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### *Principal objectives*

The main focus of this paper is to document as complete as possible the data used for the elaboration and calibration of the presented zonation.

In chapter 2 the procedures which led to the present zonation by means of U.A. are summarized from BAUMGARTNER (1984) and modifications are explained.

In chapter 3 the established zonation is compared to earlier radiolarian biostratigraphic work and to chronostratigraphy.

Chapter 4 draws the consequences resulting from the radiolarian dating of the studied sequences: A chronostratigraphic correlation between Atlantic and Western Tethys and the timing of Middle–Late Jurassic siliceous sedimentation in Tethys and its paleoceanographic significance. Radiolarian faunal changes are related to paleo-oceanography.

Chapter 5 gives an alphabetic listing of genera and the 110 species used in the zonation, including 5 new genera, 16 new species and 2 new subspecies.

Chapter 6 gives the data pertaining to the studied localities: Access, lithology, location of samples and radiolarian and other biostratigraphic data for those sections not illustrated in Plate 12. Detailed objectives and procedures are given in the introduction to each chapter.

## **2. Radiolarian biochronology**

### *2.1 Introduction*

In a recent paper (BAUMGARTNER 1984) the Middle Jurassic–Early Cretaceous database (as included herein except minor revisions) was used to compute Unitary Associations (U.A.) and probabilistic ranking and scaling (RASC, AGTERBERG & NEL 1982a, b), in order to test “deterministic” versus probabilistic quantitative biostratigraphic methods applied to radiolarians. Since the Mesozoic radiolarian fossil record is largely dissolution-controlled, the sequence of first and final appearances of taxa differs greatly from section to section and the scatter of these events along a relative time scale is large compared to the range of the taxa. Thus, these data do not satisfy the statistical assumptions made in probabilistic methods. U.A. produce maximum ranges of the taxa relative to each other by stacking cooccurrence data from all sections and therefore compensate for local dissolution effects (poor preservation). Ranking and scaling, assuming a symmetrical, random scatter of the events narrowly clustered around the endpoints of a species range, produces “average” ranges which are for most species much shorter than the maximum U.A. ranges and can easily be contradicted by any well preserved sample. It is therefore clearly indicated to use U.A. for the elaboration of a radiolarian biochronology which should account for the nature of the data and produce a zonation of wide, non-contradictory applicability.

The procedures which led to the presented zonation by means of Unitary Associations (U.A.), computed by a program by DAVAUD (in GUEX & DAVAUD 1982, 1984) is explained in detail in BAUMGARTNER 1984 and will not be repeated here.

## 2.2 *Recent modification of the zonation*

GUEx (in press) has since proposed an additional test which constructs a second graph "Gk 2" in which the vertical sequencing of A.U. is based on the observed stratigraphic relationships of all species, rather than only the characteristic species (or species pairs) of single U.A., as in the graph "Gk 1" of the program in GUEx & DAVAUD (1984). The longest path in this additional solution should generally result longer than the one of the standard program, which may in some cases produce a desirable increase of vertical resolution, at the cost of good lateral reproducibility and superpositional control. The slightly updated database was run with this new option and the results are found to confirm the earlier version of the zonation. In addition, they allow for a better resolution in Zone A0.

Instead of 13 U.A. resulting from the coalescence of 28 initial U.A. as given in Gk 1 (see BAUMGARTNER 1984, Fig. 2) the new option resulted in 26 U.A. with only one case of gathering (of 27 initial U.A.). However, the superpositional control and the lateral reproducibility of these alternative U.A. is very poor. It results that the gathering as calculated in Gk 1 is an optimal way of grouping the initial U.A. for most of the studied interval. In Gk 1 three initial U.A. were gathered into U.A. 1 of BAUMGARTNER (1984), whereas in Gk 2 these appear to be superposed based on their specific content. Indeed, there is now also physical superpositional control in locality 26 (see Pl. 12) which allows to divide U.A. 1 into "U.A. 0" which results from a coalescence of the two lowest initial U.A. (I.U.A. 10 and 1 of BAUMGARTNER 1984) and "U.A. 1" which is initial U.A. 17 (*ibid.*). This new subdivision increases the resolution at the lower end of the zonation in that many species that reached the base of the zonation now are excluded from U.A. 0 and therefore receive a defined base.

The Cretaceous portion of the zonation continues to be a problem in the calculated versions. Although the physical superpositional control of samples is good, it seems that very incomplete superpositional relationships between the included species result in unrealistic virtual associations. The present solution is taken from BAUMGARTNER (1984) without changes. Of the four proposed U.A. only U.A. 11 and U.A. 14 have a good reproducibility (see Fig. 1). U.A. 12 and 13 remain to be confirmed by further locality data of Neocomian sections. It is hoped that the Neocomian part of the zonation can be refined by the inclusion of more localities and more species.

## 2.3 *Procedure of data acquisition*

*Step 1: Definition of morphotypes.* – The definition of morphotypes is based without exception on an SEM study of well preserved material prior to the actual search for stratigraphic data: For the lowest levels (Zone A0) the sample IN 7, provided by A. Yao (loc. 40, see locality descriptions) and samples from Lombardy basin were used. For the Callovian–Oxfordian interval (Zones A1–A2) very well preserved material of DSDP Site 534 (loc. 30) substantially increased the understanding and selection of morphotypes used in this zonation. For the Oxfordian–Tithonian interval (Zones B–C) samples from the Argolis Peninsula, Greece, northern and central Italy and Sicily were used. For the Neocomian interval (Zones D–E) well preserved samples from the Maiolica in Lombardy and excellent samples from the Murcugeva Formation, Romania (loc. 16), provided by P. Dumitrica were studied.

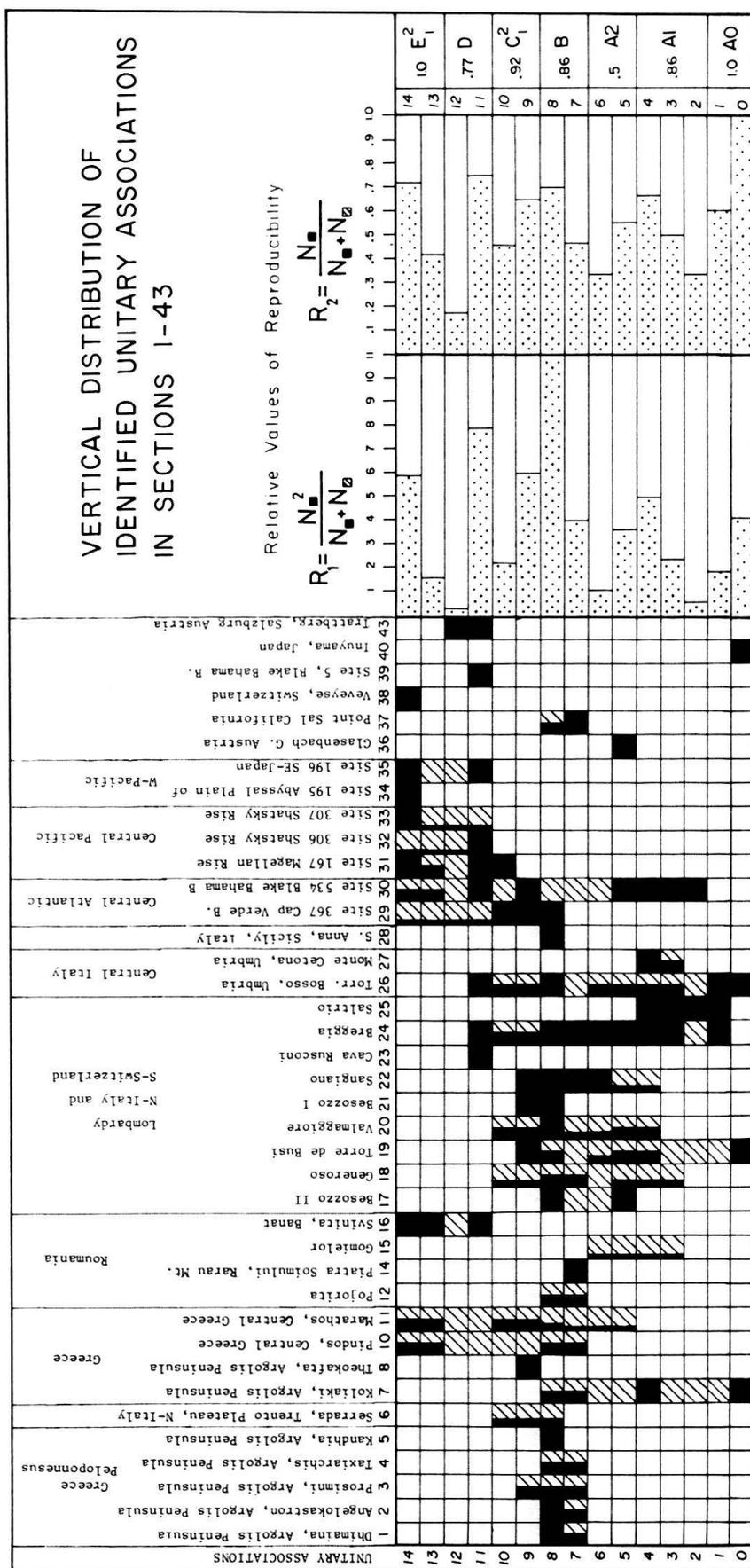


Fig. 1. Distribution of identified (black) and potentially identifiable (hatched) Unitary Associations in studied localities 1-43. Samples assignable to 2, 3 or 4 U.A. receive 2 superposed half, 3 third or 4 fourth squares respectively. R1 and R2 are relative values of reproducibility. A0 to E2 are proposed biochronozones with R2 indicated, taking the identification of the zone as a whole. Modified after BAUMGARTNER (1984).

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 ( $2 \times 4.5$  cm, subdivided into  $5 \times 12$  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. Doubtful 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 biochronozones is based on the principle of lateral reproducibility (GUÉX 1979). The values of reproducibility given in Figure 1 are, of course, only guidelines for establishing biochronozones. 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.