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Strontium-isotope stratigraphy of Upper Cretaceous rudist bivalves: Biozones, evolutionary patterns and sea-level change calibrated to numerical ages

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ABSTRACT

Numerical ages derived from strontium-isotope stratigraphy of 81 Late Turonian–Maastrichtian rudist localities from the Caribbean to Oman are used to establish stratigraphical ranges of readily identifiable taxa of rudist bivalves (Hippuritida). Based on these ranges, seven biozones for the Turonian–Maastrichtian of the central-eastern Mediterranean Tethys, and three biozones for the mid-Campanian–Maastrichtian of the Arabian Plate are established. Most of these are interval zones, each based on the first stratigraphical appearance of the nominal taxon. Micro-evolutionary patterns such as phyletic size increase have been demonstrated for some of the nominal species, as well as a trend of stratigraphical range expansion from the Turonian to the Maastrichtian. Implications of the geochronology of Late Cretaceous carbonate platforms for the biostratigraphy of other benthic fossils are briefly discussed.

Three significant gaps in the stratigraphical distribution of rudist localities in the lower, middle, and uppermost Campanian, respectively, correlate with other records of sea-level change, indicating that they correspond to major eustatic sea-level falls. Only a limited number of rudist taxa is evaluated here, but the early and latest Campanian sea-level falls correspond to faunal turnover and extinction of characteristic associations of Late Cretaceous Hippuritida.

The final extinction of the Hippuritida at the Cretaceous/Paleogene boundary is evaluated based on the available numerical ages of eighteen Late Maastrichtian localities. Eighteen genera are recorded at the six youngest localities, which thus have a species richness similar to older Late Cretaceous localities. While the ultimate cause for extinction of the Hippuritida must be evaluated on time scales beyond the resolution of strontium-isotope stratigraphy, the data set evaluated provides some insight into the pattern of their demise, which is considered to be the result of a high degree of endemism indicating limited exchange between increasingly isolated populations. This isolation was possibly related to the gradual decrease in the areal extent of Maastrichtian carbonate platforms due to a long-term cooling trend and local tectonics that affected carbonate platform growth in the regions studied.

Contents

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1. Introduction

Rudist bivalves (order Hippuritida Newell; as currently classified in Carter et al., 2011) were characteristic components and major carbonate producers of Cretaceous carbonate platforms (Scott et al., 1990; Gili et al., 1995b; Scott, 1995; Philip, 1998a; Skelton, 2000; Steuber, 2000; Skelton, 2003). Their rapid evolution into a wide range of morphologies (Gili et al., 1995a) is reflected in a large number of taxa (c. 1500 species in more than 150 genera, Steuber, 2002a; Skelton, 2011), but biostratigraphy of the Upper Cretaceous based on rudists has been difficult, and has only been attempted for a few regions. In contrast to pelagic fossils, the occurrence of rudists is frequently restricted to a single or few horizons of transgressive or highstand systems tracts due to their shallow subtidal habitat. They are typically absent from marginal marine or deep subtidal deposits above or below rudist formations. Consequently, ranges of taxa cannot generally be derived using the standard approach to biostratigraphy, i.e. by recording the vertical distribution of species in continuous sections of sedimentary rocks.

Nevertheless, Upper Cretaceous biostratigraphy based on rudist bivalves has been attempted for a few regions (Fig. 1). Coenozones for several Upper Cretaceous stages were established for the external Dinarides (Polšak et al., 1982) and the western Mediterranean (Bilotte, 1985; Philip, 1998a). Cestari and Sartorio (1995) established a series of Cretaceous rudist events in the Periadriatic area, including ranges for characteristic taxa, but without providing data to support these ranges. Philip (1998b) provided numerical ages for numerous species from western Europe and the Periadriatic (central Mediterranean), however, without giving the source for these data. Vicens et al. (2004) introduced characteristic biohorizons for the Campanian–Maastrichtian of the Pyrenees, but without linking these to chronostratigraphy. The major problem with these previously proposed rudist zonations is the lack of correlation with ammonoid zones, as both groups of fossils typically do not occur together.

Strontium-isotope stratigraphy (SIS) uses the changing Sr-isotopic composition of seawater (McArthur, 1994; Veizer et al., 1997) and provides an alternative tool to establish a chronology of first and last occurrences of benthic fossils, because it correlates these with well-defined biostratigraphical zonations of other marine fossils, irrespective of depositional environment and palaeobiogeographical provinces. For the Late Cretaceous, the Sr-isotope evolution of seawater (Fig. 2) is derived from ammonite-bearing sections with a well-defined biostratigraphy (e.g., McArthur et al., 1993, 1994; Crame et al., 1998; McArthur et al., 1998) that has been calibrated to chronostratigraphy (McArthur et al., 2001). Previous studies using SIS of rudist bivalves have shown that the ranges of some rudist species must be revised significantly (Swinburne et al., 1992; Steuber, 2001, 2003a, 2003b; Steuber et al., 2009).

In the present contribution, previously published numerical ages and new data are combined to summarize the current knowledge about the ages of key rudist-localities (Fig. 1), and the stratigraphy of rudist-bearing Late Cretaceous carbonate platforms. A biostratigraphical zonation is introduced that is based on occurrences of taxa that have been recorded at localities age-dated with SIS. Ranges of relatively few taxa that are easy to identify have been used in the zonation. It is considered important that the zonation should be

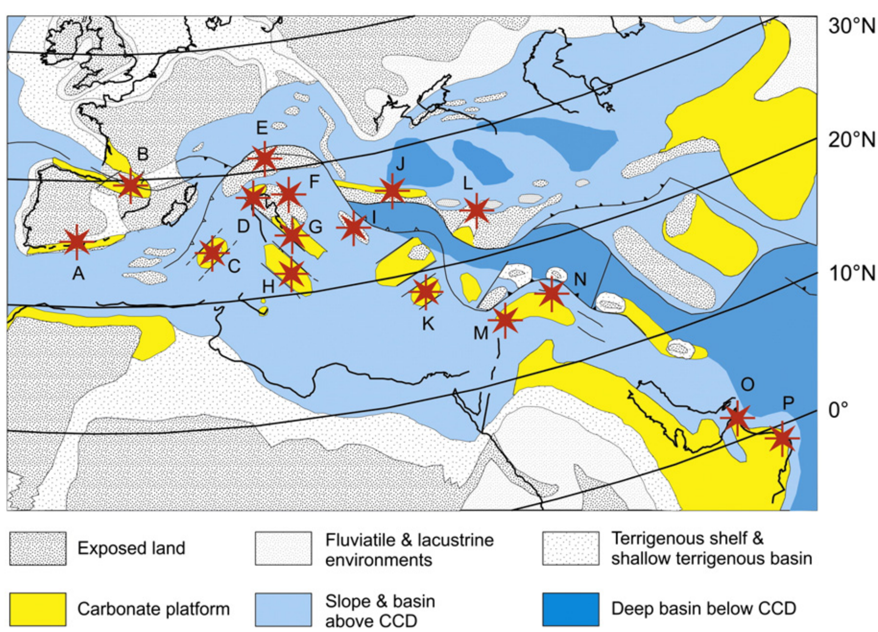

Fig. 1. Palaeo-positions of regions studied (red stars) in the Mediterranean Tethys and the Afro-Arabian region, plotted on Maastrichtian palaeogeography (after Camoin et al., 1993). (A) southern Spain (loc. 47); (B) Pyrenees (locs. 23, 25); (C) Apennines (loc. 21); (D) southern Alps (locs. 11, 26, 53); (E) Gosau basins of Northern Calcareous Alps (locs. 1, 2, 4, 5, 7, 8, 16–19, 24, 28–32); (F) Austroalpine unit (locs. 36, 40); (G) Adriatic carbonate platform (locs. 15, 27, 34, 41, 43, 44, 48, 80); (H) Apulian carbonate platform (locs. 42, 45, 55, 60, 64, 71, 73); (I) central Greece, Pelagonian unit (locs. 6, 9, 10, 12–14, 20, 22, 33); (J) Western Pontides, Istanbul zone (loc. 35); (K) Bey Dagları, southwestern Turkey (loc. 3); (L) Eastern Pontides and central-eastern Anatolia, Anatolide-Tauride units (locs. 37, 38, 46, 49, 50, 78); (M) Hatay, southeastern Turkey, Arabian Platform (loc. 54); (N) southeastern Turkey, Arabian Platform (locs. 52, 56, 59); O, UAE/Oman border region (locs. 51, 57, 61, 65, 66); P, eastern Oman (locs. 39, 81).