Cahiers Univ.Catho.sér.Sci.,n°3,p.127-136,5 tabl.

THE OCCURRENCE OF CALCAREOUS NANNOFOSSILS IN THE TRIASSIC/JURASSIC BOUNDARY INTERVAL

by

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ABSTRACT.

The earliest preserved coccoliths and other calcareous nannofossils are known from the late Triassic of Tethys, where they are presumed to have originated. An almost total nannofloral turnover is believed to have occured at the Triassic/Jurassic boundary, with apparently only one coccolith species surviving into the Lower Jurassic. Subsequent development and diversification of, especially, coccoliths during the early Jurassic established evolutionary patterns for the rest of the Mesozoic. The boundary is thus well marked by calcareous nannofossils but this conclusion is based upon limited data.

INTRODUCTION.

In the last decade a series of papers (Moshkovitz 1982, Jafar 1983, Bown 1985,1987, Posch and Stradner 1987, Janofske 1987) have established beyond doubt the existence of calcareous nannofossils, including coccolithophorids, within sediments of Triassic age. All these studies have been based upon Upper Triassic sections (the majority of Rhaetian age) from the Northern Calcareous Alps of Austria and southern Germany. Identical nannofossils have recently been found by the authors from a Triassic section in western Timor, while ODP Leg 122 off north-west Australia has penetrated a long Triassic marine sequence with very diverse calcareous nannofloras (W.G.Siesser, pers.comm.). For a review of the history of research for pre-Jurassic nannofossils see Jafar (1983).

Calcareous nannofossils from the Lower Jurassic have been documented for some time (e.g.Deflandre 1952, Stradner 1963, Noël 1965, Prins 1969, Barnard and Hay 1974), and the majority of stratigraphic studies in North-West Europe have recorded the appearance and diversification of nannofossils, particularly coccoliths, in the Hettangian and Sinemurian. It is now clear that colonisation from Tethys during the late Triassic-early Jurassic transgression and the formation of epicontinental seas in northern Europe continued during the Lower Jurassic, with Tethys continuing to be a locus of evolutionary development. Morphological diversification was rapid and the evolution of coccolith rim types during the Lower Jurassic established patterns which prevalied for the rest of the Mesozoic (Bown 1987).

This paper aims to synthesise recent information concerning Triassic nannofloras and to examine and evaluate the relationship between the distinctive and mutually exclusive assemblages which are found on either side of the Triassic/Jurassic boundary.

TRIASSIC CALCAREOUS NANNOFOSSILS.

Sections studied.
Authors Research:

(a.) Austria: Weissloferbach (KS) P; Fischerwiese (ZM) P; Kendelbachgraben (KS) P; Pass Lueg (DF) B; Öfenbach (DF) B; Lehenmuhlengraben (DF) B; Grosse Zlambach/Leislingbach (ZM) P; Geissau (KS) P; Eiberg (KS) P; Postchenhohe B;

(b.) Other areas: Picolbach, Italy (SCA) B; Britain B; Canadian Arctic B; Nevada, U.S.A. B; Malaya B; Timor P; Sumatra B;

Moshkovitz (1982) - Austria: Fischerwiese, Kendelbachgraben, Rossmoosgraben (ZM).

Jafar (1983) - Austria: Lahnewiesgraben (KS), Kleiner Zlambachgraben (ZM), Geissau (KS), Pass Lueg, Misurina (SCA).

Posch and Stradner (1987) - Austria: Fischerweise, Potschenpass, Hohe Wand(ZM), Vorder Ampelsbach, Geissau.

Janofske (1987) - Austria: Lahnewiesgraben, Fonsjoch, Weissloferbach, Kleiner Zlambachgraben.

Key: KS = Koessener Schichten ZM = Zlambach Mergel DF = Dachstein Facies SCA = Southern Calcareous Alps P = productive - B = barren.

The great majority of productive Austrian samples described in these studies are from the Koessener Schichten and Zlambach Mergel, which represent diachronous sedimentary sequences deposited in differing facies belts during the Norian and Rhaetian at the northern edge of the Tethyan Ocean; both represent marginal basin environments, the Koessner Schichten being the less open marine of the two. All the studies have produced essentially identical results, with assemblages of abundant calcispheres and conical nannoliths together with subsidiary small coccoliths found consistently in the Rhaetian (*i.e.* Suessi and Marshi ammonite zones). Differences in interpretation have occurred (further confused by the work of Moshkovitz (1982) and Jafar (1983) taking place independently and published within 6 months of each other) and Jafar, in particular, has identified rather dubious calcareous objects along with possible contaminants - he describes 6 coccolith species whereas all other studies report a maximum of three.

Assemblage Components.
(a.) Nannoliths.
Prinsiosphaera triassica JAFAR 1983

Reported in all the publications above and also in earlier papers e.g. Fischer *et al.*(1967); Wiedmann et al.(1979). Jafar used the name *P.triassica* to encompass all the circular shaped forms he observed in the light microscope (LM) and, using same specimen techniques, the scanning electron microscope (SEM). The variation in appearance in the light microscope led Jafar to establish six subspecies together with an additional discrete species, P.geometrica. Five of the subspecies have been recognised in the present work together with *P.geometrica* (see Bown 1987, pl.15, fig.17-24). However, the variations observed in the LM are not easy to distinguish in the SEM where these forms appear as variable spheres, hemispheres and flattened plates with varying degrees of observable organisation in their ultrastructure. Is preservation causing differing LM appearances or are internal ultrastructural variations present, not apparent in the SEM, which represent significant taxonomic variation? The consistent way in which these "morphotypes" are observed tends to favour the latter view. The discrete species P.geometrica shows a far greater degree of structural organisation and this has led Bown (1987) to include it in the genus *Thoracosphaera*, and Janofske (1987) to include it in *Orthopithonella*. Janofske also argues that the subspecies *P.triassica hyalina* is the light microscope image of *P.geometrica* (not illustrated in the LM by Jafar 1983).

At present the only discernable stratigraphical difference between the species and subspecies of *Prinsiosphaera* is the presence of *P.triassica punctata* in the oldest Norian and Carnian samples before other forms are first recorded.

The biological affinities of Prinsiosphaera are unknown. It appears to represent an abundant but relatively short-lived group (Carnian or earlier to top Rhaetian) with no known ancestors or descendants. It has been pointed out that the Jurassic nannofossil *Schizosphaerella punctulata* DEFLANDRE and DANGEARD shares a similar morphology and size range and was equally abundant particularly in the equivalent area of western Tethys. However, in detail the ultrastructures are significantly different and no link can be proven at present (Bown 1987, p.1O1). The species *geometrica*, in contrast, has a distinctive morphology which appears to be characteristic of calcareous dinoflagellates.

Eoconusphaera zlambachensis (MOSHKOVITZ 1982)Bown and Cooper 1988. This species has been reported in all the above publications; *E.tollmanniae* JAFAR 1983 is a junior synonym. The possible evolutionary relationship between *E.zlambachensis* and the Lower Jurassic *Mitrolithus jansae* (WIEGAND) Bown and Young is discussed by Bown and Cooper (1988). Sections consisting of favourable environmental and sediment types crossing the Triassic/Jurassic boundary are needed to resolve this question and other problems of relationships between Triassic and Jurassic assemblages, as there appears to be very little overlap between them. The morphological similitary between

E.zlambachensis (Norian-Rhaetian) and *M.jansae* (Sinemurian-Toarcian) is, however, striking and some relationship is predicted. In the Grosse Zlambach section a number of samples contain Eoconusphaera which appear very similar to *M.jansae* (samples 9774-9779), however, this is thought to be due to poor preservation.

Stratigraphically, *E.zlambachensis* has been found in Norian and Rhaetian samples. At Weissloferbach it first occurs at the base of the Koessener Facies (sample A22),a number of samples above the appearance of *P.triassica* in the Swabische Facies.

(b.) Coccoliths.

The commonest and most consistently occurring Triassic coccolith is *Crucirhabdus minutus* JAFAR. It is an extremely tiny form (around 2um) with a distinctive LM appearance, while in the SEM it is seen to possess a protolith rim type with a central area spanned by a cross which supports a spine (see Bown 1985,1987). It is likely that *C.minutus* gave rise to the larger *Crucirhabdus primulus* PRINS ex ROOD et al. which has also bee recorded in the Rhaetian. *C.primulus* is the only calcareous nannofossil which has been recorded in the Triassic and across the boundary in the Lower Jurassic. Thus, *C.minutus* represents an important ancestral form which gave rise to the major Jurassic lineage represented by the families *Parhabdolithaceae* and *Stephanolithiaceae.*

C.minutus has been found in the lowest sample in the Grosse Zlambach section (sample 9705) of Norian age.

Archaeozygodiscus koessenensis BOWN has been reported by Bown (1987 and this paper) from high samples in the Rhaetian. See Bown (1987, p.13,87) for description and discussion of this coccolith.

Other reported coccoliths include:

Crucirhabdus curvatus JAFAR 1983 - considered a synonym of *C.minutus*.

Vekshinella thiersteinii JAFAR 1983 - not recorded by other authors.

Ellipsochiastus primitus JAFAR 1983, and possible contaminants.

Paleopontosphaera repleta - reported by Jafar (1983) but not figured. This placolith form of coccolith is not recorded in the Lower Jurassic until the Upper Sinemurian, thus contamination is again suspected.

Cleosphaera tripartita JANOFSKE 1987 - junior synonym of *C.minutus*.

EARLIEST JURASSIC CALCAREOUS NANNOFOSSILS.

The earliest Jurassic assemblages from North-West Europe have been recorded by:

a) Barnard and Hay (1974) - pre-Planorbis Zone assemblage consisting of *Annulithus arkellii* (considered to be an inorganic artifact) and *Tubirhabdus patulus* PRINS ex ROOD et al.
b) Hamilton in Lord *et al.*(1982) - Rhaetian to Hettangian (Angulata Zone) samples yielded *Annulithus arkellii* (see comment above) and *Schizosphaerella punctulata*.
c) Bown (1987) - Hettangian liasicus Zone samples yielded *S.punctulata*, Angulata Zone samples yielded additionally *C.primulus* and *Parhabdolithus liasicus* DEFLANDRE.

By the first zone of the Sinemurian stage a relatively diverse assemblage had become established, including *S.punctulata*, *C.primulus*, *P.liasicus*, *Parhabdolithus marthae* DEFLANDRE, Mitrolithus elegans DEFLANDRE and Tubirhabdus patulus. With the exception of *S.punctulata* (whose affinities are uncertain), the other forms are coccoliths with discolith morphologies, some with inclined rim elements and some with vertical rim elements. Both these rim types are known to be present in Rhaetian coccoliths i.e. *C.minutus* and *A.koessenensis*, and thus their ancestry appears relatively certain.

Recent sampling of the Eiberg Cement Quarry section in western Austria allowed us to analyse a sample suite which spanned the Triassic/Jurassic boundary. The section consists of steeply dipping Koessener Schichten overlain by Lower Jurassic sediments, predominantly limestones with thin intercalations of marl. Between these two units is the Grenzemergel horizon which marks the boundary and which shows evidence of tectonic movement within it (i.e.scaly clay). The Koessener Schichten samples yielded abundant assemblages of *Prinsiophaera triassica*, *E.zlambachensis* and rare *C.minutus*. Sample 9766 taken within the Grenzemergel similarily yielded *P.triassica* and *E.zlambachensis*. The first sample above the Grenzemergel, however, contained an assemblage consisting of *Crucirhabdus primulus* and *S. punctulata*, with no typically Rhaetian forms present. Higher in the section samples yielded assemblages consisting of *P.liasicus*, *M.elegans*, *Crepidolithus pliensbachensis* CRUX, *C.primulus*, *S.punctulata* and *Crepidolithus* sp.1 BOWN. The *M.elegans* has an extended spine and together with the form *Crepidolithus* sp.1 has also been found in earliest Jurassic sediments from Timor. The similarity between Austrian and Timorese faunas and facies has been well documented (KRISTAN-TOLLMANN 1987) and the nannofloras also reflect this pattern.

Despite a number of problems with the Eiberg Quarry section (i.e. there are very few marly layers on the Jurassic side of the boundary, and the Grenzemergel itself was obviously tectonically disturbed and yielded only one productive sample) the results demonstrate that calcareous nannofossils have great biostratigraphical value, both in indicating Upper Triassic sediments and for marking the Triassic/Jurassic boundary.

The Grenzemergel in the classic Kendelbachgraben section was intensively sampled but was barren of nannofossils throughout; further boundary sections need to be studied to confirm the Eiberg data. Samples from both Triassic and Jurassic clays in New York Canyon, Nevada were also barren.

CALCAREOUS NANNOFLORAS AND THE TRIASSIC/JURASSIC BOUNDARY.

The oldest coccoliths and calcareous nannofossils (other calcareous organic forms of roughly similar size) so far recorded are of Carnian age and there is debate as to the nature of their first appearance: a genuine evolutionary appearance or a preservation event due to commencement of biogenic mineralisation. The early history of these fossils was in Tethys and it is to that paleobiogeographical entity that we must look for the oldest forms and for evidence as to the nature of their appearance. From the foregoing text it is clear that most records are from the western end of Tethys, from its northern margin, a relatively restricted oceanographic feature. In contrast, the great expanse of Triassic Tethyan Ocean to the east has only recently yielded information about early nannofloras but promises to reveal older and more diverse assemblages than previously known. The significance of this information lies in the fact that coccoliths dominate the modern phytoplankton and their appearance was an event of great importance for oceanic biological and chemical systems.

In the Triassic (Norian/Rhaetian) abundant calcareous nannofossil assemblages occur which are characteristically composed of *Prinsiosphaera triassica*, *Eoconusphaera zlambachensis* and *Crucirhabdus minutus*; recent data from Austria and Timor indicate the large geographical distribution of these species. This assemblage became extinct at or very close to the Triassic/Jurassic boundary with only *Crucirhabdus primulus* surviving into the Jurassic. The earliest Jurassic nannofloras contain the coccolith *C.primulus* and the nannolith *Schizosphaerella punctulata*, followed by rapid diversification of the coccolithophorid group.

The floral turnover at the Triassic/Jurassic boundary was almost total, however, it does not bear close comparison with the change in nannofloras around the Cretaceous-Tertiary boundary which was also dramatic. In the Triassic, nannofossil diversity was low and our knowledge of the floral patterns elsewhere does not yet allow us to judge how critical the extinctions were. In contrast, the Cretaceous-tertiary boundary extinctions follow a period of extraordinay diversity and abundance of coccoliths and other calcareous nannofossils, and although extinctions began well before the end of the Cretaceous (e.g. nannoconids in the Campanian) the changes around the boundary were fundamental for the composition of Cenozoic assemblages.

ACKNOWLEDGEMENTS.

We are indebted to Dr.L.Krystyn (Universitat Wien) and Dr.H.Löbbitzer (Geologische Bundesanstalt, Wien) for guidance in the field. The work is supported by the Leverhulme Trust. Field collecting in Nevada (ARL) was supported by the Geological Survey of Canada and the Royal Society, with field guidance kindly provided by Dr.J.Guex (Lausanne) and Dr.D.Taylor (Portland).

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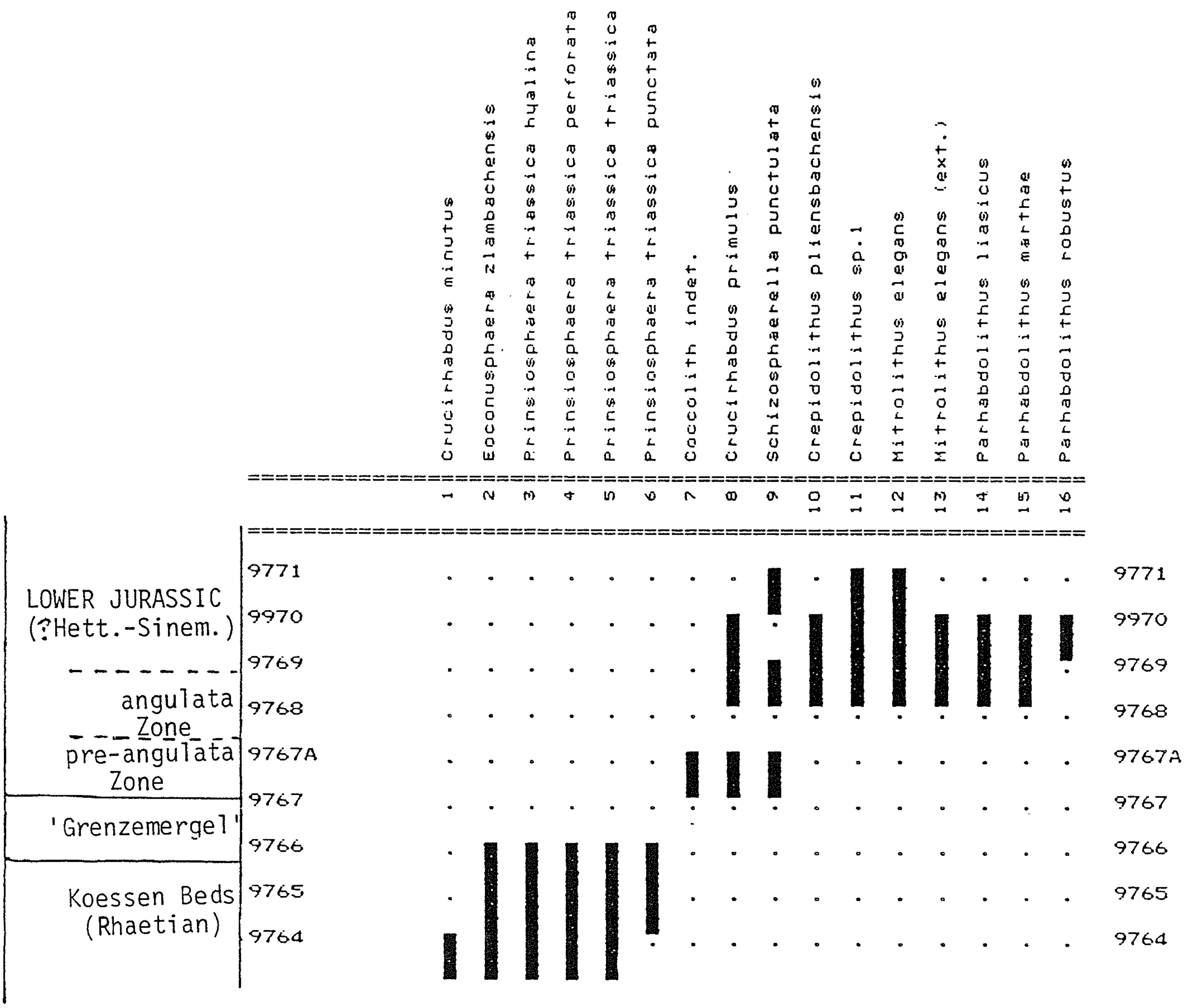
APPENDIX.

Distribution of calcareous nannofossils in Austrian sections; 1: Eiberg Quarry; 2: Kendelbachgraben; 3: Weissloferbach; 4: Grosse Zlambach/Leislingbach; 5: Fischerwiese; 6: Geissau.

I. CALCAREOUS NANNOFOSSILS - EIBERG, AUSTRIA

RANGE CHART OF PRESENCE/ABSENCE BY LOWEST APPEARANCE



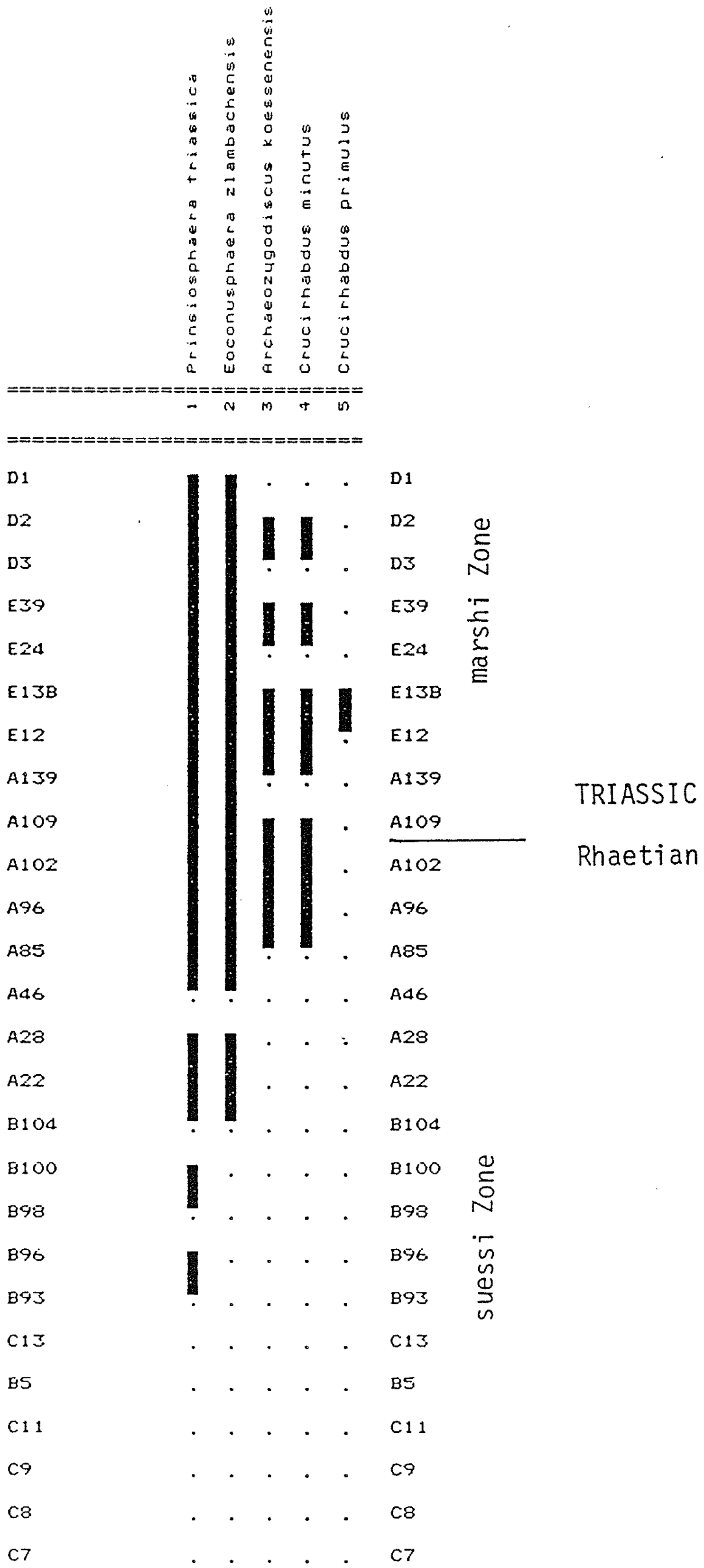
2. CALCAREOUS NANNOFOSSILS - KENDELBACHGRABEN, AUSTRIA

RANGE CHART OF PRESENCE/ABSENCE BY LOWEST APPEARANCE

Sample	1 Prinsiosphaera triassica	Sample	Unit	Age
9723A	.	9723A	Kendelbach Beds	LOWER JURASSIC
9723	.	9723		
9722	.	9722		
9721	.	9721		
9720	.	9720		
9719	.	9719	'Grenzemergel'	
9718	.	9718		
9717	.	9717		
9716	.	9716		
K37	.	K37		
K25	.	K25	Koessen Beds	TRIASSIC
K23	.	K23		
K21	.	K21		
K19	.	K19		
K17	.	K17		
K11	.	K11		
K13	.	K13		
K15	.	K15		
K26	.	K26		
K28	.	K28		
K29	.	K29		
K30	.	K30		
K31	.	K31		
K32	▮	K32		
K34	.	K34		
K36	▮	K36		

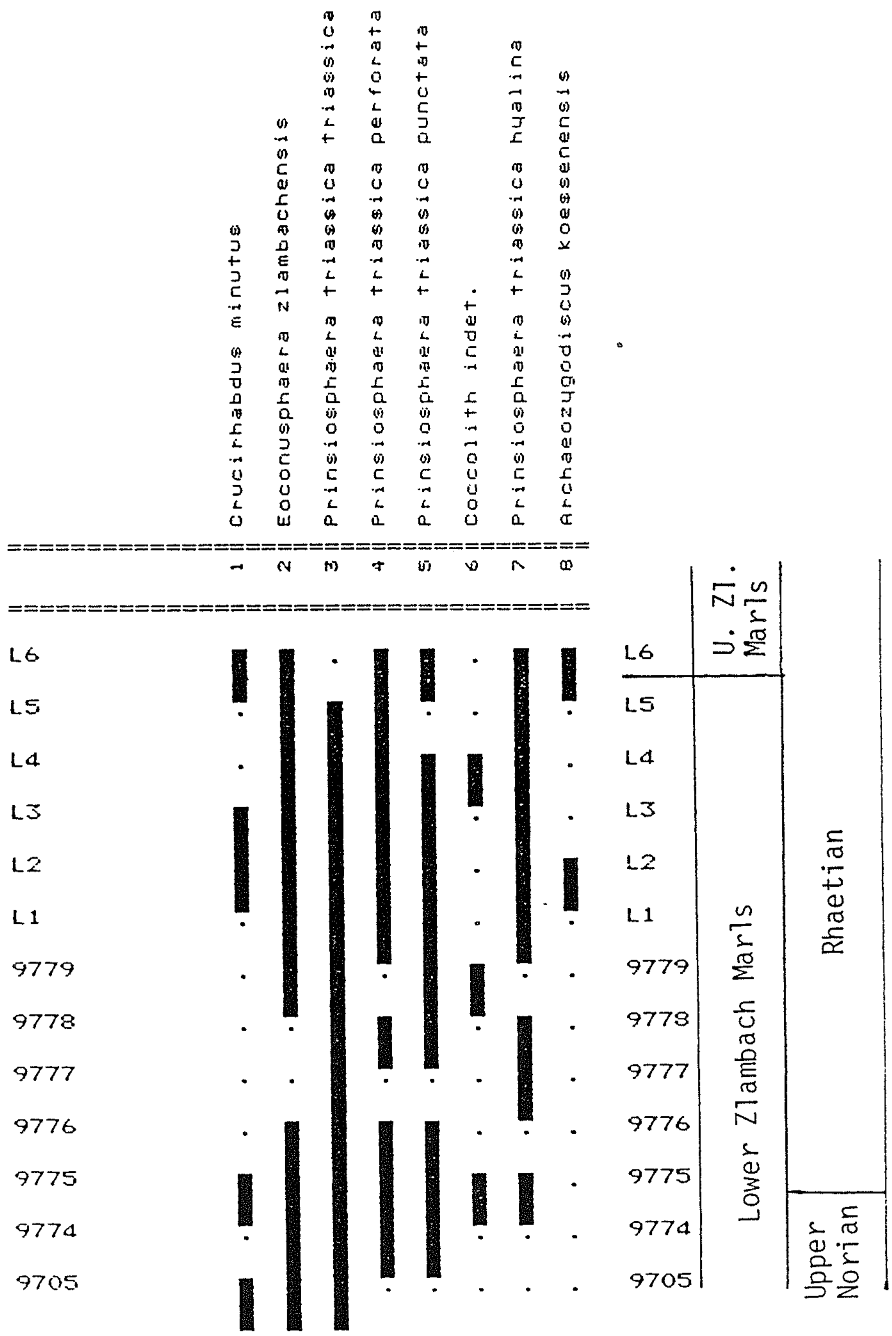
3. CALCAREOUS NANNOFOSSILS - WEISSLOFERBACH, AUSTRIA

RANGE CHART OF PRESENCE/ABSENCE BY LOWEST APPEARANCE



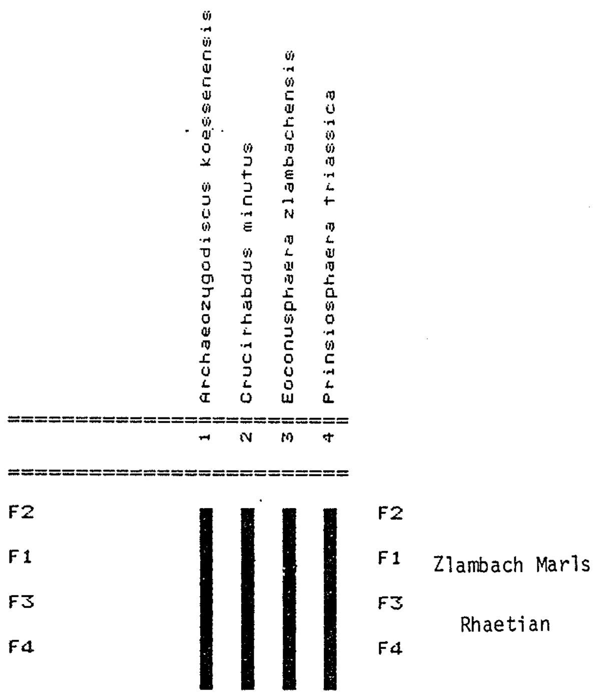
4. CALCAREOUS NANNOFOSSILS - GROSSE ZLAMBACH/LEISLINGBACH

RANGE CHART OF PRESENCE/ABSENCE BY LOWEST APPEARANCE



5. CALCAREOUS NANNOFOSSILS - FISCHERWIESE, AUSTRIA

RANGE CHART OF PRESENCE/ABSENCE BY LOWEST APPEARANCE



6. CALCAREOUS NANNOFOSSILS - GEISSAU, AUSTRIA

RANGE CHART OF PRESENCE/ABSENCE BY LOWEST APPEARANCE