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To avoid any bias towards preselected morphologic units all encountered morphotypes were included without any attempt to group them. Morphotypes appearing during the stratigraphic search were examined by means of the SEM and included, which often required reexamination of a number of samples.

Step 2: Stratigraphic search. – For the stratigraphic search at least two densely strewn Plummer cells (2×4.5 cm, subdivided into 5×12 squares) were searched systematically through (2–5 hours) by means of a stereomicroscope at $100\times$ magnification. Encountered morphotypes were always compared to posted SEM reference pictures to avoid a subjective shift of morphologic concepts. The nearly 300 morphotypes initially included (pob 1–300) represent an estimate of 80–90% of the total assemblages for the Callovian–Tithonian interval (Zones A1–C) but only a small percentage of the earliest (Zone A0) and the Neocomian assemblages. A presence is defined as the occurrence of at least one securely identified specimen. Doubted identifications are treated as absences.

Step 3: Compilation for U.A. treatment. – A selection of 110 morphotypes was prepared for computer treatment owing to the limitations of the U.A. program. Excluded were: very rare, very long ranging and morphologically poorly defined morphotypes. In some cases, the data for two morphotypes were merged for treatment as one species. The data included in the database as presented herein (and as used by U.A. treatment) were compiled from the original sample data and consist in the lowest and highest occurrence of each morphotype at each locality, hence do not reflect the consistency of occurrence within the local range.

2.4 *Definition of zones*

The biochronologic interpretation of the U.A. resulting in the definition of biochrono-zones is based on the principle of lateral reproducibility (GUEX 1979). The values of reproducibility given in Figure 1 are, of course, only guidelines for establishing biochrono-zones. The criteria for the proposed zonal limits are discussed in BAUMGARTNER (1984) and will not be repeated here.

It should be noted that each zone is defined by one or more U.A. each of which is defined by the totality of its characteristic species or species pairs. Hence a given sample can be assigned to a zone if one or more of its U.A. can be identified by means of one or more characteristic species or species pairs. In practice, U.A. and the defined zones work exactly like concurrent range zones.

The advantage of this type of zonation is obvious: The more species included in the zonation the better is the definition of each zone. A zonal unit defined by many species pairs has more chances to be recognized in a poorly preserved sample than a zone based on the presence of one or two “marker” species.

3. Comparison to other zonations and chronostratigraphic calibration

3.1 *Comparison to earlier zonations*

3.1.1 Introduction

The comparison of the present zonation with earlier ones depends on a number of factors that need to be mentioned.

1. The correlation is strictly based on species that are represented in the range charts of both zonations.
2. The specific concept (morphologic delimitations) of these species has to be the same in both zonations, as far as this is defined in illustrations, synonymy and descriptions.
3. A zonation based on maximum ranges compiled from cooccurrences in a large number of samples is likely to demonstrate partial or total overlap of earlier zones established on the basis of local or incomplete ranges. It should be noted that this is not the effect of virtual associations produced by the computer program. For most of the cooccurrences which result in overlap of earlier zones there is direct sample evidence documented in the database (appendix). The correlations discussed below are graphically presented in Figure 2.

3.1.2 Correlation with BAUMGARTNER et al. (1980)

The zonation presented in BAUMGARTNER et al. (1980) was based on a limited database, a small number of species and some rather lumping specific concepts. The data for the present zonation are completely revised on the basis of more accurately defined specific delimitations and both the number of samples and included species have increased by a factor of about three. As a consequence, some earlier ranges prove to be incomplete, others tend to be shorter owing to narrower specific definitions. A number of new U.A. arise from the inclusion of much more species.

A chronostratigraphic comparison of the two zonations was given in BAUMGARTNER (1983, Fig. 1). However, the mentioned figure does not give the actual correlation of old and new U.A. Instead, it compares the tentative time range of the old U.A. (as suggested in BAUMGARTNER et al. 1980, Table 3a) with the time range of the present U.A. For instance that new U.A. 9 (Zone C1) covers part of old Zone B and part of old Zone C is a result of a new calibration of the limit B/C and does not represent the correlation of the faunal content of the U.A. (it is theoretically impossible that a new U.A. recovers parts of old U.A.).

The fact that old Zone A is now part of new Zone B, etc. may equally be misleading. However, since Figure 2 illustrates that overlaps are inevitable it is hoped that the present definitions only will be used for subsequent radiolarian work.

- *Old A1* is correlated to new U.A. 3–5 on the basis of the present range of *Stylocapsa oblongula*.
- *Old A2* is correlative of new U.A. 4–6, based on the cooccurrence of *Mirifusus mediodilatatus* with *Guexella nudata* and *Napora pyramidalis*. The partial overlap of old A1 and A2 is the result of the now established cooccurrence of *M. mediodilatatus* s.l. and *Stylocapsa oblongula* in new U.A. 4–5 (see also KOCHER 1981).
- *Old A3* can be correlated with new U.A. 6–8, if the cooccurrence of *Emiluvia pessagnoi* with *Ristola procera* is considered, it is new U.A. 7–8, if it is with *Emiluvia orea*.
- *Old B4–5* is correlative with new U.A. 8 or 7–8 on the basis of *Podocapsa amphitreptera*, defining the base of old B4 now in new U.A. 8, *Formanella hipposidericus*, defining the base of old B5, now in new U.A. 7, and all tops of old B4 and B5 now in new U.A. 8.

- *Old B6*, defined by the cooccurrence of *Sethocapsa cetia* with *Triactoma cornuta* coincides with new U.A. 9. Owing to a more restricted definition of *S. cetia* it is no longer cooccurring with *Mirifusus guadalupensis*.
- *Old C7–9* can be correlated with new U.A. 9–10, since the base of old C7, *Acaeniotyle umbilicata* and the base of old C8, *Acanthocircus dicranacanthos* are both in new U.A. 9 and all tops of old C7–9 are in new U.A. 10. The base of old C9 was defined by *Obesacapsula rotunda* which now first appears in new U.A. 11 (owing to narrower specific definition), thus old C9 = old C8.
- *Old D10*, defined by the cooccurrence of *Napora losensis*, *Emiluvia pessagnoi* and *Podocapsa amphitreptera* with *Ristola cretacea*, *Ditrabs sansalvatorensis* and *Parvicingula cosmoconica* equals new U.A. 11.
- *Old D11*, defined by the cooccurrence of *Alievum helenae* with *Ristola cretacea* is correlative of new U.A. 11–13, as *A. helenae* is now known to cooccur also with *P. amphitreptera* (e.g. loc. 24 sample 24: POB 1330, see database, appendix).
- *Old D12* equals new U.A. 14, defined by the base of *Cecrops septemporatus*.

3.1.3 Correlation with KOCHER (1981)

The zonation presented by KOCHER (1981) is based on Unitary Associations which were calculated by means of a first program by DAVAUD (in DAVAUD & GUEX 1978) which had the principal drawback of eliminating all those species which left indetermi-

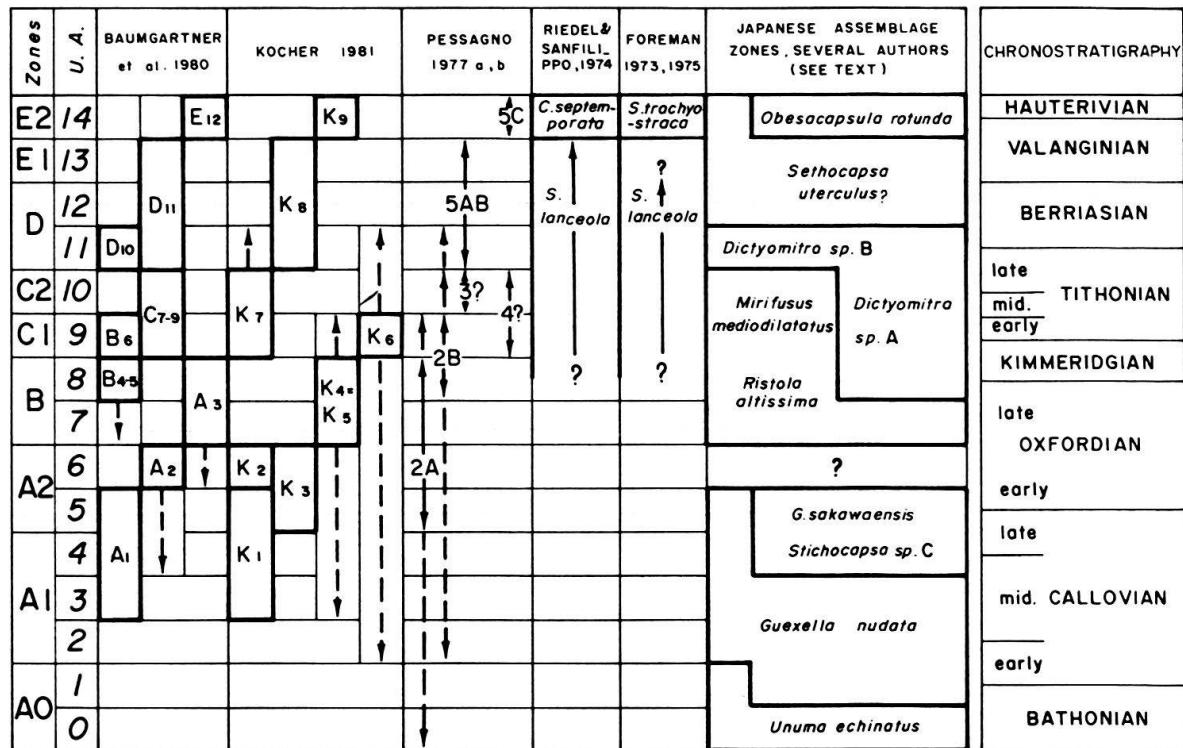


Fig. 2. Comparison of the Unitary Associations 0–14 with earlier zonations, based on species occurring in both zonations. The thick-lined squares and continuous arrows represent a minimal correlation based on defining species with a minimal range in terms of U.A. Dashed arrows gives the maximal correlation based on species which have a maximal coverage of U.A. For details see text.

nate stratigraphic relationships in the species/species matrix. In the case of KOCHER's data this was about a third of all species, which were manually reintroduced by KOCHER based on observed cooccurrences. Despite the problems arising from this procedure, KOCHER's zonation easily compares with the succession of the present U.A., if only the bulk of the defining species pairs is considered (heavy lined rectangles in figure 2). Nevertheless, there are "extreme" species pairs which produce much overlap (arrows in Figure 2, see below). In the following KOCHER's U.A. are designated with the letter "K".

- *K1*, defined by the cooccurrence of *Stylocapsa oblongula* with many other species corresponds to U.A. 3–5. Some species zoned by KOCHER as *K1* are now zoned as U.A. 1–2, based on the presence of other species not included with KOCHER's zonation.
- *K2*, defined by the cooccurrence of *Hagiastrid* sp. A with *Mirifusus chenodes* equals U.A. 6.
- *K3*, defined by the cooccurrence of *Napora pyramidalis*, *Gorgansium pulchrum* and *Guexella nudata* with *Tritrabs exotica*, corresponds to U.A. 5–6.
- *K4* is the same U.A. as *K5*, since no cooccurrences other than those in *K5* are present. The bulk of defining species pairs have their cooccurrence in U.A. 7–8 of the present zonation. Some of the pairs defining *K4–5* are no longer cooccurring in the present zonation: *Higumastra imbricata*, *Monotrabs plenoides* and *Theocapsomma cordis* are not cooccurring with *Sethocapsa cetia* and *Podocapsa amphitropa*. Extreme pairs of *K4–5* include *Triactoma blakei* cooccurring with *Paronaella mulleri* and *Tritrabs hayi* which span U.A. 2–9 of the present zonation.
- *K6* is defined by cooccurrences of *Acanthocircus* with many species, the bulk of which occur in U.A. 9 of the present zonation. However, the occurrence of *Spongocapsula palmerae* with *Triactoma tithonianum* spans U.A. 2–11! And on the other hand, *Tritrabs casmiliaensis* and *Bernoullius dicera* do not cooccur with *A. dicrananthos*.
- *K7* is defined by cooccurrences of *Acaeniotyle umbilicata* and *Triactoma echiodes* with many other species, the bulk of these cooccurrences are found in U.A. 9–10 of the present zonation. The extreme correlation extends to U.A. 11 because of *Emiluvia sedecimporata salensis* which has its top in *K7*. It should be noted that *Mirifusus guadalupensis* which reaches up to *K7*, in the present zonation only reaches up to U.A. 8 and thus does not cooccur with the young species of *K6–7*.
- *K8* is equal to D10–11 and *K9* is equal to E12 of BAUMGARTNER et al. (1980), they thus correlate to U.A. 11–13 and U.A. 14 respectively (see Fig. 2).

3.1.3 Correlation with PESSAGNO (1977a, b)

The correlation of this type of biostratigraphy with the range charts presented by PESSAGNO (1977a, b) is very difficult owing to extreme discrepancies in first and final appearances of the species used for definition, as discussed in BAUMGARTNER et al. (1980, p. 44). The purpose of the few following remarks is to explain the ranges given in Figure 2. Only species which occur in both zonations with a similar delimitation are mentioned.

PESSAGNO's Zones 0 and 1 do not appear in Figure 2, since they are based on absences only (further detail given in BAUMGARTNER et al. 1980). The base of PESSAGNO's Zone 2 (and Subzone 2A) is defined by the first occurrence of *Emiluvia hopsoni*, *Paronaella bandyi*, *Perispyridium ordinarium*, *Ristola procera*, *Mirifusus guadalupensis* and other species which have their base in the present zonation in U.A. 0-5. The top of Subzone 2A is defined by the final appearance of *M. guadalupensis* and *Angulobracchia purisimaensis* which have their top in U.A. 8-9 of the present zonation.

The base of Subzone 2B is defined by the first appearance of *Ristola altissima* which has its base in U.A. 2 and *Mirifusus mediolatatus baileyi* (not included in database) which may have its base in U.A. 8. The top of Subzone 2B (and Zone 2) is defined by the final appearance of *Emiluvia hopsoni*, *Perispyridium ordinarium* and *Hsuum maxwelli* and other species which have their highest appearance in U.A. 9-11.

Zone 3 of PESSAGNO (1977a) is an interval zone which is defined as between the final appearances of the species which mark the top of Zone 2 and the final appearances of *Triactoma blakei* and *Eucyrtidiellum ptyctum* which both terminate in U.A. 10. Thus Zone 3 may either not exist or be at best located in U.A. 10.

The base of Zone 4 of PESSAGNO (1977a) is defined by the first appearance of *Sethocapsa cetia* based in U.A. 9, though with a different specific delimitation. The top is given as the final occurrence of *Ristola altissima* which has its top in U.A. 10 and *R. procera* which has its top in U.A. 8. Thus Zone 4 certainly overlaps with Zone 3 and part of Subzone 2B. It should be noted that Zones 3 and 4 are superposed on the basis of cooccurring *Buchia* only. There is no lithostratigraphic control of this superposition.

Zone 5A-B of PESSAGNO (1977b) can be reasonably well correlated to U.A. 11-13 on the basis of the lowest occurrence of *Obesacapsula rotunda* and the base of *Cecrops septemporatus* which forms the base of Zone 5C, which equals U.A. 14.

3.1.4. Correlation with RIEDEL & SANFILIPPO (1974) and FOREMAN (1973, 1975)

The correlation with these earlier zonations was discussed in BAUMGARTNER et al. 1980 and is given in Figure 2.

3.1.5 Correlation with the Japanese assemblage zones

Numerous Japanese workers have made a fantastic effort in the last few years to unravel the complex Japanese geology by means of radiolarian biostratigraphy (summary e.g. in YAO 1983). The volume edited by NAKASEKO (1982) gives part of the wealth of new data and at the same time documents the striking similarity of Tethyan and Japanese radiolarian morphotypes. A framework of assemblage-zones has been developed, in which rather coarse biostratigraphic units, each defined by a number of characteristic species, are superposed on the basis of stratigraphic sequences and radiolarian faunal content. This concept lends itself for comparison with the present zonation based on U.A.

It appears, however, that the studied sequences often have a complex anatomy due to resedimentation (olistostromes) and tectonism (YAO 1984). Hence, it cannot be excluded that the present scheme of assemblage-zones includes some gaps which could reflect times of nondeposition and/or tectonism. Further work, especially a U.A. treatment

of Japanese data together with the present database is required to elucidate this problem.

The *Unuma echinatus* Assemblage-zone (YAO et al. 1980) has been amply described by several Japanese authors: YAO (1972, 1979, 1983, 1984), ICHIKAWA & YAO (1976), YAO & MATSUOKA (1981), YAO et al. (1982). It is characterized by *Unuma echinatus* and several other species not included in the present zonation. This assemblage is clearly represented by U.A. 0 but may also (at least in part) be represented by U.A.1, and thus partly overlap with the *Guexella nudata* Assemblage-zone since *Unuma echinatus* and *Guexella nudata* are cooccurring in U.A. 1.

The *Guexella nudata* Assemblage-zone was described by MATSUOKA (1981), YAO & MATSUOKA (1981), MATSUOKA (1982), YAO et al. (1982), and YAO (1983, 1984). A characteristic species is *Stylocapsa oblongula* and some other species included in the present zonation have their base in this assemblage-zone: *Guexella nudata*, *Ristola altissima* and *Eucyrtidiellum ptyctum*. Based on these species, this assemblage-zone may be correlated with U.A. 1-5 and thus, in the present zonation seems to overlap with the *Gongylothorax sakawaensis*-*Stichocapsa* sp. C Assemblage-zone.

The *Gongylothorax sakawaensis*-*Stichocapsa* sp. C Assemblage-zone as defined by YAO et al. (1982) can be correlated on the basis of the top of *Tricolocapsa plicarum* and *Mirifusus fragilis* and of the base of *Mirifusus mediodilatatus* s.l. in that zone to U.A. 4-5 of the present zonation. However, more species have to be examined to firmly establish this correlation. The *Tricolocapsa* sp. 0 Assemblage-zone cannot be recognized on the basis of the presently included species.

The *Mirifusus mediodilatata*-*Ristola altissima* Assemblage-zone as introduced by NAKASEKO et al. (1979) and redefined by NAKASEKO & NISHIMURA (1981) includes, besides the defining species which in the present zonation range farther down, *Archaeodictyomitria apiara*, which allows a correlation to U.A. 7-10. The *Mirifusus baileyi* Assemblage-zone introduced by MIZUTANI (1981) and described also by ADACHI (1982) probably corresponds also to this interval.

The *Dictyomitria* sp. B-*Dictyomitria* sp. A Assemblage-zone as defined in YAO et al. (1982) and YAO (1983, 1984) includes *Podocapsa amphitreptera* and thus may be correlated with U.A. 8-11. However it would be desirable to have more common species for comparison.

The *Obesacapsula rotunda* Assemblage-zone was introduced by NAKASEKO et al. (1979) and redefined by NAKASEKO & NISHIMURA (1981). It includes *Cecrops septemporus* and is thus correlative with U.A. 14. The *Sethocapsa uterculus* Assemblage-zone as defined by YAO (1984) is probably also correlative with U.A. 14 as it includes *Sethocapsa uterculus*. However, many species defining this latter assemblage zone range from U.A. 11-14 in the present zonation: *Obesacapsula rotunda*, *Alievum helenae*, *Pseudodictyomitria carpatica* and *Xitus* sp. (cf. *X. spicularius*). It may thus be possible that *Sethocapsa uterculus* has a lower range in Japanese localities and hence the *S. uterculus* Assemblage-zone would be an equivalent of U.A. 11-14.

3.2 Chronostratigraphic calibration and distribution of Unitary Associations

Introduction

It is well true that the first step in working out a fossil zonation is to obtain the relative succession of the used taxa and we have followed this rule. However, in order

to date rocks a chronostratigraphic calibration is essential. While it is believed that the present zonation has reached a certain degree of stability not affected by future inclusion of more localities and more species, it is obvious that the correlation to other fossil zonations, magnetostratigraphy and ultimately to chronostratigraphy needs much further work and the solution presented here is preliminary (Fig. 2, 3, Pl. 12).

A primary problem with radiolarians is their general occurrence in siliceous lithologies usually devoid of ammonites which would allow to tie radiolarian zones directly to Jurassic ammonite zones and thus to stages. It is well known and logic, considering dissolution facies and diagenesis, that radiolarians and aragonitic macrofossils like ammonites are hard to be found together. Radiolarians tend to calcify in the presence of abundant lime and thus lose much of their specific characters, whereas ammonites almost never are found in silica-rich sediments, because these are, as we believe, certainly deposited below the ACD and probably near or below the CCD. Rare and invaluable exceptions have been found in the Subbetic and in the Lombardy Basin, where single ammonites or masses of ammonite-bearing limestones were gravitationally displaced into deeper basins hosting silica-rich lithologies (see below). An other possible solution is to search for basinal sequences including very detrital calcareous and partly organic-rich lithologies in which both ammonites and radiolarians have a preservation potential (Lower–Middle Jurassic of Oregon see PESSAGNO & BLOME 1980 and PESSAGNO & WHALEN 1982, and loc. 38 herein). The third and much less reliable way is to tie radiolarian zones to zonations of other microfossils coexisting with radiolarians: calpionellids, calcareous nannofossils, dinoflagellates. Owing to lack of better criteria much of the present calibration is based on this indirect correlation.

U.A. 0–1 (Zone A0) have been found in Tethyan and Japanese basinal sequences but have not been directly dated. At DSDP Site 534A (loc. 30) it becomes clear that they must be of pre-middle Callovian age. In the Sierra de Ricote (Subbetic, loc. 45) U.A. 2 was found less than 20 m above *Cadomites* sp. (cf. *C. daubenyi*) (Bathonian, see SEYFRIED 1978) in a basinal cherty limestone sequence. More samples from this section are in preparation. On the other hand in BAUMGARTNER et al. (1980) we have, following KÄLIN et al. (1979), used the argument that the uppermost Marne a Posidonia (which in basinal sections show U.A. 0–1) are of Callovian age, to date the earliest radiolarite deposition as late Callovian. It is now evident that the onset of radiolarite deposition is very diachronous and essentially dependent of the local subsidence history (see Fig. 3 and conclusions). Southeastern Tuscany, where KÄLIN et al. (1979) suggested much of the Callovian to be represented by the Marne a Posidonia facies may be an area where radiolarite deposition started slightly later than in the surrounding deeper basins (e.g. Fiume Bosso, Umbria, loc. 26), a hypothesis which needs to be tested by radiolarian faunas from these localities. Thus it is believed that U.A. 0–1 (Zone A0) may correspond to much (if not all) of the Bathonian and probably the basal part of the Callovian.

U.A. 2–4 (Zone A1) have been found in various Tethyan sections and at DSDP Site 534A (loc. 30) from Core 126-4, 14 cm to Core 124-1, 52 cm. This interval is assigned to the middle Callovian by HABIB & DRUGG (1983) based on dinoflagellates, and by ROTH (1983, p. 603) based on calcareous nannofossils (*Stephalolithion hexum* Subzone). In Sierra de Ricote (Subbetic, Spain, loc. 45) two samples assignable to U.A. 4–5 are found directly above displaced limestones containing middle to late Callovian ammoni-

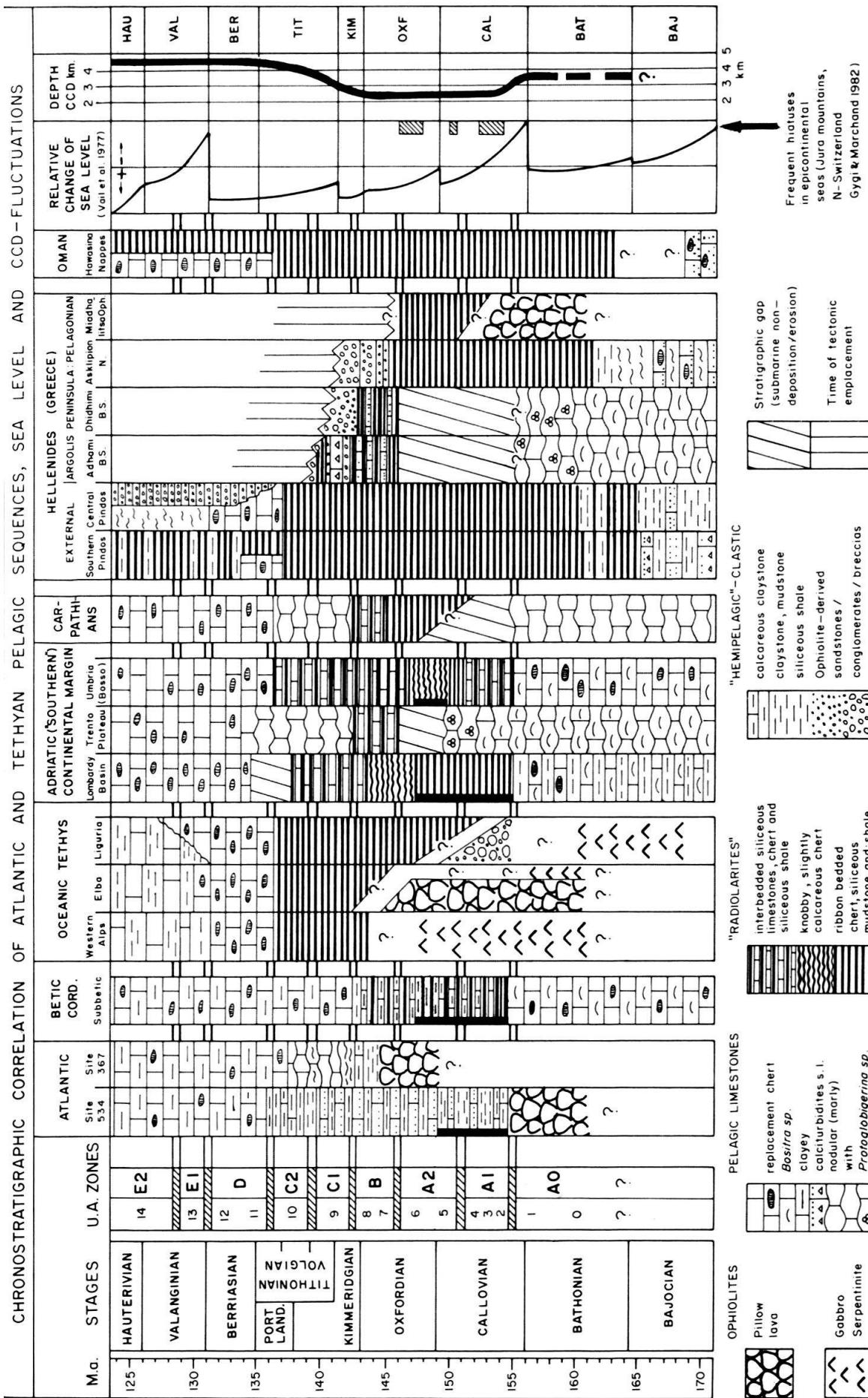


Fig. 3. Chronostratigraphic correlation of Atlantic and Tethyan pelagic sequences for the Bajocian-Hauterivian time interval, principally based on radiolarian data presented in this paper. Note the Bathonian onset of radiolarite deposition in basins existing since the Triassic, early Callovian onset in basins individualized since the Early Liassic and late Oxfordian onset on seamounts and plateaus. The early Callovian onset seems to express a rise of the calcite compensation depth in concert with a rapidly rising sea level. Note also a minimum late Middle Jurassic age for oceanic crust in Greece (Pelagonian s.l.).

Apart from radiolarian data and own field observations the following sources were consulted for lithology and age information: Site 534: SHERIDAN, GRADSTEIN et al. 1983, Site 367: LANCELOT, SEIBOLD et al. 1978, Subbetic SEYFRIED 1978, Western Alps (Schistes lusters): DE WEVER & CABY 1981, Trento Plateau: STRUANI 1964, FOEGLESANG 1975, Carpathians: AGRAM 1976 and references summarized in BAUMGARTNER et al. 1980. Southern Pindos: THIEBAULT et al. 1980, DE WEVER & THIEBAULT 1981, Central Pindos: FIEURY 1974, 1975, Argolis Peninsula: BAUMGARTNER 1980, 1981, BAUMGARTNER & BERNOLLI 1980, 1981, OMAN: GLENNIE et al. 1974, BERNOLLI & WINTERER 1975, LAUBSCHER & BERNOLLI 1977, WINTERER & BOSELLINI 1981, JENKINS & WINTERER 1982 and own interpretations.

tes (see Pl. 12 and SEYFRIED 1978). U.A. 2-4 (Zone A1) thus certainly represent the middle Callovian and probably parts of the early and the late Callovian.

U.A. 5 (Zone A2) has been found in several Tethyan sections and at DSDP Site 534A (loc. 30) from Core 122-1, 131 cm to Core 111-1, 12 cm. This interval includes the upper Callovian and the entire Oxfordian according to HABIB & DRUGG (1983) based on dinoflagellates. According to ROTH (1983, p. 603) this interval includes the *Cyclage-lopsphaera margarelii* nannofossil Subzone which spans the late Callovian and the early Oxfordian and the lower part of the *Vagalapilla stradneri* Zone (starting in Core 113-1, 47 cm) which would represent at least part of the middle Oxfordian.

U.A. 6 (Zone A2) has thus far only been positively identified in the Lombardy basin without coexisting other fossils. It has a very low value of reproducibility (see Fig. 1) and may or may not have a biochronologic significance.

The level of the Callovian/Oxfordian boundary at Site 534A was a matter of considerable debate amongst the various nannofossil and dinoflagellate specialists involved. This is reflected by some discrepancies between the Site Report (SHERIDAN, GRADSTEIN et al. 1983) and the papers by ROTH et al. (1983), ROTH (1983) and HABIB & DRUGG (1983) in the same volume. The calibration presented in BAUMGARTNER (1983) was based on preliminary dinoflagellate data giving the Callovian/Oxfordian boundary above Core 124 (and thus coinciding with the limit of Zones A1/A2). The present solution follows the consensus ROTH (1983)-HABIB & DRUGG (1983). Further work is needed to substantiate the age assignment of the limit of Zones A1/A2.

U.A. 7-8 (Zone B) is widely distributed in Tethys, Atlantic and California (Point Sal). It marks the time of onset of radiolarite deposition on most deeper submerged submarine highs in Tethys (see conclusions and Fig. 3). Considerable uncertainty still exists concerning the chronostratigraphic range of this zone, which partly results from a scarcity of coexisting fossils throughout the studied localities and partly from fundamental problems concerning the Tethyan Late Jurassic biochronostratigraphy. U.A. 8 was determined at DSDP Site 367 (loc. 29) in Core 37-1, 147 cm to Core 36-3, 49 cm, an interval which was assigned to the Oxfordian and possibly the lower Kimmeridgian based on foraminifers, aptychi and calcareous nannofossils (see LANCELOT, SEIBOLD et al. 1978). In Santa Anna (Sicily, loc. 28) Oxfordian to earliest Kimmeridgian ammonites were found above U.A. 8 (BAUMGARTNER et al. 1980, p. 31). In the Ceniga section (Trento, northern Italy, loc. 44) U.A. 8 is included in late Oxfordian to earliest Kimmeridgian siliceous limestones (FOGELGESANG 1975). Thus it is concluded that U.A. 7 represents part of the middle and part of the late Oxfordian and U.A. 8 part of the entire late Oxfordian and part of the early Kimmeridgian.

U.A. 9 (Zone C1) has been found in the Atlantic, Lombardy and Greece. At DSDP Site 534A (loc. 30) it was found in sample 106-1, 29 cm which is located near the top of the *Valagapilla stradneri* Nannofossil-Zone which is given as latest Kimmeridgian (ROTH 1983, p. 603). HABIB & DRUGG (1983), based on dinoflagellates locate the Kimmeridgian/Tithonian boundary just above this sample in Cores 105-1 to 104-2. At DSDP Site 367 (loc. 29) U.A. 9 was found in Cores 35-2, 42 cm to 34-4, 104 cm, which is immediately below a sample (34-4, 44 cm) containing the latest Kimmeridgian/earliest Tithonian apytychus *Granulaptychus planulati* (QUENSTEDT) (RENZ 1978, see remarks in BAUMGARTNER et al. 1980, p. 32). In Lombardy, Tuscany and Umbria U.A. 9 is found in the middle and upper parts of the Rosso ad Aptici, which are dated by apytychi and rare ammonites as Tithonian (summary of biostratigraphic data in

BAUMGARTNER et al. 1980). It is concluded that U.A. 9 (Zone C1) represents the late Kimmeridgian (*sensu gallico*) and the early Tithonian (Volgian).

U.A. 10 (Zone C2) has been recorded in the Atlantic, Tethys and Pacific. At DSDP Site 367 it is present in the sample 32-4, 9 cm just above samples (up to 32-4, 136 cm) assigned to the *Parhabdolithus embergeri* Nannofossil-Zone, but below samples assigned to the *Nannoconus colomi* Zone, which has its base in sample 32-3, 59 cm. Thus the sample is certainly of middle-late Tithonian age. In Tethyan sections U.A. 10 is found in strata immediately below the basal Maiolica limestone which in some places reach the late Tithonian dated by the first calpionellids corresponding to the *Crassicollaria* Zone A of REMANE. Thus U.A. 10 (Zone C2) may represent the middle and part of the late Tithonian.

U.A. 11 (Zone D) is widely distributed in Atlantic, Tethyan and Pacific localities. Its lowest occurrence coincides with the onset of nannofossil limestone sedimentation of the basal Maiolica Limestone in Tethys and the Blake Bahama Formation in the Atlantic. In the Fiume Bosso section (Umbria, loc. 26) U.A. 11 has been found a few meters above the base of the Maiolica Limestone where it is associated with *Crassicollaria intermedia*, *C. brevis* and *Calpionella alpina* (MICARELLI et al. 1977) indicating a latest Tithonian age. At DSDP Site 534A, sample 89-2, 47 cm contains U.A. 11, immediately above samples assigned to *Calpionella* Zone B, earliest Berriasian. In the Svinita section (Romania, loc. 9.) U.A. 11 is dated as late Berriasian by ammonites and calpionellids (AVRAM 1976, summary in BAUMGARTNER et al. 1980). Thus U.A. 11 (Zone D) spans the latest Tithonian to late Berriasian.

U.A. 12 (Zone D) has only been found in one section: Trattberg (Austria, loc. 43), its biochronologic significance is thus not yet established.

U.A. 13 (Zone E1) has been positively identified in the Svinita section, where it occurs at the top of the *Calpionellopsis* Zone and in the *Calpionellites* Zone. It does not reach the top of this zone, hence, represents the early Valanginian. At DSDP Site 534A, three samples in Core 81-2 are assignable to U.A. 13-14 and occur immediately below dinoflagellate samples indicating the basal Valanginian.

U.A. 14 (Zone E2) is widely distributed in Tethyan, Pacific, Japanese and possibly also Atlantic sections. In the Svinita section (Romania, loc. 16) it occurs first at the very top of the *Calpionellites* Zone and starts thus in the late early Valanginian. In the Veveyse section (Switzerland, loc. 38) U.A. 14 coexists with the *Callidiscus* Ammonite-zone of the terminal Valanginian. At DSDP Site 167 (Central Pacific, loc. 31) it occurs in samples from core 76-2, 67 cm upwards which according to nannofossils are of Late Valanginian age and younger. The upper limit of this U.A. has not been established.

4. Significance of dating radiolarites and conclusions

4.1 Chronostratigraphy: Correlation of Atlantic and Tethys and timing of Middle-Late Jurassic siliceous sedimentation

4.1.1 Correlation of Atlantic and Tethyan pelagic sequences

The occurrence of the same succession of U.A. at DSDP Site 534 and in various Tethyan basinal sections allows for a detailed correlation of the middle Callovian to