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Coral meets Milankovitch – or: time-distribution in shallow-marine carbonate sequences

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It is challenging to compare Recent or Holocene accumulation rates of shallow-marine carbonates with accumulation rates interpreted from the fossil sedimentary record. Today, a single coral branch can grow up to 10 cm/year, and vertical accumulation rates may reach 1.4 cm/year if the ecological conditions are favorable for the carbonate-producing organisms and if there is space to accommodate the sediment. However, due to common reworking and transport by waves and currents, and because of potential subaerial exposure, the time-distribution within the sedimentary record is highly irregular.

In ancient carbonate sequences, this time-distribution is difficult to evaluate, and a time-resolution as high as possible has to be sought for. Identification of the record of orbital cycles (Milankovitch cycles) is the best way to obtain a relatively narrow time-window, which in the best case corresponds to the 20-kyr precession cycle. During green-house conditions, orbitally-induced climate cycles translated into more or less symmetrical sea-level cycles, which at least partly controlled sediment production and accumulation. This allows for a sequence-stratigraphic subdivision of each individual depositional sequence. Thus, a time-frame is given for the interpretation of facies evolution and sedimentary structures within such a sequence.

Based on this hypothesis, two examples are presented, both from the Swiss and French Jura Mountains. A 2-m thick (decompacted) Oxfordian sequence displays carbonate-dominated transgressive deposits followed by marl-dominated highstand deposits. The sequence took 20 kyr to build, but sediment accumulation was episodically interrupted by storm events, and a hardground formed during maximum flooding. The maximum rate of sea-level rise is estimated at 30 cm/kyr (which is ten times slower that today's sea-level rise). The second example is of Berriasian age and shows a 45-cm thick bed of beachrock composed of slabs of oolite. The bed overlies tidal-flat deposits and is capped by a 4-cm thick calcrete crust, over which follows a polymictic conglomerate. According to the cyclostratigraphic analysis, this sequence represents 100 kyr. Ooid production and beachrock formation can happen within a few 100 to a few 1000 years, and the formation of the calcrete took a few 1000 years more. The rest of the time available thus is represented by the transgressive surface at the base of the sequence, by subaerial exposure, and especially by the conglomerate composed of different facies that formed, were cemented, and then were reworked during several 20-kyr cycles.

The conclusion is that, by careful analysis of ancient shallow-marine carbonate sequences and within a cyclostratigraphic framework, depositional processes may be reconstructed and compared with processes that can be observed and quantified in the Holocene and today, and this at comparable time-scales. Thus, a dynamic and realistic picture of the ancient depositional systems is offered.