Relative sea level history of the uppermost Cenomanian of southwestern Utah: evidence for Milankovitch−driven eustasy?

Laurin, Jiri, Institute of Geophysics, Academy of Sciences of the Czech Republic, laurin@ig.cas.cz; Sageman, B. B., Northwestern University, brad@earth.northwestern.edu; Meyers, S. R., Northwestern University, meyers@earth.northwestern.edu; Waltham, D. A., Royal Holloway University of London, d.waltham@gl.rhbncac.uk

Many aspects of Late Cretaceous eustasy, including timing, amplitudes, and forcing mechanisms, remain poorly understood. Recent studies suggest a possibility of Milankovitch forcing of the Cretaceous "greenhouse" eustasy (e.g. Plint, 1991; Fischer Hinnov, 2000; Gale et al., 2002), but stratigraphic data, which would exceed, in their temporal resolution, the constraints given by biostratigraphic zonation are extremely rare. The latest Cenomanian interval of the Western Interior Seaway, which was characterized by coexistence of climate−sensitive hemipelagic rhythmites (e.g. Gilbert, 1895; Fischer, 1980) and sea−level sensitive siliciclastics (Elder et al., 1994), and is suitable for high−resolution correlations (e.g. Elder, 1985, 1991), provides an excellent opportunity to improve our understanding of climate−ocean interactions during "greenhouse" times.

The remarkably complete stratigraphic record of the proximal part of the Sevier foredeep of southwestern Utah provided detailed information on relative sea level history of the latest Cenomanian interval of this part of the basin. A resulting genetic−stratigraphic framework, which differs from the existing stratigraphic concepts (e.g. Elder et al., 1994) in both stratigraphic resolution and interpreted along−dip genetic relationships, was correlated, in both outcrop and subsurface, with an offshore setting of Kaiparowits Plateau. A high−resolution stratigraphic framework, established for offshore strata by Elder (1985, 1991) and Elder et al. (1994), was further used to pin our data on relative sea level history to a detailed, Milankovitch−based time scale established recently for the Bridge Creek Limestone by Meyers et al. (2001). Temporal resolution of our stratigraphic data obtained by this method was at the order of tens of kyr (depending largely on uncertainties in the proximal−distal correlation in the nearshore parts of the basin).

According to our data, at least two orders of relative sea level (RSL) change are superimposed on the long−term relative sea level rise spanning the latest Cenomanian through mid or late Early Turonian (the corresponding transgressive trend culminated during the late P. flexuosum or early V. birchbyi Zones in southern Utah). The higher order of RSL change is represented by three cycles, in the latest Cenomanian Sciponoceras gracile Zone and the early part of Neoceradioceras juddii Zone. Their duration approximates 90−110, 50, and 110−160 kyr (from oldest to youngest). These RSL cycles include a minimum of 3, 2, and 2 sub−ordered units, respectively, which are attributable to short−term RSL changes. In most instances, these lowest−order units cannot be individually correlated with the hemipelagic setting. Their approximate durations were thus estimated using the simplistic assumption that each short−term cycle represents an equal increment of time. Resulting average durations range from 25 to 80 kyr. Since some short−term RSL cycles are likely to have remained unidentified by us, these estimates represent the maximum average duration of short−term RSL cycles in the interval of study.

Since tectonically−induced RSL changes of such extremely short time scales and hierarchical organization are not known from foreland settings, we propose that at least part of the interpreted RSL history is due to short−term eustatic oscillations. The estimated durations would be consistent with Milankovitch−related forcing. To test this hypothesis, we performed a series of numerical simulations and tested reproducibility of both the interpreted relative sea level curve (based on decompacted stratigraphic profiles) and the observed progradational patterns with Milankovitch−like eustatic forcing. The major patterns of the interpreted RSL curve and stratigraphy were reproduced using 22, 39, 95 and 413 kyr periods (adopted from spectral analyses of the Bridge Creek Limestone; Meyers et al., 2001) with 0.2−2.5, 2, 0.8−6, and 8 m of amplitude of eustatic change, respectively, superposed upon 35m/100kyr of linear rise (sum of subsidence and long−term eustatic rise). The same eustatic curve and clastic−input conditions, superimposed upon 20m/100 kyr of linear rise (simulating the assumed low−accommodation conditions in the Bridge Creek source area) can reproduce the 413 kyr maximum in Ti accumulation (proxy for detrital flux) documented from the latest Sciponoceras gracile Biozone of the Bridge Creek Limestone by Meyers et al. (2001). Similar results were obtained after exclusion of the obliquity (~39kyr) cycle from the synthetic eustasy. In contrast, obliquity−like eustasy alone failed to reproduce the observed stratigraphy.

In summary, the combination of genetic stratigraphy of the marginal part of the Western Interior Seaway with results of spectral analysis of the Bridge Creek Limestone (Meyers et al., 2001) and numerical stratigraphic modeling, suggests that Milankovitch−scale eustasy does not contradict stratigraphic observations from nearshore settings. In spite of "imperfections" in the relative timing of Cenomanian RSL changes in southwestern Utah and the Milankovitch cycles recorded in central Colorado, the study presented herein suggests that combined eccentricity/precession−driven eustasy is a possibility to consider when dealing with the "greenhouse" Cretaceous world (cf. Fischer Hinnov, 2000).