Abstract

In the absence of an accurate age model, high-resolution chronostratigraphy of carbonate successions often relies on spectral analyses of cycle-stacking patterns and the comparison to the frequencies of orbital-forcing mechanisms. There is, however, overwhelming evidence in the modern and the Pleistocene of Great Bahama Bank that carbonate depositional cycles are unreliable recorders of both the frequency and the amplitude of orbitally driven sea-level fluctuations. This unreliability causes large uncertainties for forward modeling of reservoir units in shallow-water carbonates.

Uncertainties in the assessment of the amplitude are caused by unfilled accommodation space and the inability to measure the amount of sea-level fall in platform-top sediments. Unfilled accommodation space is not recorded in the strata. Likewise, the amount to which sea level drops below an exposure surface is not recorded in the stacked shallow-water cycles. As a consequence, carbonate cycles record only a fraction of the amplitude of a sea-level cycle: a portion of the rise and nothing of the fall.

Uncertainties in the frequencies are caused by the variable amplitude of sea-level change, producing "missed beats" on the platform, and meter-scale oscillations of sea level within highstands that potentially produce cycles of very short durations. "Missed beats", where a sea-level fluctuation is not recorded because the subsequent sea-level rise does not create accommodation space and a new cycle, occur preferentially during times of long-term sea-level fall but are also produced by the depositional topography that is created by the irregularly filled accommodation space. Furthermore, sea-level amplitudes based on the isotope record document random amplitude variability during the last 57 glacio-eustatic changes, complicating a model-based solution for capturing missed beats. In addition, suborbital oscillation of the sea level during highstands with amplitudes of up to 15 m produce cycles of short durations. Suborbital, intermittent sea-level oscillations during the last interglacial (MIS 5e) are documented in the Bahamas in stacked reefs, in repetitions of beach-eolian successions, and by subaerial exposure surfaces on subtidal facies.
The combined effects of missed beats and oscillations within highstands are difficult to extract from the rock record. Consequently, establishing a chronostratigraphic framework in carbonates based on astrochronology is full of uncertainty.

**Selected References**


Uncertainties of Extracting Amplitude and Frequency of Orbitally Driven Sea-Level Fluctuations from Shallow-water Carbonate Cycles

Gregor P. Eberli
CSL – Center for Carbonate Research
**Assumption:**
Precession (19 – 21 kyrs) is the highest recorded frequency
Astrochronology is the dating of sedimentary units with calibration of astronomically tuned times scales, such as Milankovitch cycles.

“Some orbital eccentricity modes can be used for orbital-stratal calibrations to several hundred million years ago”

Hinno 2000
Key Points

Depositional cycles are unreliable recorders of amplitude and frequency of orbitally driven sea-level fluctuations because:

1. Amplitude is impossible to measure
2. Shallow-water carbonates have an incomplete record of sea-level changes
3. Sea level oscillates within highstands to produce sub-Milankovitch cycles
AMPLITUDE OF SEA-LEVEL FLUCTUATIONS
Variable filling of accommodation space creates depositional topography and thickness variations.
PRESERVATION OF DEPOSITIONAL TOPOGRAPHY

Pleistocene ooid shoal

Everglades

Pleistocene reef tract

Florida Bay (Mud Mounds)

Florida Keys (Pleistocene Reef)

Present-day Reef Tract

Holocene

Pleistocene

Holocene Reef

Biscayne Bay

Miami-Oolite

Florida Keys
Beach and Shoal Facies
3 cycles within Brunhes

Platform Interior
8 cycles within Brunhes

Kievman 1995
Aurell et al. 1994
Cycle thickness and sea-level amplitude

Only a fraction of the sea-level amplitude is recorded on the platform top.
UNCERTAINTY IN AMPLITUDE ESTIMATES
Cycle thickness variations: Cretaceous Maiella Platform Margin

Stössel 1999
Cycle thickness variations Maiella

From Sanders 1996
Frequency of orbital driven sea-level changes

Latemar: ~ 600 shallow-water carbonate cycles

600 precession cycles at 20 kyr = 12 my.

Latemar cycle interval = 2.5 my.
average duration of cycles: 1.5 - 2.5 kyrs

Biostratigraphic and radiometric age data question the Milankovitch characteristics of the Latemar cycles (Southern Alps, Italy)

Peter Brack
Institut für Mineralogie und Petrographie, Eidgenössische Technische Hochschule, 8092 Zürich, Switzerland
Roland Mundil
Felix Oberli
Martin Meier
Institut für Isotopengeologie und Mineralische Rohstoffe, Eidgenössische Technische Hochschule, 8092 Zürich, Switzerland
Hans Rieber
Paläontologisches Institut der Universität Zürich, 8006 Zürich, Switzerland

Mundil, Zühlke et al., 2003
Kent, Muttoni, Brack 2004, 2006

Photo: P. Brack

Mundil, Zühlke et al., 2003
Kent, Muttoni, Brack 2004, 2006

Photo: P. Brack

magmatic zircons

U-Pb-ages

single zircon data

3.2 ± 0.6 Ma
Pleistocene Cycles on Great Bahama Bank

8 cycles but only 3 platform floodings

Redrawn from Haddad et al. (1993)
Sea-Level Oscillations within Highstands

Pleistocene interglacials display oscillations of several meters.
Sedimentary Record of Highstand Oscillations

New Providence (Reid, 2010)

Eleuthra (Kindler and Hine, 2009)

San Salvador (Thompson et al., 2011)
Sedimentary Record of Highstand Oscillations

2 Successions of Beach-Eolianites within MIS 5E

Boiling Hole Eleuthra

Kindler and Hine, 2009
Sea-level oscillations during the last interglacial highstand recorded by Bahamas corals

William G. Thompson¹*, H. Allen Curran², Mark A. Wilson³ and Brian White²

Figure 1 | Great Inagua site A: two successive fossil reefs directly
Basinal Cycles in the Straits of Florida

Red boxes indicate sites with marl-limestone alternations
Marl-Limestone Alternations

Core 1007, 84R

Dark, clay-rich intervals
= sea level lowstand

Light, carbonate-rich intervals
= sea level highstand
Half-Precession Signal in the Alternations

ODP Site 1006,
802 – 910 mbsf = 12.7 -13.6 myrs
81 alternations in 900 kyrs
cycle duration of 11.1 kyrs

Late Miocene - Gamma-ray

Bernet, 2000
Presenter’s notes: Top—Core-derived magnetic susceptibility and log-derived resistivity (SFLU) log of parts of sequence f. The core-derived magnetic susceptibility log is dominated by a precession signal; log-derived SFLU in contrast, by a semi-precessional signal (Kroon et al., 2000). The age of the examined interval was established by counting core-derived magnetic susceptibility cycles from the nearest foraminifer/algae datum. Owing to the uncertainty of this floating stratigraphy, age between 4.0 and 4.1 Ma was assigned to the two precessional cycles.

Bottom—Sampled interval. The aragonite content shows a semi-precessional frequency and seems to dominate the SFLU signal. FO is first occurrence; LO is last occurrence.
Conclusions

1. Depositional cycles are unreliable recorders of the amplitude and frequency of sea level changes
2. Their frequency is not in concert with orbitally controlled climate cycles
3. Sea-level oscillations within highstands are of sufficient magnitude to add complexity to the stratigraphic record