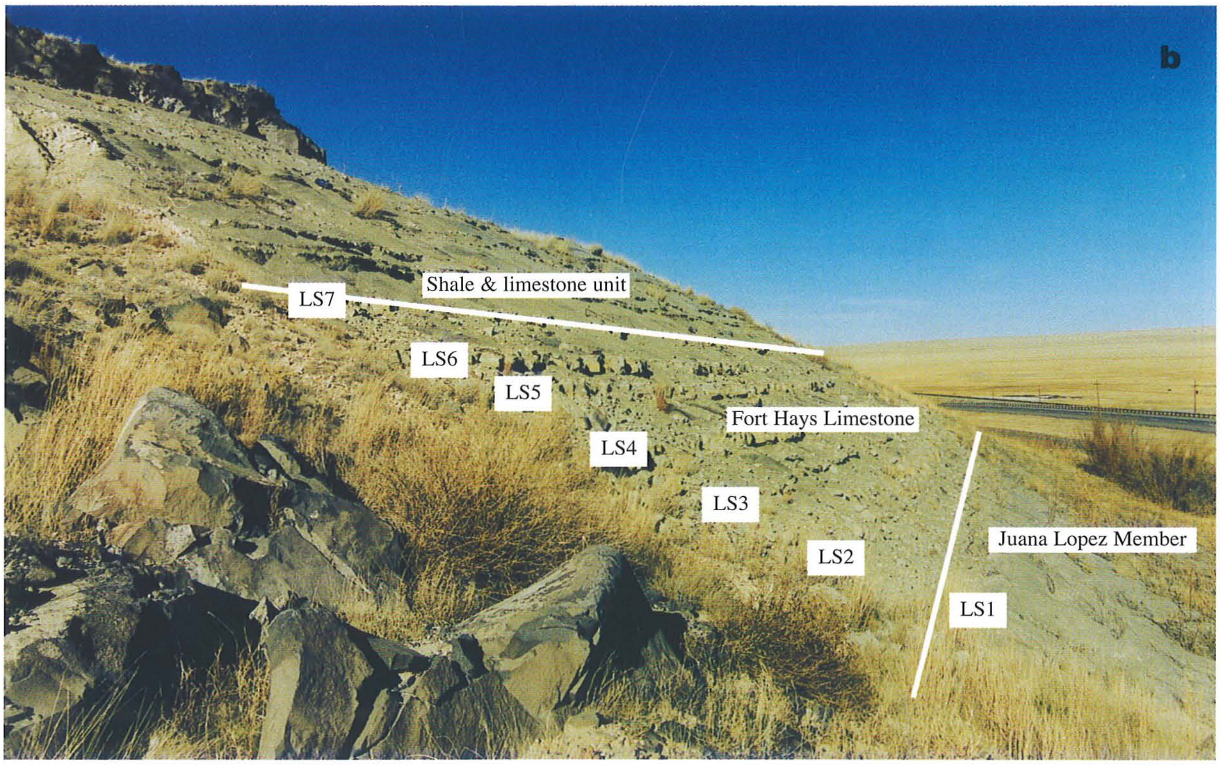


Fig. 5. Litho and chronostratgraphical correlation of the Springer-Wagon Mound and Pueblo section





Springer and Wagon Mound sections; a – Springer section: in foreground visible topmost part of the Fort Hays Limestone, in background - middle and upper parts of the shale & limestone unit; the Turonian/Coniacian boundary lies in the topmost part of the hill in the upper right corner of the photograph; b – Road-cut section at Wagon Mound; the main part of the photographed section comprises limestone beds 1-7 of the Fort Hays Limestone; at the bottom – topmost part of the Juana Lopez Member of the Carlile Shale, above – lowermost part of the shale & limestone unit of the Smoky Hill Member

Basal Mytiloides horizon

The lowest horizon with inoceramids above the "barren interval" was found about 1 m below the *Didymotis* I Event in the Springer section (Text-fig. 4). Near Pueblo it is most probably fused in the same shale bed in which the *Didymotis* I Event was recognized. The basal *Mytiloides* horizon is characterized by small-sized mytiloids (*M. herbichi* and *M. scupini*), *Inoceramus longealatus*, and rare, small-sized *Didymotis* bivalves.

Didymotis I Event

This event is very well represented both in the Pueblo and Springer sections. Near Pueblo it occurs in bed 26 and is characterized by flood occurrence of small- to medium-sized representatives of *Mytiloides herbichi* (ATABEKIAN), *M. scupini*, and common *Didymotis* sp. The latter is represented by poorly elongated and weakly ornamented forms lacking radial ribbing. The co-occurrence of this *Didymotis* morphotype and *Mytiloides herbichi* enables a very convincing correlation of this horizon with the *Didymotis* I Event of Europe.

Flat Surface

In Pueblo bed 29 is characterized by a smooth upper surface (see SCOTT & COBBAN 1964) which is, moreover, characterized by a relatively common *Mytiloides* fauna, most of which may be referred to *M. herbichi* (ATABEKIAN). This level, marking possibly an erosional event, is easily identifiable and represents a very convenient marker for local correlation. It may correspond to the *herbichi* Event of the European succession (see WALASZCZYK & WOOD 1998).

"websteri fauna"

The bottom part of bed 31 of the Pueblo section is characterized by very characteristic inoceramids referred here to the "*websteri* fauna" owing to the resemblance of at least some forms found here to Woods' concept of *Inoceramus websteri* (WOODS 1912, pl. 53, figs 1-2). This very peculiar fauna is very poorly known in respect of its taxonomy, phylogeny as well as stratigraphical occurrence. Recently, *websteri*-like forms were found in the Vistula section, Central Poland, in the horizon just below the *waltersdorfensis* Event. No further investigations, however, were made.

waltersdorfensis Event

In the lower third of bed 31 in the Pueblo section, and about 1 m above the *Didymotis* I Event in the Springer section occurs a level with flood occurrence of small-sized, geniculated, highly inflated representatives of *Cremnoceramus waltersdorfensis waltersdorfensis* (ANDERT). Two closely-spaced *waltersdorensis* events were recognized in the Salzgitter-Salder section (*waltersdorfensis* I and *waltersdorfensis* II events - see WALASZCZYK & WOOD 1998). In most of the sections, however, these two events, as well as the intervening *Didymotis* II Event, are fused into a single event and referred to *waltersdorfensis* Event (e.g. WALASZCZYK 1992). As demonstrated by the numerous collections of the Geological Survey in Denver, it is a well recorded event over all the Western Interior.

In most of the European sections the *waltersdorfensis* Event is characterized usually by the co-occurring *Didymotis* bivalves. They were not found by us in any of the studied sections. However, the elongated, radially-ribbed morphotype of *Didymotis* associated with *C. waltersdorfensis* and early *C. deformis erectus* it present in some collections from the T/C boundary interval of Texas.

erectus I Event

The *erectus* Event, characterized by a flood abundance of the *C. deformis erectus* (MEEK) is well documented in both sections. The first forms referable to *C. erectus* (MEEK) were found, however, both in Pueblo and in Springer, already below this event (topmost part of bed 31 in Pueblo), marking the Turonian/Coniacian boundary in the interval between the *waltersdorfensis* and *erectus* I events.

erectus II Event

The second horizon with flood occurrence of *Cremnoceramus erectus* (MEEK), observed only in the Pueblo section (the succession in the Springer section does not range as high), is even better developed than the *erectus* I Event and is well visible in the lower part of bed 35.

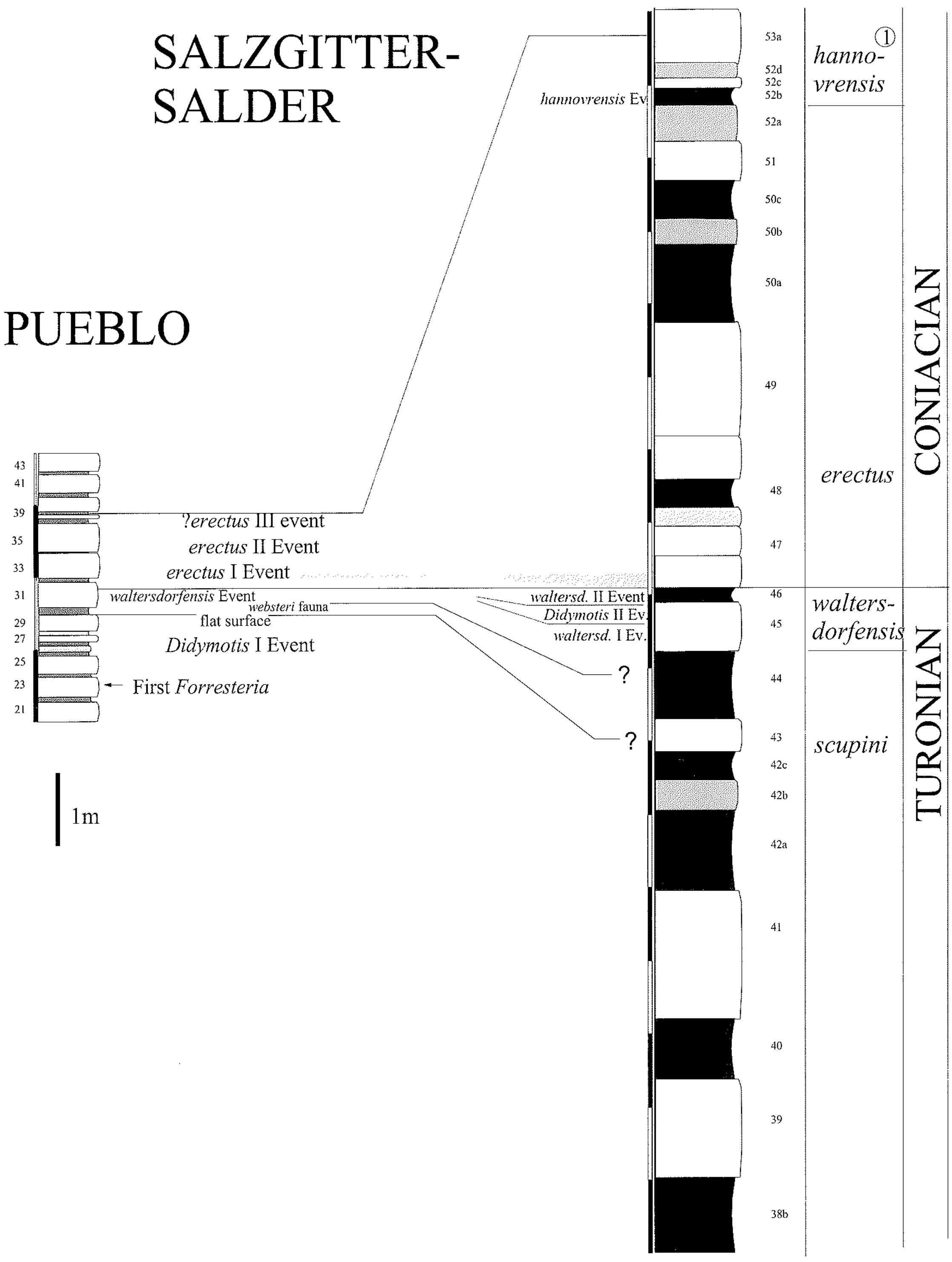


Fig. 7. Bio- and eventratigraphical correlation of the Pueblo and Salzgitter-Salder section; for details see Text-fig. 2 (in the case of the Pueblo section) and WALASZCZYK & WOOD (*this volume*, Text-fig. 2); bed numbers on left side of the Pueblo sections are after SCOTT & COBBAN (1964), those on the right side of the Salzgitter-Salder section are after WOOD & *al.* (1984) (*see also* WALASZCZYK & WOOD, *this volume*

?erectus III Event

The upper surface of bed 37 near Pueblo, a very thin limestone intercalation between shales of beds 36 and 38, is crowded with inoceramids of the *deformis* lineage, represented in part by *C. deformis erectus* (MEEK) and in part by forms which may represent already *C. deformis dobrogensis* (SZASZ). The interpretation of this horizon, in terms of the European event succession, is very uncertain. In the approximately equivalent interval in Europe, there occur two well developed events; the *hannovrensis* Event, marking the base of the *hannovrensis* Zone, and the *erectus* III Event, located slightly higher (see WALASZCZYK & WOOD 1998) (Text-fig. 7). The former event is characterized by a flood occurrence of *C. waltersdorfensis hannovrensis* (HEINZ). The latter event has a more variable fauna with the most characteristic *C. waltersdorfensis hannovrensis* and large representatives of the genus *Tethyoceramus* SORNAY (non HEINZ). Both *C. waltersdorfensis hannovrensis* and tethyoceramids are, however, extremely rare in the Western Interior, where the succession is characterized almost entirely by representatives of the *C. deformis* lineage (see WALASZCZYK & COBBAN *in press*). We compare our event with the European *erectus* III event, basing it on the appearance there of early forms comparable to *C. deformis dobrogensis*, which are present in that level also in the Western Interior, but the correlation is very uncertain.

EVALUATION OF THE WAGON MOUND SECTION

As shown in the previous chapter, the Wagon Mound section (Text-figs 4, 6b), proposed by KAUFFMAN (1995, and *in* KAUFFMAN & *al.* 1996) as a candidate for the Turonian – Coniacian boundary stratotype, was misinterpreted in respect of its biostratigraphical position and, consequently, can not be further regarded as a potential stratotype section for the Turonian/Coniacian boundary. The exposed part, composed of the Fort Hays Limestone (limestone beds 1 through 7 *in* KAUFFMAN 1995) and of the shale & limestone unit of the Smoky Hill Member (limestone beds 8-10 *in* KAUFFMAN 1995, and higher part of the succession), belong entirely to the Turonian (lower and middle parts of the *scupini* Zone) (see Text-fig. 6). The boundary between the lower, fossiliferous part (limestone beds 1 through 5) and the successive interval, characterized by a significant loss in inoceramid diversity, interpreted by KAUFFMAN (1995, and *in* KAUFFMAN & *al.* 1996) in terms of the Turonian/Coniacian boundary, represents actually a horizon well below the boundary. It corresponds to the boundary between the inoceramid-rich basal *scupini* Zone and the successive "barren interval" of the middle *scupini* Zone, characterized by an almost complete absence of macrofauna, a phenomenon known widely in the Western Interior (see e.g. HATTIN 1975), and also reported from Europe (WOOD & *al.* 1984).

COMPARISON OF THE FAUNAL SUCCESSION AT THE TURONIAN – CONIACIAN BOUNDARY INTERVAL BETWEEN THE WESTERN INTERIOR AND EUROPE

Beginning at the top of the "barren interval" up through the *erectus* Zone, the inoceramid succession in the Western Interior is identical to that in Europe (Text-fig. 7). It concerns both the taxonomic composition of the inoceramid assemblages as well as the mode of their occurrence, with inoceramids concentrated in distinct horizons instead of being randomly distributed (see Text-figs 2 and 4). Of importance is also the same mode of occurrence of *Didymotis*. Although only *Didymotis* I Event was recognized in the Pueblo and Springer sections, some unpublished data from southwestern Texas prove its presence also in the interval equivalent to the *waltersdorfensis* Event corresponding to the *Didymotis* II Event. Similarly as in Europe, these two horizons are represented by two distinct morphotypes of *Didymotis*; the lower event characterized by more rounded, weakly ornamented or smooth forms, while the upper level yields elongated forms with well developed radial ornament.

The first *Cremnoceramus deformis erectus* (MEEK) appears slightly below the *erectus* I Event (=*rotundatus* Event) and simultaneously above the *waltersdorfensis* Event. In the following interval, up to the appearance level of *Cremnoceramus crassus crassus* (PETRASCHECK), the succession is characterized almost exclusively by representatives of the *Cremnoceramus deformis* lineage (see WALASZCZYK & WOOD 1998 for definition); *C. deformis erectus* below and *C. deformis dobro-*

gensis above. The *waltersdorfensis* lineage (subspecies *waltersdorfensis* and *hannovrensis* – see WALASZCZYK & WOOD, *this volume*), dominating much of the Lower Coniacian succession in Europe, is almost absent in the Western Interior, with the exception of the basal *waltersdorfensis* Event (see Text-figs 2 and 4). The base of the *dobrogensis* Zone coincides either with the base of the European *hannovrensis* or is an equivalent of a slightly higher horizon corresponding to the *erectus* III Event.

CORRELATION WITH KAUFFMAN'S ZONAL SCHEME

Direct correlation with KAUFFMAN's zonal scheme for the topmost Turonian and Lower Coniacian is very difficult or actually impossible because many of his zonal inoceramid indexes were referred to in open nomenclature and have never been characterized by him subsequently. The following remarks are based thus on the comparison of our scheme and the inoceramid zonation he applied to the Pueblo section (KAUFFMAN & PRATT 1985), shown in our Text-fig. 2. This comparison reveals a marked difference between our concept of the Turonian/Coniacian boundary and that of KAUFFMAN. Moreover, it indicates considerable differences in the taxonomic concept of many inoceramid species characterizing the boundary (see WALASZCZYK & COBBAN, *in press*). KAUFFMAN (*in* KAUFFMAN & PRATT 1985 and *in* KAUFFMAN & *al.* 1993) placed the T/C boundary at the base of the "barren interval", which lies very low within the *scupini* Zone (see Text-figs 2, 4). In terms of the Salzgitter-Salder section, it is the level corresponding approximately to the *Micraster* Ecoevent, about 50 m below the actual Turonian/Coniacian boundary (see WOOD & *al.* 1984). The base of the *erectus* Zone, as here recognized, corresponds to the base of KAUFFMAN's *Cremnoceramus deformis deformis* Zone (Text-fig. 2). His zone of *Inoceramus* (*Cremnoceramus*?) *deformis* n. subsp. (small early form) + *I. erectus* n. subsp. (late form) corresponds approximately to the interval spanning the *Didymotis* I Event through the *waltersdorfensis* Event.

It is very difficult to find out which forms were the basis of KAUFFMAN's concept of forms like *Inoceramus rotundatus* or *I. erectus*. Inoceramids occurring in the interval included by him in these zones are extremely rare, and we have not seen any specimens from much of this part of the succession. The forms like *C. waltersdorfensis waltersdorfensis* (ANDERT) and *C. waltersdorfensis hannovrensis* (HEINZ), recognized by KAUFFMAN (see *in* KAUFFMAN & *al.* 1993) in his zone of *M. fiegei* + *M. dresdensis* + *M. lusatiae*, and higher, are probably some of the morphotypes found among representatives of the *M. striatoconcentricus* group.

The correlation presented here explains many of the apparent inconsistencies existing between the European inoceramid zonation, as presented by WOOD & al. (1984; and presented recently by WALASZCZYK & WOOD 1998), and the North American record at the T/C boundary as published recently by KAUFFMAN & *al.* (1993). These inconsistencies concern mostly the presence in the KAUFFMAN's scheme of many of the Late Turonian mytiloids in the lowermost Coniacian, or a lack of rapid evolutionary turnovers in the inoceramid faunas of the latest Turonian such as in the European record.

AMMONITE/INOCERAMID ZONAL SCHEME

During the Second International Symposium on Cretaceous Stage Boundaries (Brussels, 1995), the Coniacian Working Group of the Cretaceous Subcommission on Stratigraphy recommended that the First Occurrence (FO) of *Cremnoceramus rotundatus* (*sensu* TRÖGER *non* FIEGE) [= *C. deformis erectus* (MEEK)] be the criterion for recognition of the Turonian-Coniacian boudnary. The boundary was said to lie between the LO of the ammonite *Prionocyclus germari* and the FO of the ammonite *Forresteria* ("thus preserving some of the original ammonite definition of the boundary"). In Europe, however, the lowermost Coniacian ammonite record is very poor, and first *Forresteria* is not known until the base of the *inconstans* Zone (*in* WALASZCZYK & WOOD's 1998 scheme) located relatively high in the Lower Coniacian succession (see KAPLAN 1986, KAPLAN & KENNEDY 1995, 1996). According to the much better record in the Western Interior, first *Forresteria* co-occurs with definitely Turonian inoceramids [*Mytiloides herbichi* (ATABEKIAN) and *M. scupini* (HEINZ)] from the upper *scupini* Zone (Text-fig. 2), distinctly below the FAD of *Cremnoceramus deformis erectus* (MEEK) (*see also* KENNEDY & COBBAN 1991). In the Pueblo section the oldest specimen of *F. brancoi* is known from bed 23 (*Prionocycloceras*? of SCOTT & COBBAN 1964) well below the *Didymotis* I Event (see also Text-fig. 2).

KAUFFMAN's statement (*in* KAUFFMAN & *al.* 1993, 1996) on the coincidence of the FAD of *C. rotundatus* (=*C. erectus*) and the boundary between the Turonian *Prionocyclus* and Coniacian *Forresteria* (*F. peruana* and *F. brancoi*) was based on his different concept of inoceramid fauna in that interval and, consequently, much lower position of the Turonian/Coniacian boundary (see former chapter).

Concluding, inoceramid fauna at the level recommended during the Brussels Meeting as the Turonian/Coniacian boundary, allows for a very refined zonal subdivision of that interval and its very precise correlation in a frame of Euramerican biogeographical region. Moreover, the published data suggest its usefulness for the correlation also with other regions (North Pacific Province, New Zealand) although further studies are needed (NODA 1984, 1996; CRAMPTON 1995, 1996). However, in contrast to the original intention of the Coniacian Working Group, the use of *Forresteria* as defining the base of the Coniacian should be rejected.

CONCLUSIONS

1. The topmost Turonian and lowermost Coniacian succession of the Western Interior contains the same inoceramid faunas as recognized in Europe, and allows application of the same inoceramid biozonation in the boundary interval. Moreover, the recognition of the boundary events (*Didymotis* I, *waltersdorfensis*, *erectus* I, *erectus* II, and ?*erectus* III), described originally from Europe, allows almost bed-by-bed correlation of the boundary succession across the Atlantic. The former discrepancies in correlation of the boundary interval using KAUFFMAN'S scheme (as published recently in KAUFFMAN & *al.* 1993) resulted from various taxonomical concepts as applied by him and used in Europe.

2. The first "Coniacian" ammonite fauna (*Forresteria brancoi* and *F. peruana*) appears distinctly below the FAD of the inoceramid marker of the Turonian/Coniacian boundary, i.e. *Cremnoceramus deformis erectus* (MEEK) [*Cremnoceramus rotundatus* (*sensu* TRÖGER *non* FIEGE)], and consequently, the original intention of the boundary definition to preserve its ammonite character is rejected.

3. Two North American sections, i.e. Pueblo, Colorado, and Wagon Mound, New Mexico, were proposed during the Brussels Symposium on the Cretaceous Stage Boundaries as potential boundary stratotypes. None of them, however, appears to be better than the selected German section of Salzgiter-Salder, in spite of the fact that recent studies revealed a hiatus and/or condensation close to the boundary in its succession. The Pueblo section is much more condensed in comparison with the Salzgitter-Salder section, however, its excellent exposure, accessibility, preservation in a protected area, and relatively complete record make this section a very convenient reference section for the Turonian/Coniacian boundary in the Western Interior. The Wagon Mound section (the only other section formally proposed in Brussels besides Salzgitter-Salder) was mis-interpreted in respect of its biostratigraphical position. The entire succession of this section is of Late Turonian age, and distinctly below the Turonian/Coniacian boundary as defined in Brussels.

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