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New observations on the inoceramid biostratigraphy of the higher part of the Upper Turonian and the Turonian – Coniacian boundary transition in Poland, Germany and the UK

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[This paper is dedicated to the memory of the late Professor Gundolf Ernst, who always amused himself by collecting conflicting determinations of the same inoceramid specimens from as many specialists as possible!]

ABSTRACT:

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New studies of sections in southern England (Bridgewick Pit, Downley, Shoreham Cement Works Quarry), eastern England (Kiplingcotes Station Quarry, Arras Road Pit), Germany (Salzgitter-Salder Quarry, a potential candidate GSSP for the Coniacian Stage) and central Poland (Słupia Nadbrzeżna, another potential candidate GSSP) have enabled a re-evaluation and refinement of the inoceramid biostratigraphy of the higher part of the Upper Turonian and the Turonian–Coniacian boundary transition. The inoceramid record at Słupia Nadbrzeżna below the terminal Turonian entry of *Cremnoceramus* is shown to be more complete than at the standard Salzgitter-Salder Quarry section. A new inoceramid event (*Inoceramus lusatiae* Event) identified at Słupia Nadbrzeżna is inferred to be present at the Sonnenberg Quarry, Waltersdorf, the type locality of *Inoceramus lusatiae*, as well as of *I. glatziae* and *Cremnoceramus waltersdorfensis*, and it is possibly represented in the condensed Navigation Hardgrounds in southern England. The absence of this event at Salzgitter-Salder suggests a significant hiatus. An inoceramid assemblage characterised by a taxon of uncertain affinities that immediately precedes the flood occurrence of *Cremnoceramu*s (*waltersdorfensis* I Event) at Salzgitter-Salder has been identified at a comparable biostratigraphic position in eastern England (Yorkshire) and, tentatively, also in southern England. Inoceramids from this assemblage in the UK had previously been incorrectly assigned to *Cremnoceramus waltersdorfensis* and the basal Coniacian marker taxon, *C. deformis erectus*. The position of the base of the Coniacian has accordingly been revised upwards in both the southern and eastern England successions.

Key words: Turonian/Coniacian boundary, Biostratigraphy, Inoceramids, GSSP candidate, Correlation, England, Germany, Poland.

INTRODUCTION

The main feature of the inoceramid record around the Turonian/Coniacian boundary is the distinct change from the *Mytiloides* fauna (with the youngest *Mytiloides herbichi – M. scupini* assemblage) to the *Cremnoceramus* fauna (with the oldest, almost monospecific *C. waltersdorfensis waltersdorfensis* assemblage) in the very latest Turonian, as shown originally in the Salzgitter-Salder Quarry section, Germany (WOOD & *al*. 1984) and then confirmed elsewhere (see e.g. KÜCHLER & ERNST 1989, WALASZCZYK 1992, KAUFFMAN & *al*. 1996, WALASZCZYK & WOOD 1999). Recent work in the Salzgitter-Salder Quarry itself and in other selected sections in England and Poland revealed, however, that the actual inoceramid succession in this interval is much more complicated. At least two further assemblages were recognised: the older, represented by thin-shelled inoceramids, referred provisionally to *Inoceramus glatziae* FLEGEL, and the higher, with an acme-occurrence of *Inoceramus lusatiae* ANDERT. The presence of this pattern both in the English white chalk sections and the opoka facies of the Słupia Nadbrzeżna section, as well as its inferred presence in the nearshore sandy facies of the Saxonian-Bohemian region, suggests that it is the record of the actual evolutionary changes, which, consequently, may be used for construction of a more refined biostratigraphy.

This paper aims to be a progress report. More comprehensive discussion of the Turonian/Coniacian inoceramid succession and its inferred biostratigraphy will require rigorous palaeontological study, based on more extensive material, ideally including new collections from the original ANDERT (1911, 1934) localities near Waltersdorf, SE Germany. Although preliminary, the data presented herein are, however, of critical importance in recent efforts in establishing the stratotypic Turonian/Coniacian boundary section, demonstrating that the potential candidate for the stratotype section of this boundary, the Salzgitter-Salder section, Germany, is markedly incomplete in the boundary interval. A reinterpretation of the stratigraphy of the topmost Turonian – Early Coniacian succession in southern England is suggested.

REPOSITORIES

The material from Słupia Nadbrzeżna, including the part published by WALASZCZYK (1992) and WALASZCZYK & WOOD (1999), and the most comprehensive bed-by-bed reference collection from Salzgitter-Salder Quarry, is housed in the University of Warsaw, Poland. A smaller bed-by-bed collection from Salzgitter-Salder made by CJW is housed in the Natural History Museum, London. Additional material is in the Ernst collection, which is housed in the Humboldt Museum, Berlin.

The large specimen of *Inoceramus lusatiae* from Shoreham Cement Works Quarry and inoceramids from other sections in Sussex are in the collection of RNM; inoceramids figured in this paper from beneath the Lewes Marl in the Bridgewick Pit, collected by CJW and RNM, have recently been donated to the British Geological Survey (BGS), Keyworth, where they are registered under the prefix BGS Zw

Inoceramids from Downley, collected on two visits by MAW, and on a subsequent visit (2003) by CJW and MAW, are registered in the BGS collections under the prefixes BGS MAW and BGS WMD.

Inoceramids from Yorkshire, collected by CJW together with A. A. MORTER in the 1960s, are registered in the BGS collections under the prefixes BGS CJW and BGS JL

DETAILS OF INDIVIDUAL SECTIONS AND/OR AREAS

For ease of reference to new data, the critical sections are treated from west to east, beginning with the Słupia Nadbrzeżna section in Poland and ending with the sections in the UK.

Słupia Nadbrzeżna, western side of the Vistula valley, central Poland

[For locality see WALASZCZYK & WOOD (1999)]

Field observations by IW and CJW (2003), and new collections of inoceramids, have necessitated a revision of the published details (WALASZCZYK & WOOD 1999) of the lower part of this key reference section. In the original paper, an event-occurrence of *Mytiloides herbichi* (ATABEKIAN) (*Mytiloides herbichi* Event) was identified immediately above the conspicuous up-section lithological change from chert-rich opoka to a succession of rather pure opoka (pale buff-coloured siliceous marls) with some cherts.

The *M. herbichi* Event contains abundant and exceptionally well preserved *Mytiloides herbichi*, including some bivalved specimens (see WALASZCZYK & WOOD 1999). The associated fauna comprises *Inoceramus lusatiae* ANDERT and uncommon *Mytiloides scupini* (HEINZ). In addition to the inoceramids, a fragment of *Didymotis* sp. has been collected

The interval between the *M. herbichi* Event and the terminal Turonian *Cremnoceramus waltersdorfensis waltersdorfensis* Event was originally described simply as a 2.5 m thick unit containing rare fossils. However, several new inoceramid occurrences have now been recognized within this interval (see Text-fig. 2). Approximately 0.3 m above the *herbichi* Event a new inoceramid assemblage has been collected comprising, besides rare *Mytiloides herbichi*, *Inoceramus lusatiae*, and *Inoceramus websteri* (sensu WOODS, 1912), a new thin-shelled form of uncertain affinities. In the character of its ornament this form resembles *Mytilodes scupini* (HEINZ), although the rugae are less regular. It differs from that species in its subquadrate (instead of subrectangular) outline. Despite the uncertain affinity of this morphotype, it nevertheless appears to have considerable biostratigraphical significance. We refer to it tentatively as *Inoceramus* aff. *glatziae* (sensu ANDERT 1934, pl. 6, fig. 4). This is the highest level in the section with relatively common *Mytiloides*. Higher up-section (a little over 1 m above the *herbichi* Event) and immediately below another lithological change from pure opoka to a unit of opoka with cherts, there is an interval ca. 15 cm thick containing abundant large *Inoceramus lusatiae* packed closely together. Single specimens of *I. lusatiae* were also found slightly above and slightly below the main concentration. This interval has also yielded inoceramids that we may tentatively refer to *Inoceramus glatziae* sensu ANDERT 1934 (non FLEGEL, 1904) and *I. websteri sensu* WOODS.

Above the *I. lusatiae* concentration, which we here formally designate the ***I. lusatiae* Event**, the succession comprises three additional beds (numbered informally beds 1, 2 and 3, in ascending order). No inoceramids have been collected from Bed 1, a unit of cherty opoka. The overlying unit of pure opoka is bipartite; beds 2 and 3 are separated by a thin, inconspicuous marl seam, less than a 1 cm thick. Fragmentary specimens of *Inoceramus lusatiae* and a possible *Mytiloides* were collected from the base of Bed 2. Inoceramids also occur sporadically about 10 to 15 cm below the top of bed 3. The two specimens found are small-sized juvenile fragments and may represent a possible first occurrence of *Cremnoceramus waltersdorfensis waltersdorfensis* (ANDERT).

As reported earlier (WALASZCZYK & WOOD 1999), *C. waltersdorfensis waltersdorfensis* occurs in flood abundance in a massive, prominent unit of pure opoka immediately overlying bed 3. This occurrence constitutes the *waltersdorfensis waltersdorfensis* Event. The FO of *Cremnoceramus deformis erectus* (MEEK) [formerly *Cremnoceramus rotundatus* TRÖGER non FIEGE], the internationally accepted basal marker taxon for the Coniacian Stage (see discussion in KAUFFMAN, KENNEDY & WOOD 1996; WALASZCZYK & WOOD 1999), is marked by isolated occurrences of the taxon within a unit of cherty opoka ca. 0.75 m above the base of the *waltersdorfensis* Event. The occurrence of *C. deformis erectus* in flood abundance within a unit of pure opoka, some 2.2 m above the FO of the taxon, marks the *C. deformis erectus* Event.

The *hannoverensis* Event, with a flood occurrence of *C. walt. hannovrensis*, occurs approximately 4 m above the *erectus* Event. The section in this part of the succession in not very well exposed and the details of the interval above the *erectus* Event could not be studied in detail.

Salzgitter-Salder Quarry, Lower Saxony, Germany

The following observations (see Text-fig. 2) update biostratigraphic data given by KAUFFMAN & *al.* (1996) and WALASZCZYK & WOOD (1999). For additional lithostratigraphical details on the succession see WOOD & *al.* (1984) and WOOD & ERNST (1998).

Bed 9 contains large *Mytiloides ratonensis* WALASZCZYK & COBBAN, a North American species that is now known to occur over a relatively narrow stratigraphical range in the lower part of the Late Turonian *Mytiloides scupini* Zone in northern Europe. Small specimens of this species have also been collected from an approximately correlative level at Nettlingen in the Lesse Syncline, ca. 9 km WNW of Salzgitter-Salder.

A level with small inoceramids of uncertain affinity in Bed 29 has additionally yielded an unequivocal, albeit poorly preserved, specimen of *Didymotis* (University of Warsaw collection) This marks the lowest occurrence of *Didymotis* at this locality and substantiates the tentative recognition by other workers of a so-called *Didymotis* 0 Event at or near this level here (WIESE & KRÖGER 1998).

Didymotis first occurs in abundance in Bed 39 (*Didymotis* I Event), together with common *Inoceramus lusatiae* and *Mytiloides scupini,* the zonal index of the *M. scupini* Zone. The *Didymotis* I morphotype exhibits a simple sculpture of commarginal thick, rounded rugae with relatively wide interspaces; the radial elements of the morphotype characterising *Didymotis* II are absent (see below).

In the previous paper (WALASZCZYK & WOOD 1999), we identified a *Mytiloides herbichi* Event in the middle and top of Bed 43. New collecting has shown that *M. herbichi* is also common in Bed 42c. The report (WALASZCZYK & WOOD 1999) that no inoceramids have been found in Bed 44 requires correction. The highest 15 cm of this bed contains a flood occurrence of largely completely compressed, albeit well preserved, inoceramids of uncertain affinity, representing a new and biostratigraphically significant assemblage. To judge from the few better preserved specimens, we consider that most represent a single taxon, conspecific with the Słupia Nadbrzeżna species, which we tentatively refer to *I.* aff. *glatziae* (sensu ANDERT 1934, pl. 6, fig. 4). Unidentifiable specimens of *Mytiloides* may also be present. In this material we also have at least one fairly convincing specimen of C. *waltersdorfensis waltersdorfensis* and a single *Didymotis*. The new assemblage was collected by IW from the section illustrated by WALASZCZYK & WOOD (1999, fig. 3A). A subsequent attempt (2003) by CJW to collect additional material from another section exposing the bed in question (the higher section shown in fig. 3B) proved unsuccessful. This suggests that the new assemblage may be only locally preserved in depressions at the top of Bed 44, but elsewhere has been removed by erosion.

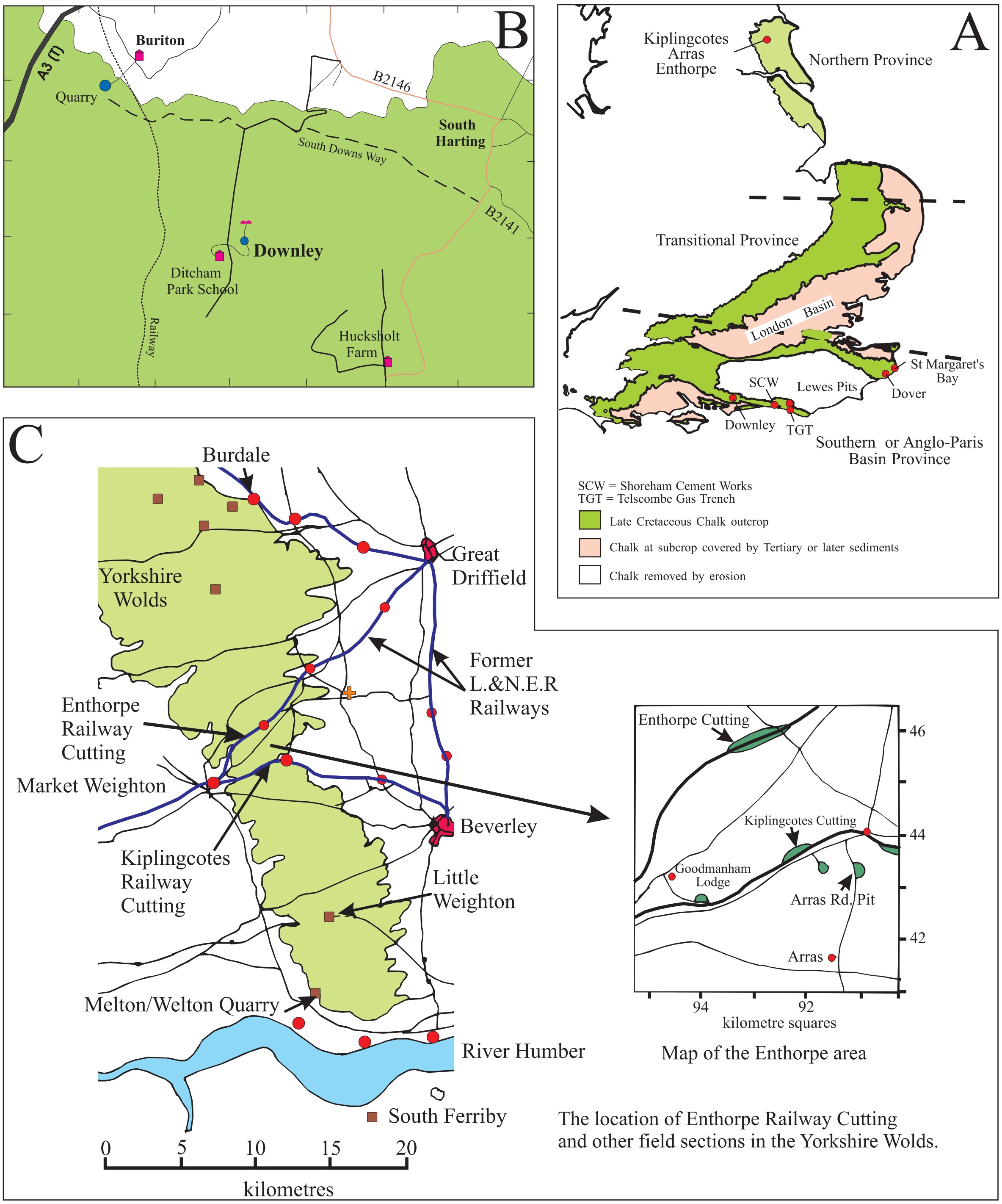
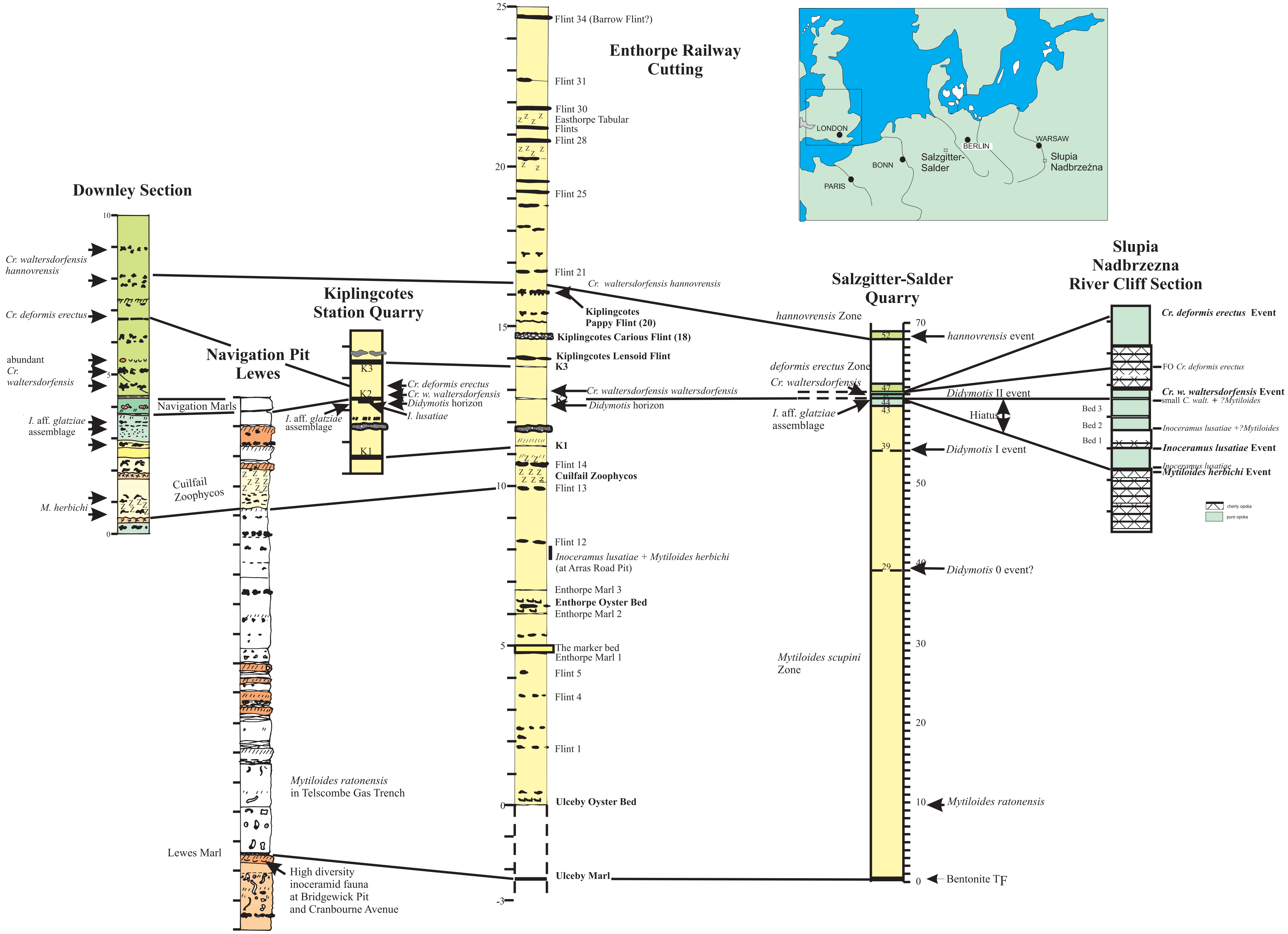


Fig. 1. Geological sketch-maps to show the location of the studied sections in southern England; A – southern England to show the main study areas; B - the area near Downley; C - part of Yorkshire to show the Enthorpe railway cutting, Arras Road Pit and Kiplingcotes Station Quarry sections



Correlation of the key sections discussed in the paper, taking the entry of *Cremnoceramus waltersdorfensis waltersdorfensis* in flood abundance as the datum, and the map of north-west and central Europe to show the location of the sections studied. Also correlated are the base of the Cuilfail Zoophycos; the bentonite Lewes Marl/Ulceby Marl/ T_F the FO of *C. erectus deformis* at the base of the Coniacian; and the entry of *C. waltersdorfensis hannovrensis*. It should be noted that detailed correlation between southern and eastern England of the beds in the interval between the bentonite and the Cuifail Zoophycos has not yet been resolved. All of the sections are drawn to the same scale, with the exception of Salzgitter-Salder, where the interval from the bentonite T_F to the datum is an order of magnitude approximately five times greater than the correlative interval in eastern England from the Ulceby Marl to the Kiplingcotes Marl 2. An attempt is made to show the inferred extent of the hiatus involving the absence of the *Inoceramus lusatiae* Event at the base of Bed 45 at Salzgitter-Salder Quarry

It must be emphasised that between the main *M. herbichi* Event in bed 43 and this new assemblage at the top of bed 44, intensive collecting has revealed no inoceramids. We no longer attribute this negative record to collection failure on the basis of the friable nature of the sediment, as previously suggested (WALASZCZYK & WOOD 1999, p. 399). This apparent absence of inoceramids cannot be explained, but may well mark a temporary change in the depositional environment.

Bed 44 is followed by a bipartite limestone bed (Bed 45), which is subdivided into two equal parts (45a and 45b) by a thin detrital marl. Apart from the sporadic records in the assemblage at the top of Bed 44 (see above), *C. w. waltersdorfensis*, associated with *Didymotis*, occurs in flood abundance right at the base of limestone 45a. The *Didymotis* II Event, with the same association, was originally recognized at the top of bed 45a. The *Didymotis* morphotype in Bed 45a is larger and posteriorly more elongate than the *Didymotis* I morphotype in Bed 39. It is additionally characterized by finer, sharper and more closely spaced commarginal rugae that are crossed by radial elements. We consider that this morphotype is best referred to *D. costatus* (FRITSCH) (see also discussion in WIESE 1997, SEELING & BENGTSON 2003).

The whole of Bed 45a, rather than its upper part, should be regarded as the interval constituting the *waltersdorfensis* I Event. The next flood occurrence of *C. w. waltersdorfensis* (*waltersdorfensis* II Event) in the marl Bed 46 is separated by a limestone (Bed 45b) that contains few fossils apart from limonitized sponges, suggesting a possible reduction in the rate of sedimentation or even a short-term stillstand (WALASZCZYK & WOOD 1999). It must be emphasized that no identifiable inoceramids have so far been collected from Bed 45b.

In contrast to Słupia Nadbrzeżna, where sporadic occurrences of *Cremnoceramus deformis erectus* have been identified below the *C. deformis erectus* Event, the (second) flood occurrence of *C. waltersdorfensis waltersdorfensis* in the Bed 46 is immediately followed by the FO and simultaneous first flood occurrence of *C. deformis erectus* in the Bed 47 (*C. deformis erectus* I Event)

Southern England

The published inoceramid record (MORTIMORE 1986; MORTIMORE *& al*. 2001) in the Upper Turonian and across the inferred Turonian/Coniacian boundary in southern England requires correction.

The beds immediately underlying the Lewes Marl yield an abundant, high-diversity inoceramid assemblage. A particularly well preserved fauna has been collected from the Bridgewick Pit [NGR TQ 4310 1117] near Lewes in Sussex, from the 30 cm interval beneath the Lewes Marl (for section see LAKE *& al*. 1987). Additional material illustrated in this paper from below the Lewes Marl came from a temporary section in Cranbourne Avenue, Eastbourne. The Lewes Marl is the inferred equivalent of bentonite T_F of the German tephrostratigraphic framework (WRAY 1999; MORTIMORE *& al.* 2001, fig. 1.12). Bentonite T_F is situated a short distance above the base of the Late Turonian *Mytiloides scupini* inoceramid Zone. The assemblage comprises: *Mytiloides incertus* (JIMBO) (Pl. 2, Figs 3, 6, 7), *Mytiloides mytiloidiformis* (TRÖGER) (Pl. 2, Figs 1, 11), *M. striatoconcentricus* (GÜMBEL) (Pl. 2, Fig. 10), *Mytiloides labiatoidiformis* (TRÖGER) (Pl. 2, Fig. 8) and *Inoceramus perplexus* WHITFIELD (Pl. 2, Fig. 12). In addition, there is a large *Mytiloides* (Pl. 1, Fig. 3, 5) of uncertain affinity that resembles the specimen from Hoppenstedt figured by TRÖGER (1999, fig. 1) and may perhaps be regarded as an early form of *M. scupini*. At a higher level of the Upper Turonian succession a 1 m thick temporary section in a gas pipeline trench near Telscombe [NGR TQ 411 052] yielded an assemblage of large *Mytiloides ratonensis* (see Text-fig 2 – correlation diagram). The exact horizon is uncertain but it is believed to be stratigraphically safely constrained between the Lewes Marl and the Lewes Nodular Beds.

Between the Lewes Marl and the Navigation Hardgrounds there is an interval marked by conspicuous, colour-contrasting *Zoophycos, the* Cuilfail Zoophycos (MORTIMORE 1986; MORTIMORE *& al*. 2001). This interval contains echinoids and, locally, abundant well preserved bryozoans, but it has hitherto yielded no inoceramids whatever. However, new collections from a section near Downley (see below) have yielded taxa characteristic of the higher part of the *Mytiloides scupini* Zone.

The overlying succession is laterally variable and everywhere more or less condensed. The currently accepted position is that the Turonian/Coniacian boundary interval is marked by a level of extreme condensation, expressed by one or more hardgrounds, the Navigation Hardgrounds (MORTIMORE 1986, MORTIMORE *& al.* 2001). Locally, e.g. the Downley section discussed in this paper (see below), the interval in question is developed as fossiliferous coarse-grained chalks rather than as indurated nodular chalks. The Navigation Hardground complex at Shoreham Cement Works Quarry in Sussex has yielded a large specimen of *Inoceramus lusatiae* (RNM collection) (Pl. 2, Fig. 15). Apart from two indeterminable inoceramid fragments from Dover (Kent), no other inoceramids have been collected from this level. A single poorly preserved *Didymotis* was collected from a soft bed between two nodular beds at this level near St. Margaret's Bay, NE of Dover (MORTIMORE *& al*. 2001).

The Navigation Hardgrounds are followed by a pair of variably developed marl seams, the Navigation Marls. The base of the Coniacian in inoceramid terms is conventially taken at the reported co-occurrence of *Cremnoceramus waltersdorfensis waltersdorfensis* and the basal marker taxon, *C. deformis erectus,* in and above the Navigation Marls at Shoreham Cement Works Quarry and above the Navigation Marls at Dover. However, inoceramid collections from the Downley section (see below) and a re-investigation of the inoceramids from between Navigation Marls 1 and 2 at Shoreham Cement Works Quarry, have necessitated a significant revision of the conventional interpretation.

The inoceramids from the Navigation Marl 1 – Navigation Marl 2 interval are typically crushed and superficially resemble *Cremnoceramus waltersdorfensis waltersdorfensis* and *C. deformis erectus*. However, we now consider that they should probably be assigned to the un-named taxon that occurs immediately preceding the flood occurrence of *Cr. w. waltersdorfensis*is in eastern England (Yorkshire: see below, p.) and at Salzgitter-Salder Quarry, Germany.

Downley section

A small, extensively faulted section beside a woodland road ca 400 m from Downley Junior School [NGR SU 7525 1778] (Text-figs 1B, 2) exposes the interval from the Cuilfail Zoophycos to a level several metres above the top of the equivalent of the Navigation Hardgrounds and the overlying Navigation Marls. The composite succession shown in Text-fig 2 combines details from several different fault blocks The Navigation Hardgrounds are developed here not as indurated nodular chalks, but as coarse-grained, flinty chalks that are slightly indurated at the top, immediately beneath the Navigation Marls. This section has yielded inoceramids from beds below the Navigation Marls for which there previously has been no record. The succession above the Navigation Marls is relatively rich in inoceramids at some horizons, particularly the immediately overlying half-metre interval, and above a higher, nodular horizon that is inferred to equate with the Cliffe Hardground.

The base of the section exposes flinty chalk with *Zoophycos* belonging to the Cuilfail Zoophycos. This level has yielded a small *Mytiloides herbichi* (BGS MAW 4755, Pl. 2, Fig. 2) and a juvenile and incomplete *Mytiloides* (BGS MAW4751). These are the only inoceramids that ever been collected from the Cuilfail Zoophycos from any locality. The coarse-grained chalk beneath the Navigation Marls is relatively thin bedded and consequently it is easy to remove blocks to search for fossils. Two horizons in this part of the succession have yielded inoceramids. The fauna includes *M. herbichi* (WMD 8926), *Inoceramus websteri* sensu Woods, 1912 (BGS WMD8924, Pl. 2, Fig. 9), and forms that we tentatively refer to *Inoceramus* aff. *glatziae* sensu ANDERT (1934, pl. 6, fig. 4) (e.g. BGS WMD8927/8918, Pl. 2, Fig. 13; BGS WMD8921-2, Pl. 2, Fig. 14).

The interval of flinty chalk immediately above the Navigation Marls has yielded a virtually monospecific inoceramid assemblage which appears to be composed of small geniculated individuals of *Cremnoceramus waltersdorfensis waltersdorfensis* (Pl. 3, Figs 1-4, 7-9, 13, 14) Such specimens occur commonly in the *waltersdorfensis* I Event in Salzgitter-Salder Quarry and in the *waltersdorfensis* Event in the Słupia Nadbrzeżna section. A single poorly preserved *Didymotis* associated with a *C. w. waltersdorfensis* (BGS MAW4776, Pl. 3, Fig. 14) was also collected. Although one or two specimens (e.g. BGS MAW4767) from this assemblage cannot readily be assigned to *C. w walterdorfensis,* no *C. deformis erectus* or even transitional forms between *C. w. waltersdorfensis* and *C. deformis erectus* have so far been identified. An exceptionally well preserved specimen from Dover (BGS Zw3063, Pl. 3, Figs 11a, b) from 0.7 m above the top of the Navigation Hardgrounds can also be determined as *C. w. waltersdorfensis*.

Higher up-section, just above a conspicuous sheet flint containing chalk clasts, a single unequivocal specimen of *Cremnoceramus deformis erectus* (BGS MAW4825, Pl. 3, Fig. 6) was collected. At and above the nodular unit, there is a significant change in the inoceramid assemblage to a nearly monospecific assemblage of *C. waltersdorfensis hannovrensis* (HEINZ) (e.g. BGS MAW4828, 4847, 4858; Pl. 4).

Eastern England (Yorkshire)

Critical sections of the higher part of the Upper Turonian succession and across the Turonian–Coniacian boundary transition are exposed in Yorkshire (Text-fig. 1C), in the continuous section in the abandoned Enthorpe railway cutting [NGR SE 9062 4568 – 9138 4594], and in partial sections in the Arras Road Pit [NGR SE 9285 4320] and the Kiplingcotes Station Quarry [NGR SE 932 437] (Text-fig. 1C, for locality details see WHITHAM 1994, fig. 15.2; MORTIMORE *& al.* 2001, figs 5.15, 5.16). Our new investigation of material from these localities in the collections of the BGS, Keyworth, has revealed that published interpretations (WOOD *in* GAUNT *& al*. 1992; MORTIMORE *& al.* 2001) of the inoceramid biostratigraphy of the succession across the Turonian–Coniacian boundary are in need of revision.

As in southern England, high diversity inoceramid assemblages are present immediately beneath the

Ulceby Marl, the bentonite that correlates with the Lewes Marl and with bentonite T_F in Germany. Material from eastern England from this level is not considered further in this paper.

An assemblage of small *Mytiloides* spp, including *M. herbichi* (BGS JL5245, 5246, 5248, Pl. 1, Figs 1, 2, 4, 6) and *Inoceramus lusatiae* (BGS JL5252, Pl. 1, Fig. 7), has been collected from the Arras Road Pit section from the interval between Enthorpe Marl 3 and the informally designated flint 12 (see MORTIMORE *& al*. 2001, fig. 5.18 and the stratigraphical section Text-fig. 2).

The Turonian–Coniacian boundary transition (Text-fig. 2) is marked by the succession comprising the interval containing the three Kiplingcotes Marls (Kiplingcotes Marls 1, 2 and 3), followed by the interval with the three distinctive Kiplingcotes Flints (Kiplingcotes Lensoid Flint, Kiplingcotes Carious Flint and Kiplingcotes Pappy Flint). The published interpretation (MORTIMORE *& al*. 2001, p. 406) is that the base of the Coniacian should be drawn at an indefinite level between Kiplingcotes Marls 1 and 2. According to this interpretation, the approximate position of the boundary is marked by a shell bed, 15 cm beneath Kiplingcotes Marl 2. This shell bed at both the Kiplingcotes Station Quarry and Arras Road Pit was reported to contain *Cremnoceramus waltersdorfensis waltersdorfensis* in association with *C. deformis erectus* and poorly preserved *Didymotis* belonging to morphotype II, i.e., *Didymotis costatus*. However, because there were also reported isolated occurences of *C. deformis erectus* only a few centimetres below the shell bed, the position of the base of the Coniacian had to be left idefinite.

Re-examination of this material by two of us (IW and CJW), in the light of the new data from the boundary succession at Salzgitter-Salder Quarry, has led to a completely different interpretation of the inoceramid assemblages. All the inoceramids from and around the *Didymotis* horizon that were previously identified as *Cremnoceramus w. waltersdorfensis* and *C. deformis erectus* are now assigned to *Inoceramus websteri* sensu WOODS, 1912 (e.g. BGS JL5275, Pl. 2, Fig. 4), or the same taxon of uncertain affinities that occurs locally at the top of Bed 44 in Salzgitter-Salder Quarry, Germany and also in the top Turonian of the Słupia Nadbrzeżna section, Poland, and referred herein to *I*. aff. *glatziae* sensu ANDERT (1934, pl. 6, fig. 4) (see e.g. BGS CJW7986, 7989, illustrated in Pl. 1, Fig. 8). In addition, a single specimen of *Inoceramus lusatiae* (BGS JL5258) was collected from the interval between the *Didymotis* horizon and Kiplingcotes Marl 2 at the Arras Road Pit.

The 25 cm interval immediately above Kiplingcotes Marl 2 at Kiplingcotes Station Quarry yielded a monospecific assemblage of *Cremnoceramus w. waltersdorfensis,* including the morphotype (BGS JL5282, Pl. 3, Fig. 12) characterised by extremely fine, closely spaced growth lines in the juvenile ontogenetic stage. This assemblage probably belongs to the terminal Turonian *Cremnoceramus waltersdorfensis waltersdorfensis* Zone. The base of the Coniacian is now marked approximately by the occurrence of an unequivocal specimen of *C. deformis erectus* (BGS JL5285, Pl. 3, Fig. 10) from 0.4 m above Kiplingcotes Marl 2 at the same locality.

The interval with the Kiplingcotes flints in the Enthorpe railway cutting section has yielded possible *Tethyoceramus* (BGS JL5218-5220) from just above the Kiplingcotes Carious Flint (MORTIMORE *& al*. 2001, p. 406), but this identification was not checked in the present investigation. *Cremnoceramus waltersdorfensis hannovrensis* (e.g. BGS JL5224) is common there 0.3 m above the Kiplingcotes Pappy Flint: this occurrence marks the approximate position of the *C. w. hannovrensis* Zone of the standard zonal scheme and the level of a major turnover in the inoceramid assemblages.

DISCUSSION

The recognition, in the topmost part of the *Mytiloides scupini* Zone, of an interval with the regular occurrence of *Inoceramus* aff. *glatziae* sensu ANDERT (1934, pl. 6, fig. 4) in most of the sections studied, and of the acme-horizon with *I. lusatiae* ANDERT at Słupia Nadbrzeżna, referred to herein as the *lusatiae* Event, is potentially of considerable biostratigraphical and correlative importance.

I. lusatiae was originally described by ANDERT (1911) from the sandstone facies in the Sonnenberg quarry in the village of Waltersdorf, Saxony, Germany, which is also the type locality of *Cremnoceramus waltersdorfensis waltersdorfensis* and *Inoceramus glatziae* sensu ANDERT. All the inoceramids from this locality are preserved as moulds, but regrettably only the internal moulds (steinkerns) were normally collected. The stratigraphy of the now overgrown and relatively inaccessible section in this quarry is uncertain and requires new investigation. Nevertheless, the abundance in the old museum collections in Dresden and Ebersbach of *Inoceramus lusatiae* and *Cremnoceramus w. waltersdorfensis*, characteristic Upper Turonian faunal elements, suggest that the *I. lusatiae* event may also be represented here. In view of the fact that *Inoceramus lusatiae* appears not to co-occur with *Cremnoceramus waltersdorfensis waltersdorfensis* in opoka, Pläner limestone or white chalk facies, it could possibly be inferred from the collections that the *lusatiae* event here is followed by a *C. w. waltersdorfensis* flood event, i.e., a comparable sequence to that now identified in the Słupia Nadbrzeżna section.

Between the *herbichi* Event (beds 42c-43) and the *waltersdorfensis* I Event, there appears to be no evidence at Salzgitter-Salder Quarry for the *Inoceramus lusatiae* Event identified at Slupia Nadbrzeżna and inferred at Sonnenberg Quarry in Waltersdorf. This suggests the existence of a possible hiatus at the boundary between beds 44 and 45, an hiatus that can also be inferred from an apparent gap in the stable isotope stratigraphy here in comparison with more expanded successions in northern Spain (WIESE 1999). Additional hiatuses (also suggested by gaps in the complete stable isotope record) in the Salzgitter-Salder succession can be likewise inferred at the level of Bed 45b and, particularly, between the *waltersdorfensis* II Event in the marl Bed 46 and the FO and simultaneous entry in flood abundance of *C. deformis erectus* at the base of the limestone Bed 47 (*erectus* I event).

It is noteworthy that the Navigation Hardground at Shoreham Cement Works Quarry has yielded a large specimen of *Inoceramus lusatiae* (see Text-fig. 2, and Pl. 2, Fig. 15) This may possibly come from an horizon equivalent to the *lusatiae* Event recognized at Słupia Nadbrzeżna (and possibly also at Waltersdorf). The hiatus inferred at Salzgitter-Salder from the apparent absence of *Inoceramus lusatiae* (see above) may therefore be an expression of the late Turonian condensation event represented by the Navigation Hardgrounds in southern England.

The recognition, below Kiplingcotes Marl 2 in the eastern England succession, of the *Inoceramus* aff. *glatziae* sensu ANDERT (1934, pl. 6, fig. 4) assemblage from the top of Salzgitter-Salder Bed 44, is of critical correlative importance, in that the occurrence of this taxon immediately precedes the (terminal Turonian) flood occurrence of *Cremnoceramus waltersdorfensis waltersdorfensis* in both areas. Moreover, if the crushed inoceramids between Navigation Marls 1 and 2 in southern England are also correctly referred to this taxon, then it follows that the previously inferred correlation of Navigation Marl 2 and Kiplingcotes Marl 2 is supported by the inoceramid evidence.

The new evidence from the Downley section suggests (1) that the inoceramid assemblage from just above the Navigation Marls is probably of latest Late Turonian *Cremnoceramus waltersdorfensis waltersdorfensis* Zone age, rather than earliest Coniacian as previously thought; (2) that the base of the Coniacian needs to be drawn at an higher horizon, provisionally at the level of the first record of *Cremnoceramus deformis erectus* at the base of the inferred equivalent of the Cliffe Hardground; (3) The base of the *Cremnoceramus waltersdorfensis hannovrensis* Zone can be placed at the top of the inferred equivalent of the Cliffe Hardground. This new interpretation of the position of the base of the Coniacian on inoceramid data has the important corollary that the massive condensation of the succession expressed by the Navigation Hardgrounds must be assigned to the late but not latest Turonian, rather than to the Turonian–Coniacian boundary.

The occurrence of *Cremnoceramus deformis erectus* 0.4 m above Kiplingcotes Marl 2 in eastern England (Kiplingcotes Station Quarry), and at the inferred level of the Cliffe Hardground in the Downley section, suggests that the correlative in southern England of Kiplingcotes Marl 3 may well be the Cliffe Marl.

Acknowledgements

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PLATE 1

Turonian inoceramids from England

1 – BGS JL5253, *Mytiloides ?herbichi* (ATABEKIAN, 1968), Arras Road Pit, 10 cm below Flint 12; **2** – BGS JL5246, *Mytiloides herbichi* (ATABEKIAN, 1968), Arras Road Pit, 30 cm below Flint 12; **3** – BGS Zw3070, *Mytilodies ?scupini* (HEINZ, 1930) (early form?), Bridgewick Pit; 0.35 m below Lewes Marl; **4** –BGS JL5245, *Mytiloides* sp., Arras Road Pit, 40 cm below Flint 12.; **5** – BGS Zw3102, *Mytiloides ?scupini* (HEINZ, 1930) (early form), Bridgewick Pit; 0.35 m below Lewes Marl [counterpart of specimen in Text-fig. 4.3] ; **6** – BGS JL5248, *Mytiloides herbichi* (ATABEKIAN, 1968), Arras Road Pit, 12–25 cm below Flint 12.; **7** –BGS JL5252, *Inoceramus lusatiae* ANDERT, 1911, Arras Road Pit, 15 cm below Flint 12; **8** – BGS CJW7986 and 7989, *Inoceramus* aff. *glatziae* sensu ANDERT (1934, pl. 6, fig. 4)., Arras Road Pit, 15 cm below Kiplingcotes Marl 2

All figures are natural size

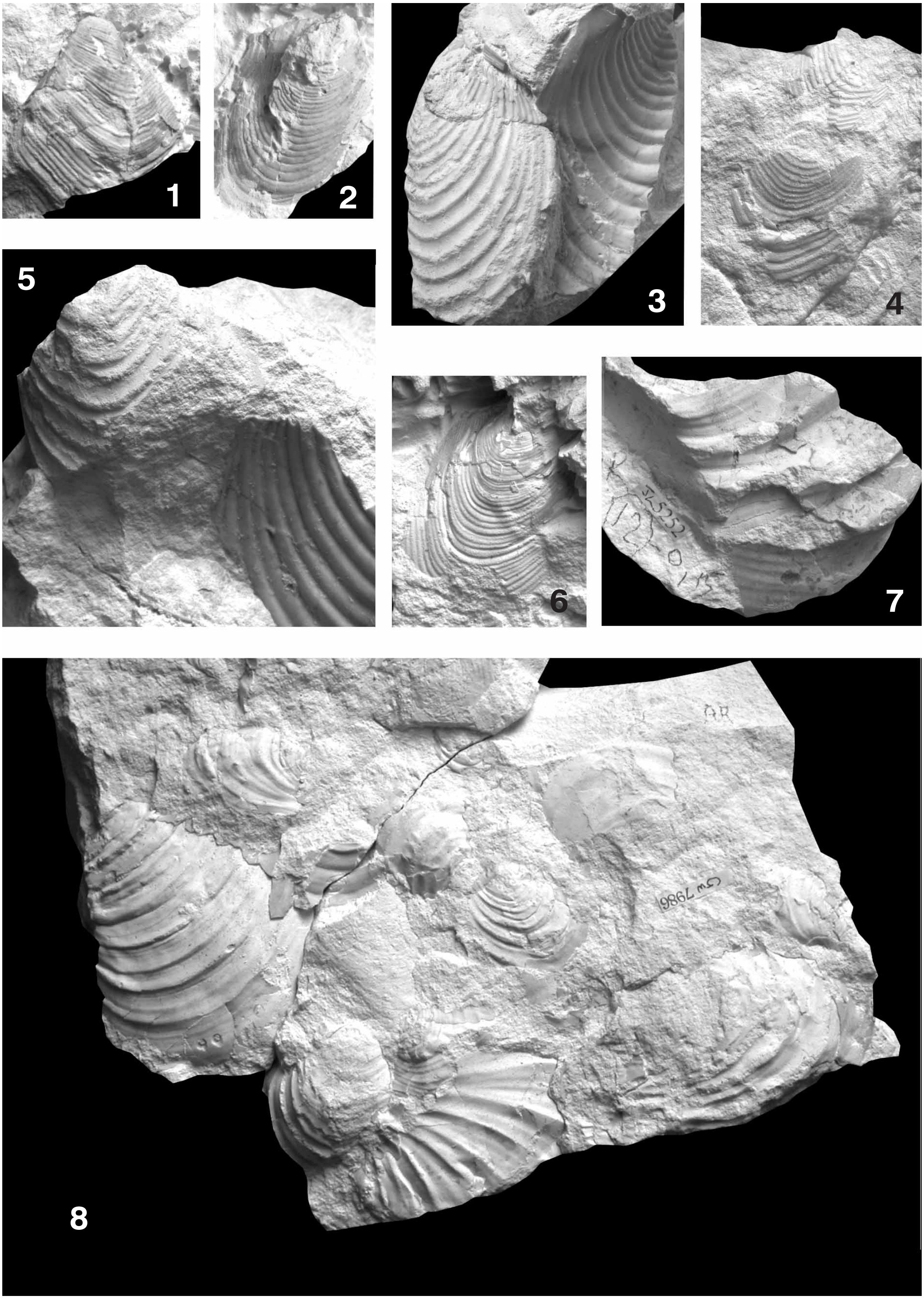
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PLATE 2

Late Turonian inoceramids from England, Poland and Germany

1, 11 – *Mytiloides mytiloidiformis* (TRÖGER, 1967); 11 – BGS Zw3067, Bridgewick Pit, 0.20 m below Lewes Marl; **2** – BGS MAW4755, *Mytiloides herbichi* (ATABEKIAN, 1968), Downley section, Zoophycos Bed; **3, 6-7** – *Mytiloides incertus* (JIMBO); 3 – BGS Zw3069, Bridgewick Pit, 0.35 m below Lewes Marl; 6 – BGS Zw3066, Bridgewick Pit, 0.10 m below Lewes Marl; 7 – BGS Zw3068, Bridgewick Pit, 0.30 m below Lewes Marl; **4, 9 –** *Inoceramus websteri* sensu WOODS non MANTELL, 1912; 4 - BGS JL5275, Kiplingcotes Station Quarry, 10 cm below Kiplingcotes Marl 2; 9 – BGS MWD8924, Downley section, 0.4 m below Navigation Marl I; **5** – ?*Inoceramus* aff. *glatziae* sensu ANDERT (1934, pl. 6, fig. 4) [this is a plasticine pull taken from the external mould of BGS WMD8927; **8** –BGS Zw3065 *Mytiloides labiatoidiformis* TRÖGER, 1967, Bridgewick Pit, 2 cm below Lewes Marl; **10** – *Mytiloides striatoconcentricus* (GÜMBEL), temporary section in Cranbourne Avenue, Eastbourne, below Lewes Marl[R.N.Mortimore collection]; **12** – *Inoceramus perplexus* WHITFIELD, 1877, temporary section in Cranbourne Avenue, Eastbourne, below Lewes Marl [R.N.Mortimore collection]; **13 –** BGS WMD8927, *Inoceramus* aff. *glatziae* sensu ANDERT (1934, pl. 6, fig. 4), Downley section, 15-30 cm below Navigation Marl I; **14** – BGS WMD8921, *Inoceramus* aff. *glatziae* sensu ANDERT (1934, pl. 6, fig. 4), Downley section, 40 cm below Navigation Marl 1; **15** – *Inoceramus lusatiae* ANDERT; Navigation Hardground at Shoreham Cement Works Quarry [R.N.Mortimore collection].

Except figure 15, which is × 0.8, all other figures are natural size

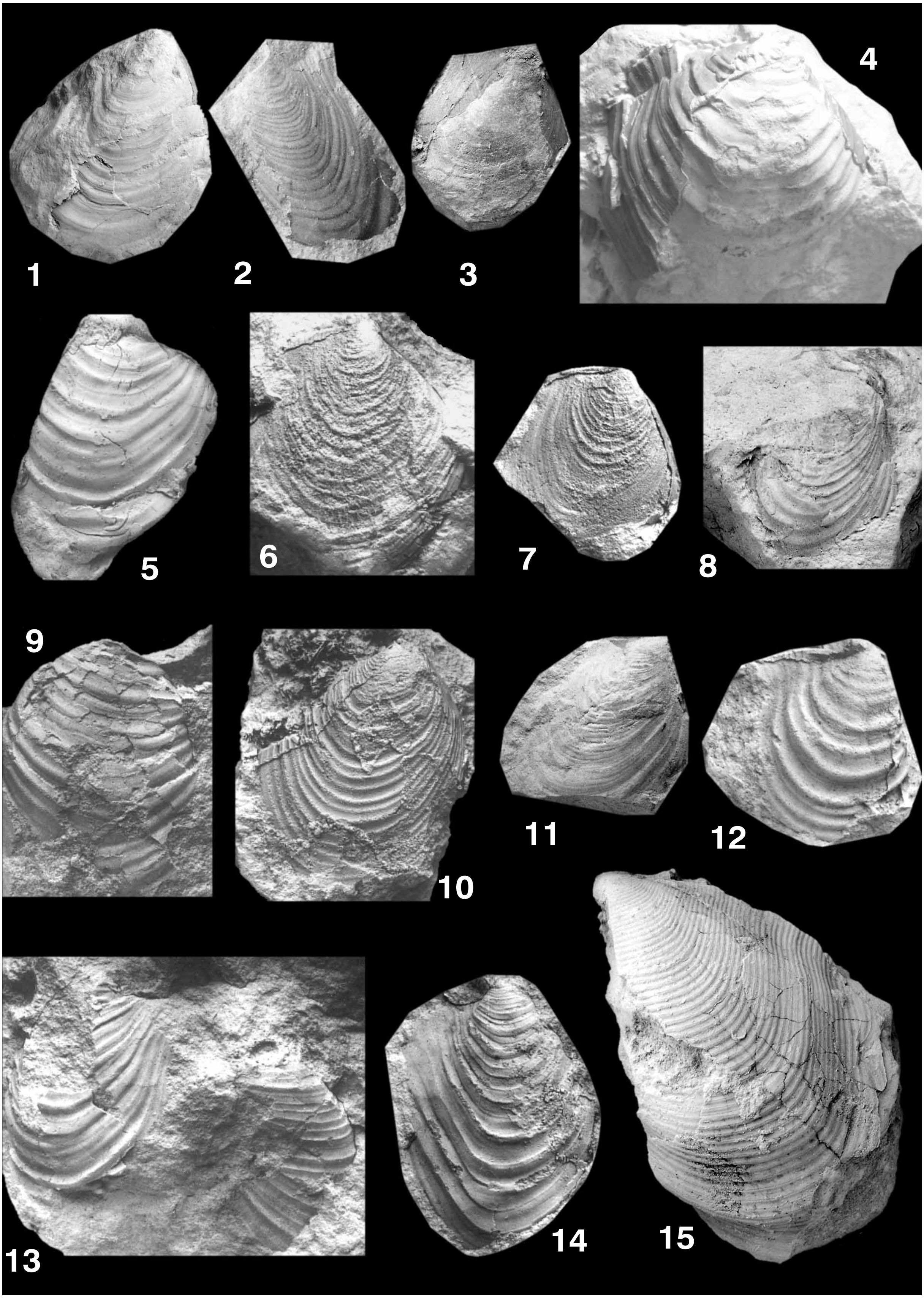
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PLATE 3

Latest Turonian and Early Coniacian inoceramids and *Didymotis* from England

6, 10 – *Cremnoceramus deformis erectus* (MEEK, 1877), lower Lower Coniacian; 1 – BGS MAW4825, Downley secton, *erectus* horizon. 2 – BGS JL5285, Kiplingcotes Station Quarry; 0.4 m above Kiplingcotes Marl 2

1-5, 7-9, 11-14 – *Cremnoceramus waltersdorfensis waltersdorfensis* (ANDERT, 1911); topmost Turonian; 1 – BGS MAW4777, Downley section, 2 – BGS MAW4768, Downley section, 3 – BGS MAW4778, Downley section, 4 – BGS MAW4768, Downley section, 5 -BGS JL5279, Kiplingcotes Station Quarry, 5 cm above Kiplingcotes Marl 2, 7 – BGS MAW4823, Downley section, 8 – BGS MAW4820, Downley section, 9 – BGS MAW4769, Downley section, 11a, b – BGS Zw3063, Dover, East Cliff Road section, 0.7 m above top Navigation Hardground: a – dorsal view to show hinge, b – lateral view, 12 –BGS JL5282, Kiplingcotes Station Quarry, 10 cm above Kiplingcotes Marl 2; 13 – BGS MAW4769, Downley section, 14 – BGS MAW4776, Downley section; the specimen of *Didymotis* is visible in lower right corner of the photograph

All figures are natural size

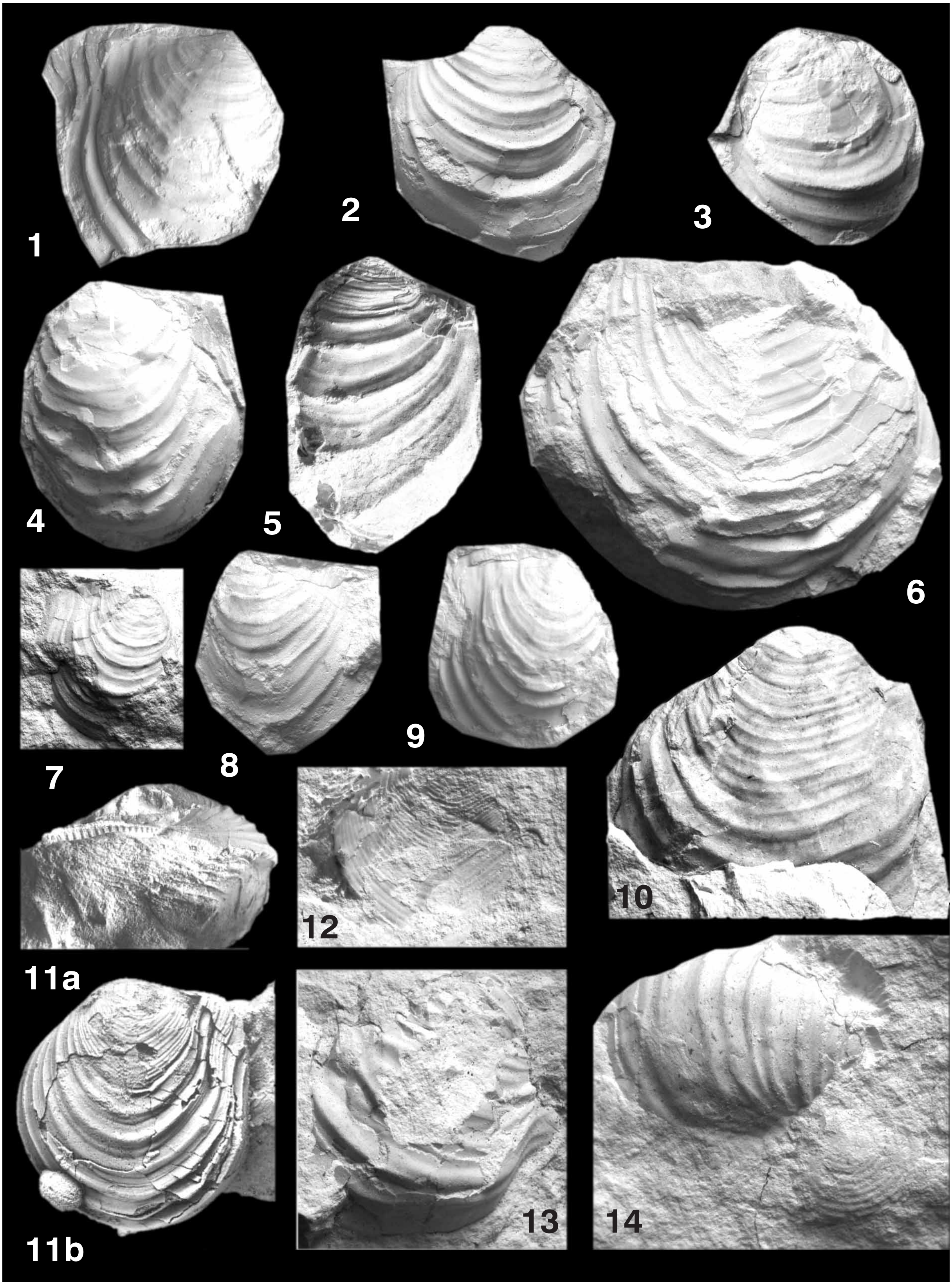
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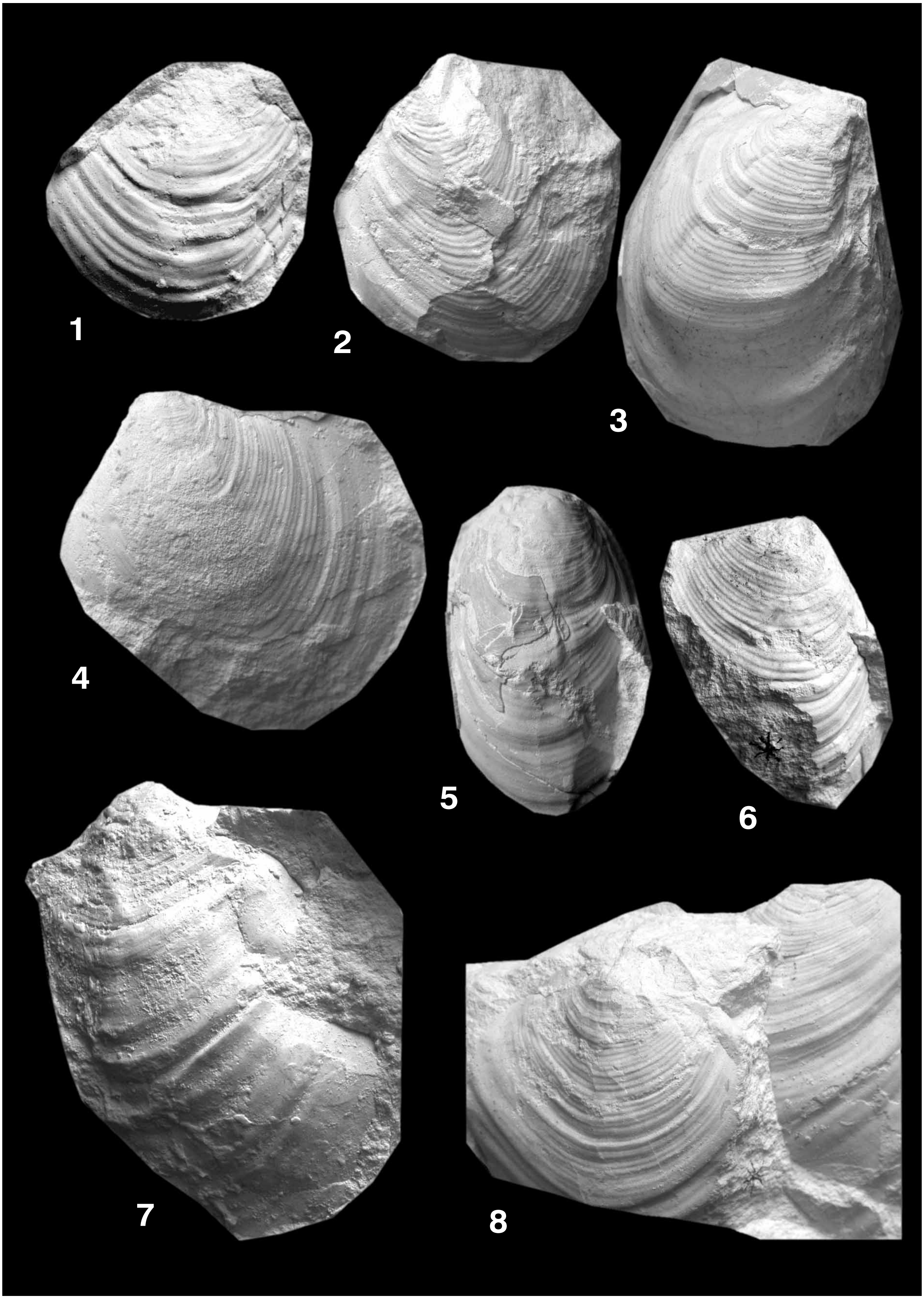
PLATE 4

Cremnoceramus waltersdorfensis hannovrensis (HEINZ, 1932)

1 – BGS MAW4855, **2** – BGS MAW4858, **3** – BGS MAW4845, **4** – BGS MAW4846, **5** – BGS MAW4852, **6** – BGS MAW4828, **7** – BGS MAW4855, **8** – BGS MAW4847; all from Downley section, *hannovrensis* horizon.

All figures are natural size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