Sequence Stratigraphy, Carbon Isotopic Signature, and Dolomitization of a Late Jurassic Greenhouse Platform, Croatia*

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Abstract

Late Jurassic platform carbonates, Croatia contain a detailed paleoclimate, stable C-O isotope, and sea level record in the stratigraphy. The Kimmeridgian supersequence has two sequences bounded by emergence breccia, with the lower sequence containing two high frequency sequences. In the lower Kimmeridgian sequence, lump-skeletal wackstone and mudstone cap most parasequences. Elsewhere, parasequences are dominated by lump-oncoid wackestone-mudstone capped by lime mudstone and microbial laminite, and packstone-grainstones are rare. Microbial laminite caps parasequences in late highstands of Kimmeridgian sequences.

The Tithonian supersequence has four smaller scale sequences. The lower Tithonian is dominated by subtidal parasequences and the upper Tithonian by peritidal and oolitic parasequences. Parasequences of basal skeletal-oncoidal wackestone-mudstone or oolite, grade up into intraclast-peloid packstone grainstone capped by lime mudstone or microbial laminite. Clayey breccias occur at sequence boundaries in the platform interior. The abundance and character of the meter-scale parasequences and duration of the Tithonian suggests greenhouse low amplitude sea level changes within the precessional band.

Carbon and oxygen isotopes were obtained from carbonate mud matrix of the Lower Tithonian mudstone-wackestone (shallow lagoon). Isotope values (PDB) of dolomite are compatible with semi-arid tidal flat and reflux origin with $\delta^{18}O$ dolomite values about 3 to 4‰ heavier than the marine calcite mudstone (0.5 to -2.0‰) and the $\delta^{13}C$ carbon values of the dolomites are similar to the calcite precursors (0 to 3‰). Low Mn (commonly below 20 ppm), and moderate strontium values (50 to over 200 ppm) suggest that there has been relatively little late diagenetic burial resetting of the dolomites.

In terms of chemostratigraphy, C and O values co-vary. Positive excursions in C isotopes (1 to 2 ‰) appear to occur toward parasequence set boundaries, and lightest values occur near floods. These light flooding values may relate to aging of interior platform waters when the whole platform was flooded, coupled with respiration, and carbonate precipitation. The heavy values may indicate the decreasing effects of interior platform waters, coupled with increasing biologic production and increased effects of evaporation as the platform shallowed under semi-arid climate. This raises the possibility that the platform C-O isotope stratigraphy may not be representative of the open ocean.

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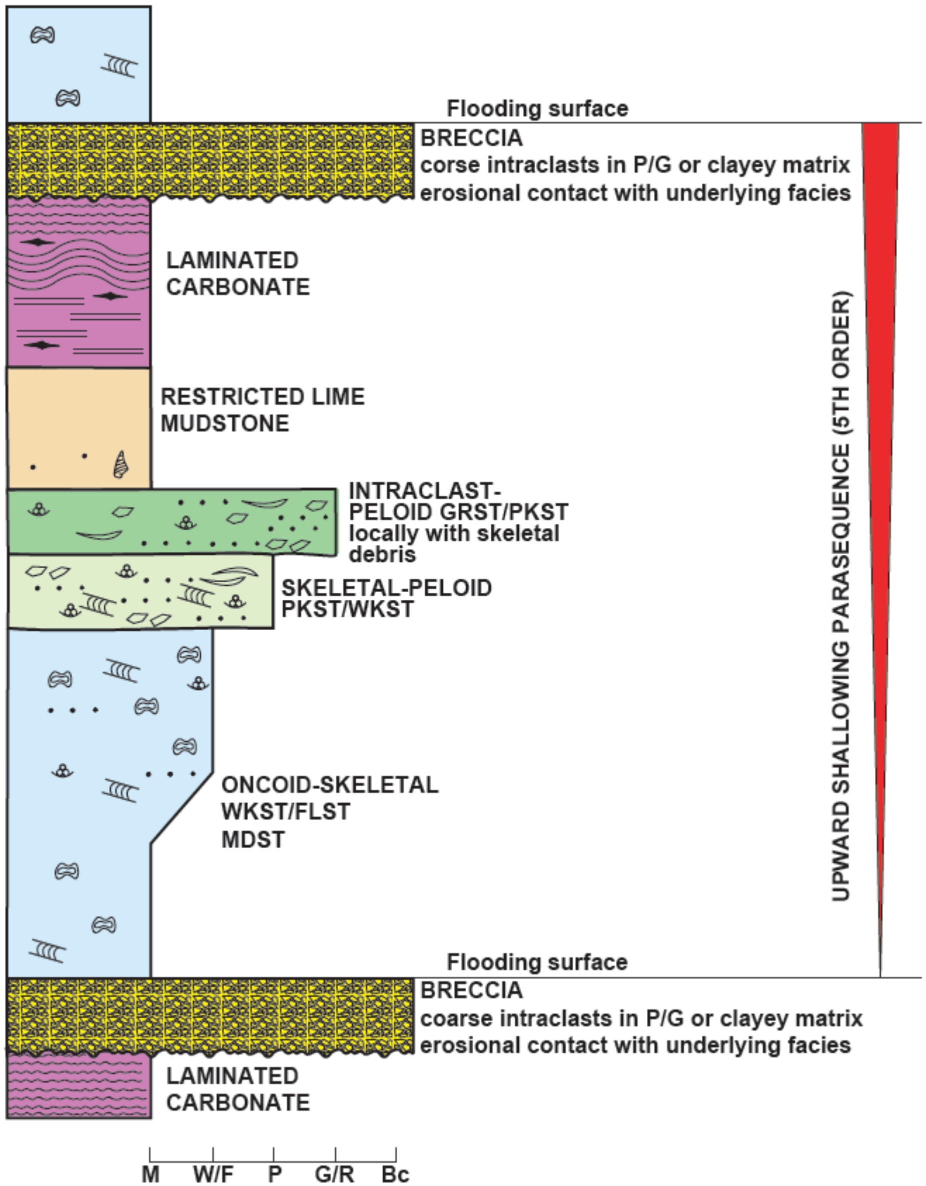
Aims

- Document high-resolution sequence stratigraphy of Late Jurassic Adriatic Platform
- Evaluate isotopic signature
- Is Late Jurassic greenhouse or transitional between greenhouse and icehouse?

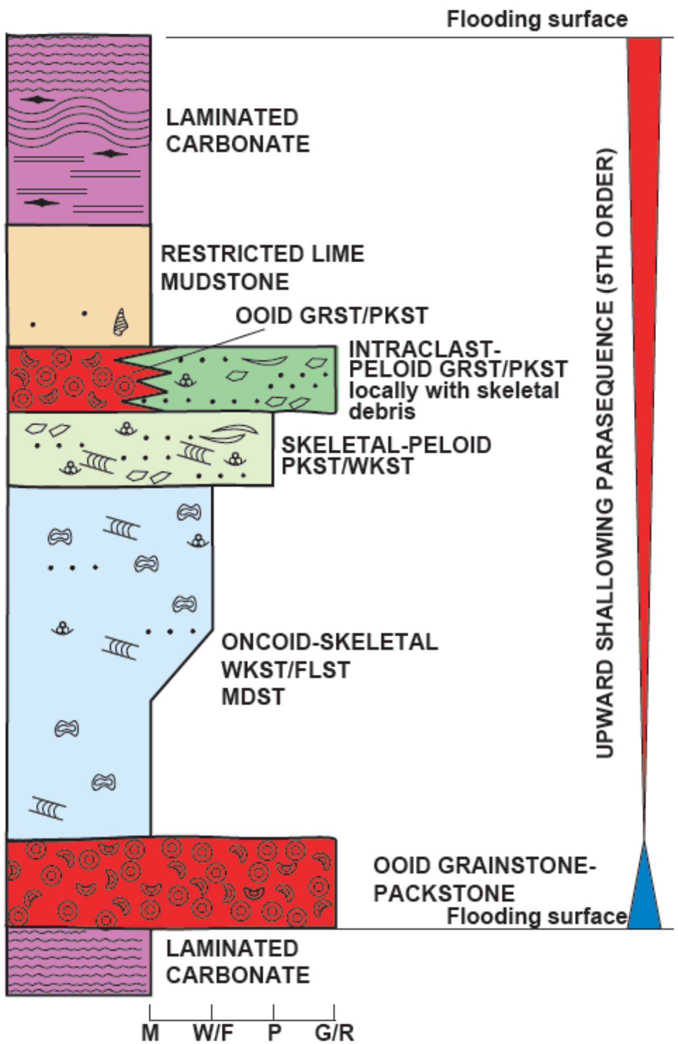
Outline of Mesozoic Adriatic Platform

Late Jurassic

Regressive muddy parasequence

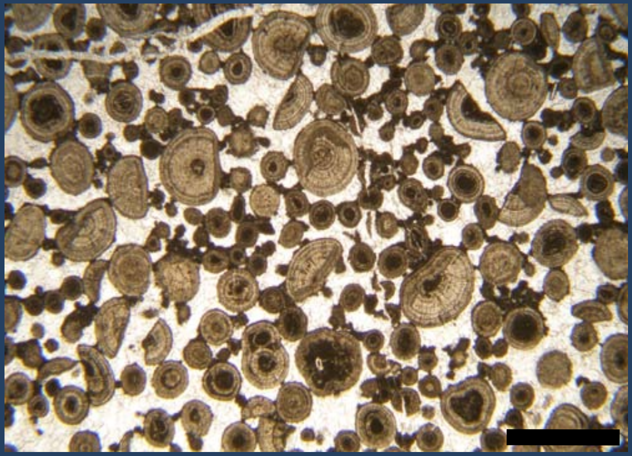


Oolitic-based parasequence

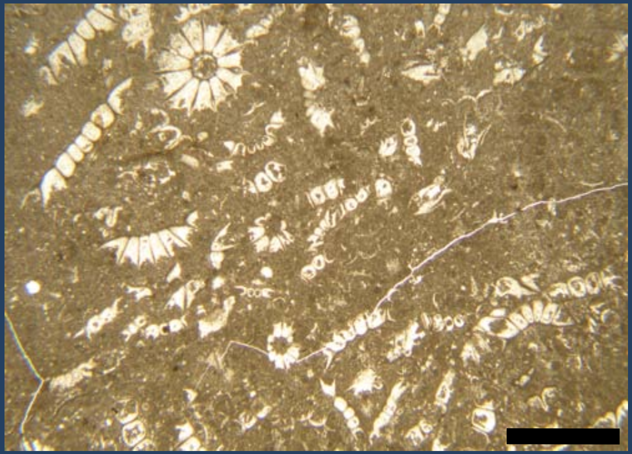


Late Jurassic Facies

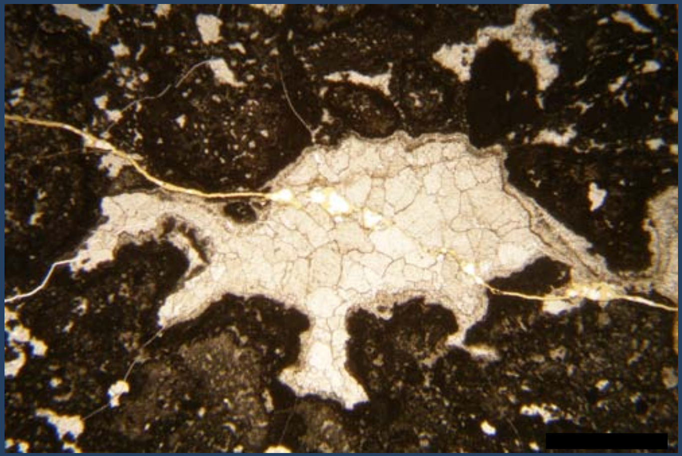
Hypersaline shallow subtidal/intertidal



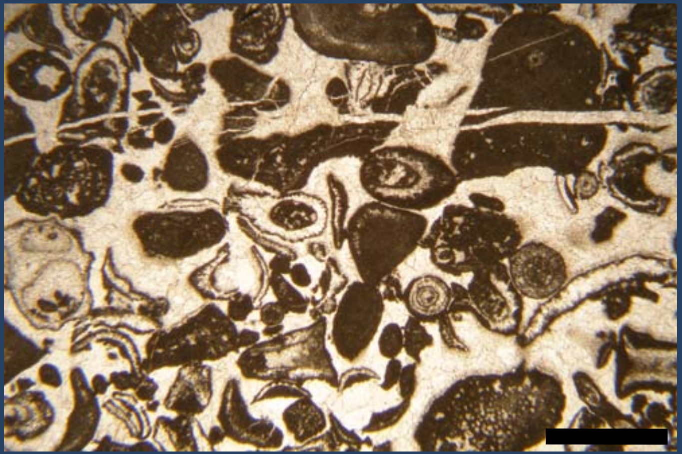
Shallow lagoon



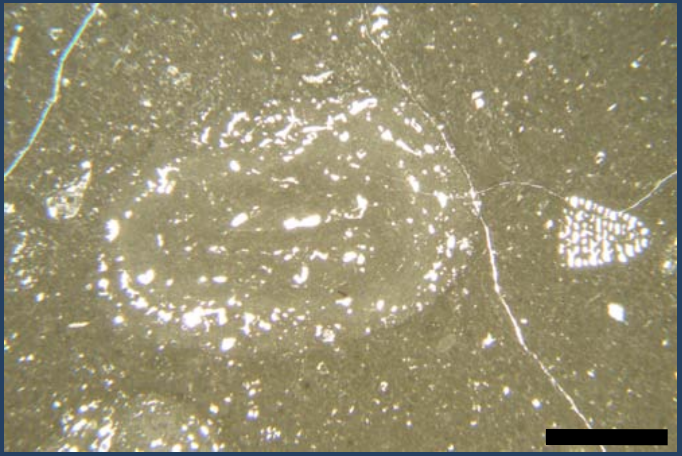
Tidal flat



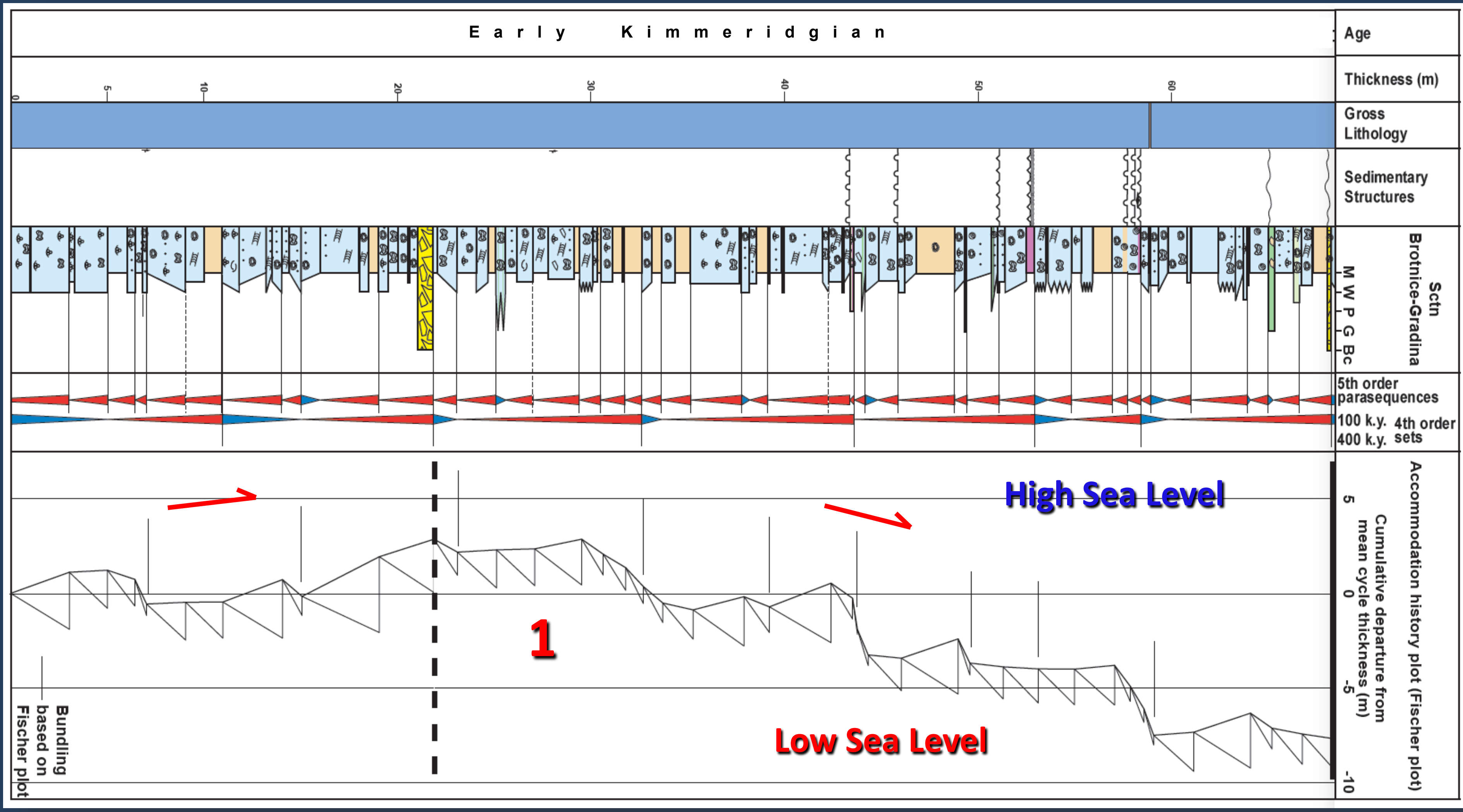
Shoal water



'Deeper' lagoon

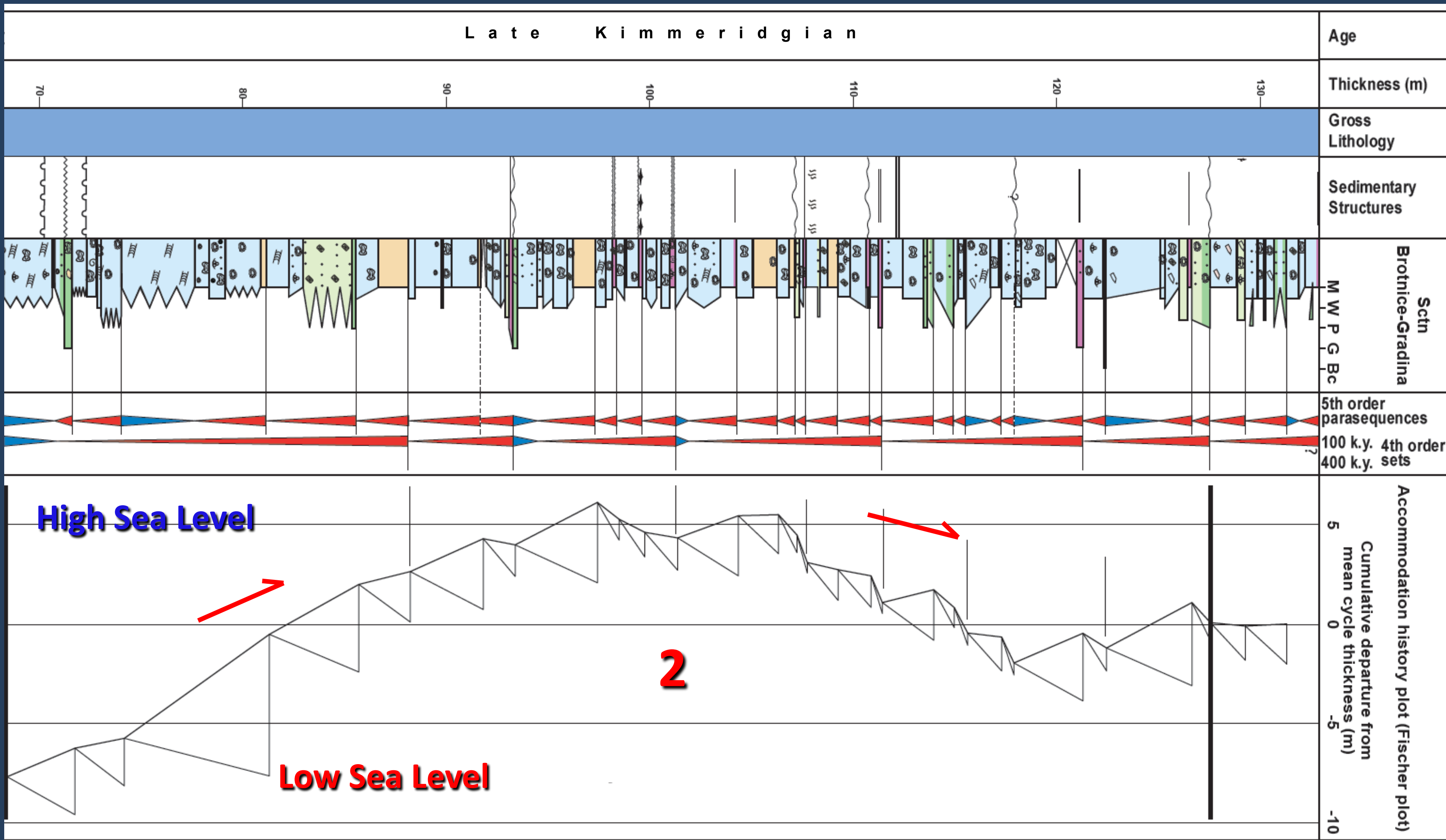


Lower Kimmeridgian relative sea-level changes defined by Fischer plots



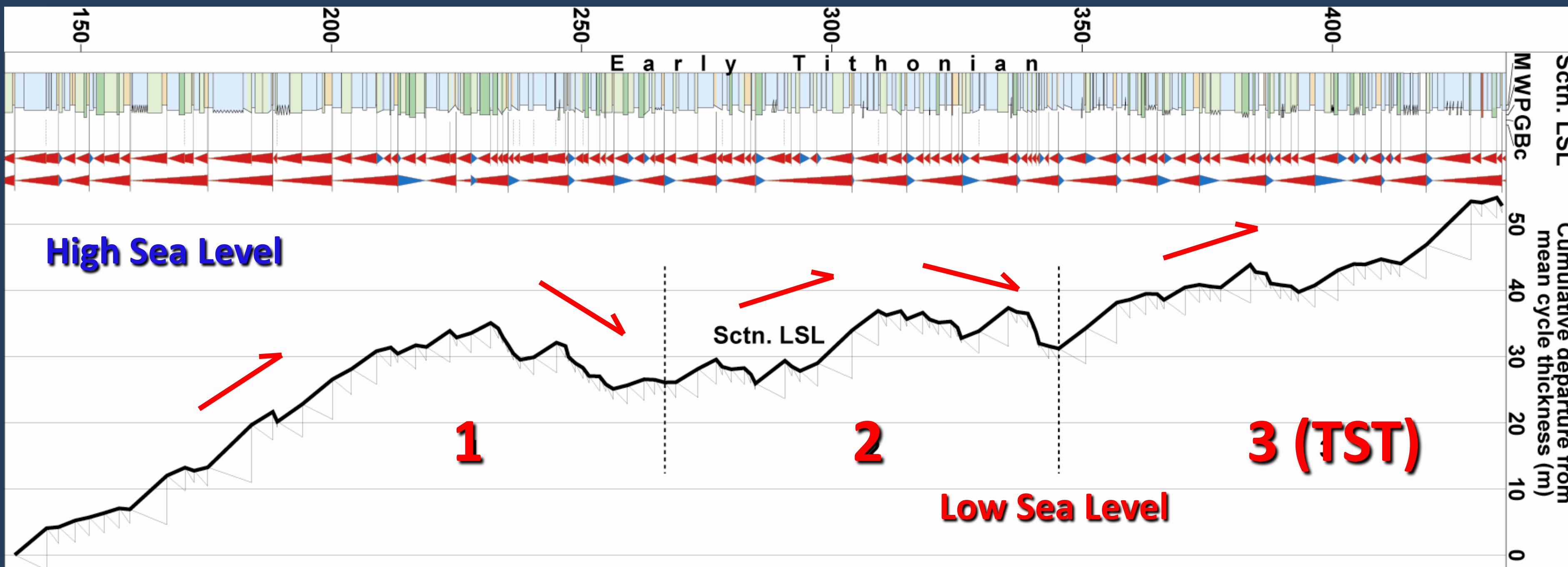
Fischer plot; column is on its side

Upper Kimmeridgian relative sea-level changes defined by Fischer plots



Fischer plot; column is on its side

Lower Tithonian relative sea-level changes defined by Fischer plots



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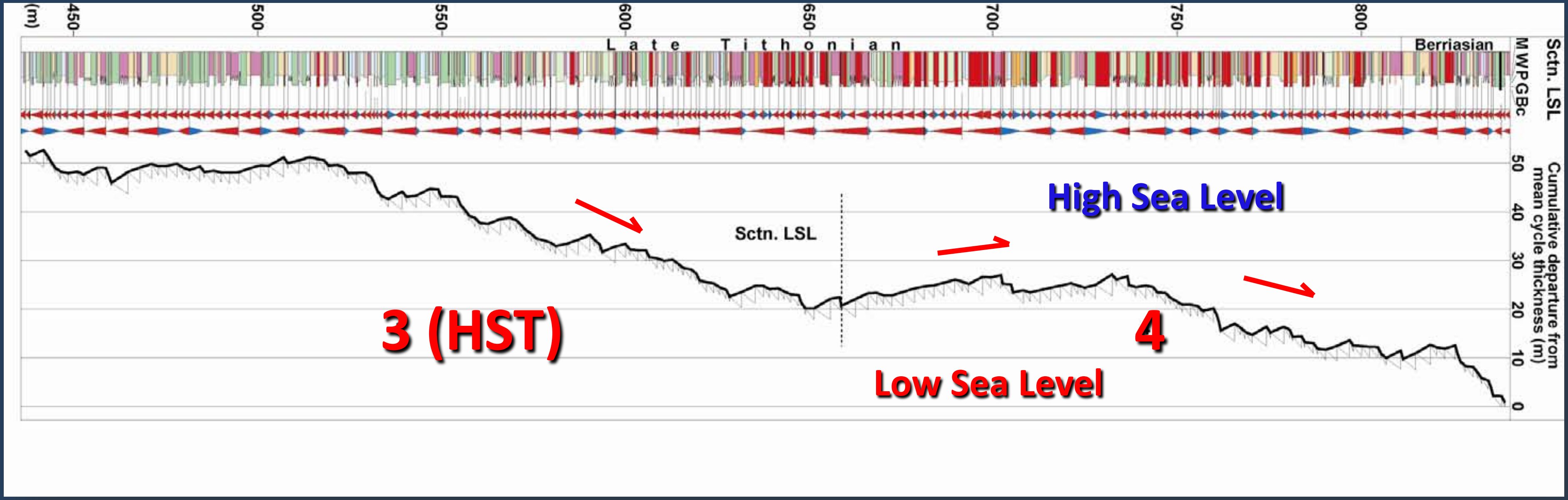
Tithonian parasequences have average durations of 16-20 k.y.

Upper Tithonian relative sea-level changes defined by Fischer plots



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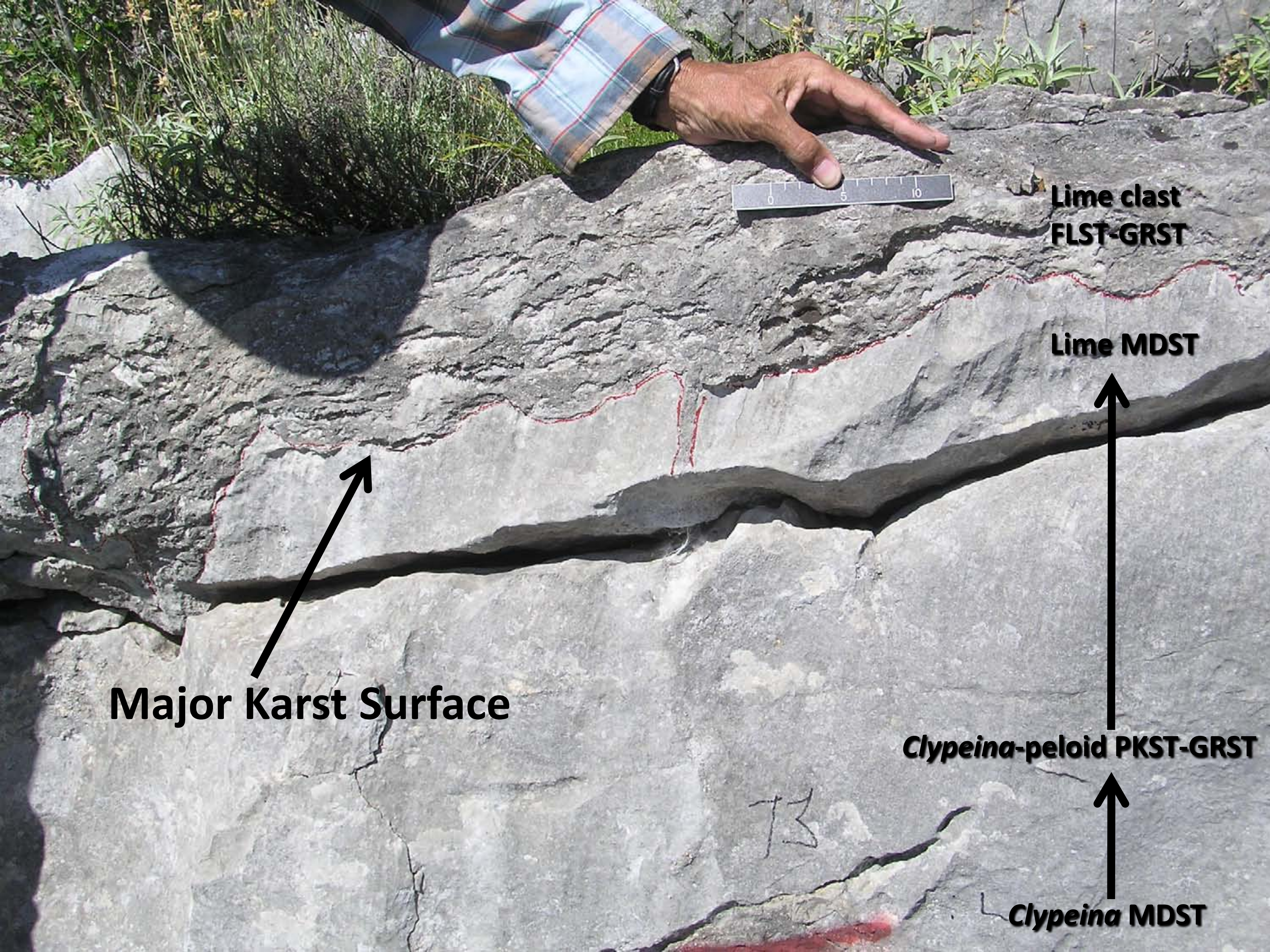
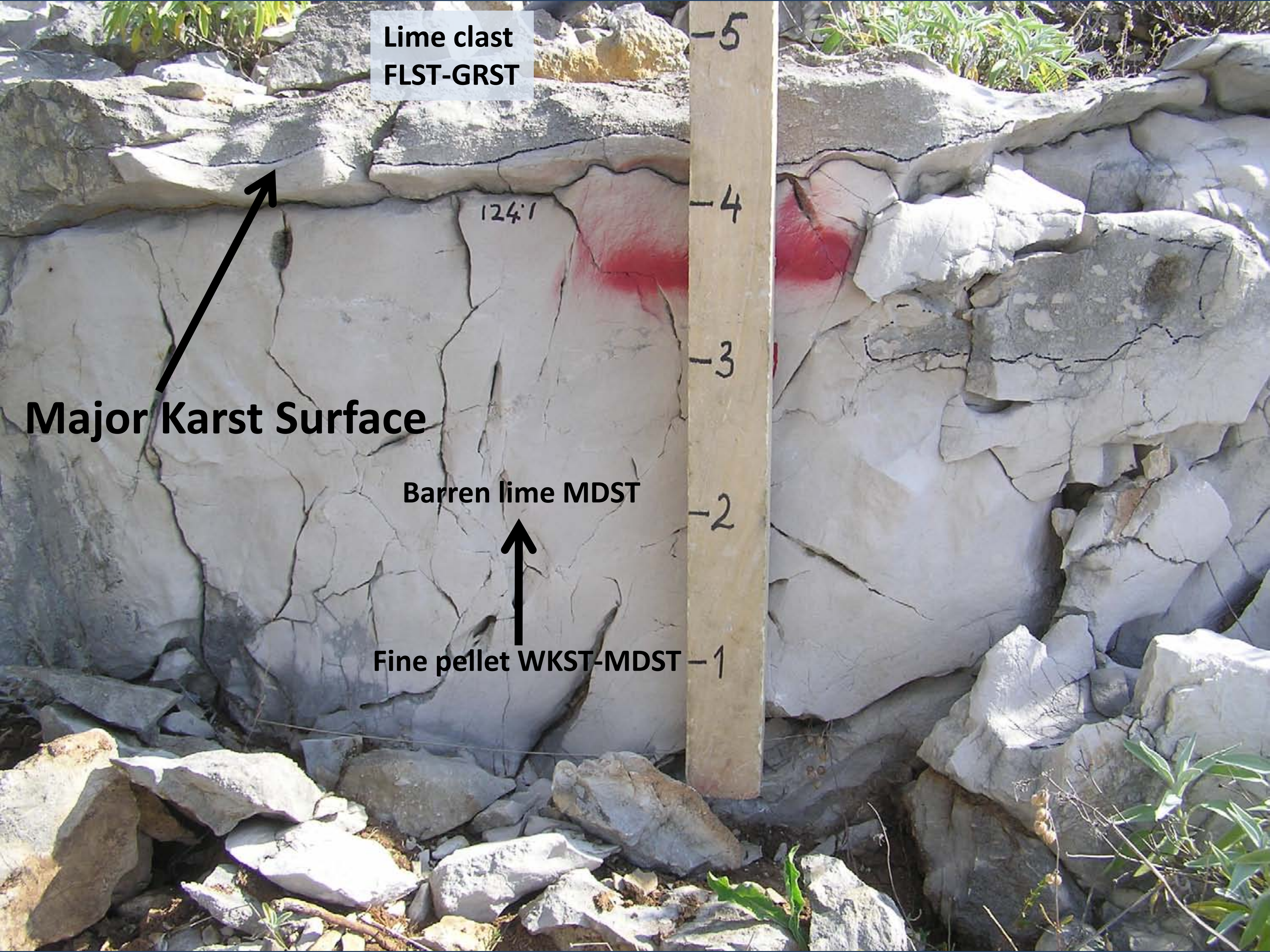


0 5 10
Lime clast
FLST-GRST
Lime MDST
Major Karst Surface
Clypeina-peloid PKST-GRST
Clypeina MDST

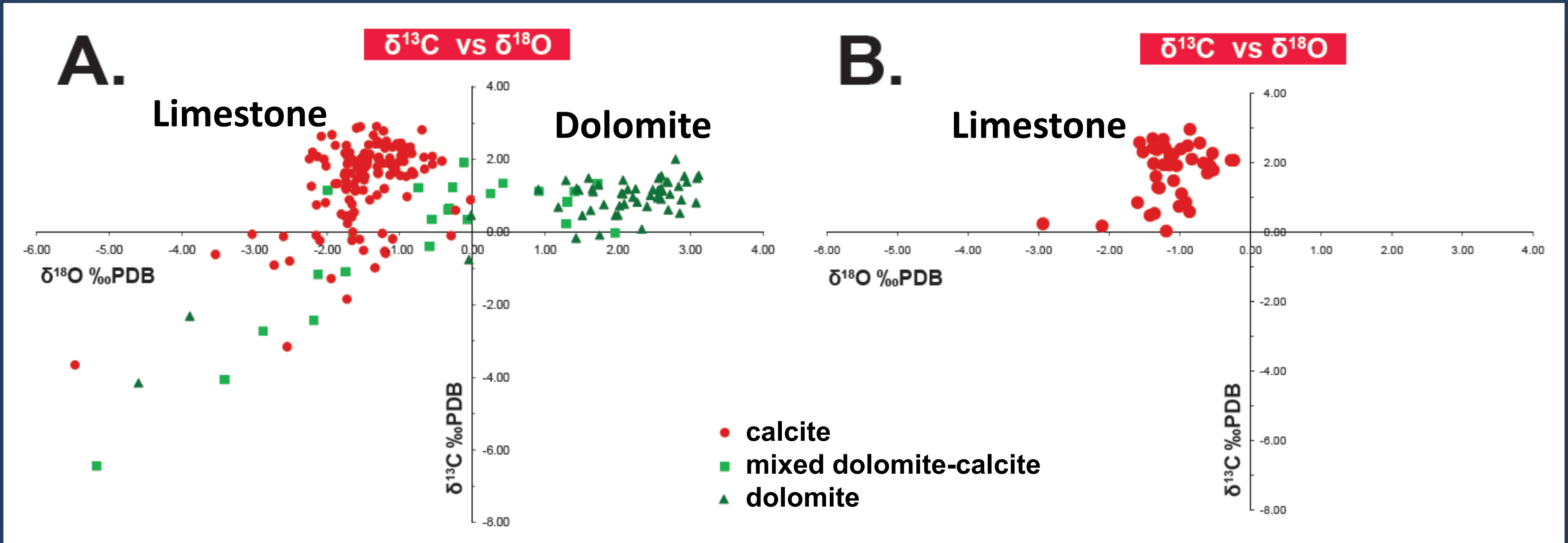

Lime clast
FLST-GRST
-5
-4
1241
-3
Major Karst Surface
Barren lime MDST
-2
Fine pellet WKST-MDST
-1

Kimmeridgian 2 sea level cycles and Tithonian 4 sea level cycles match Haq and Al-Qahtani (2005).

Carbon & Oxygen Isotopes

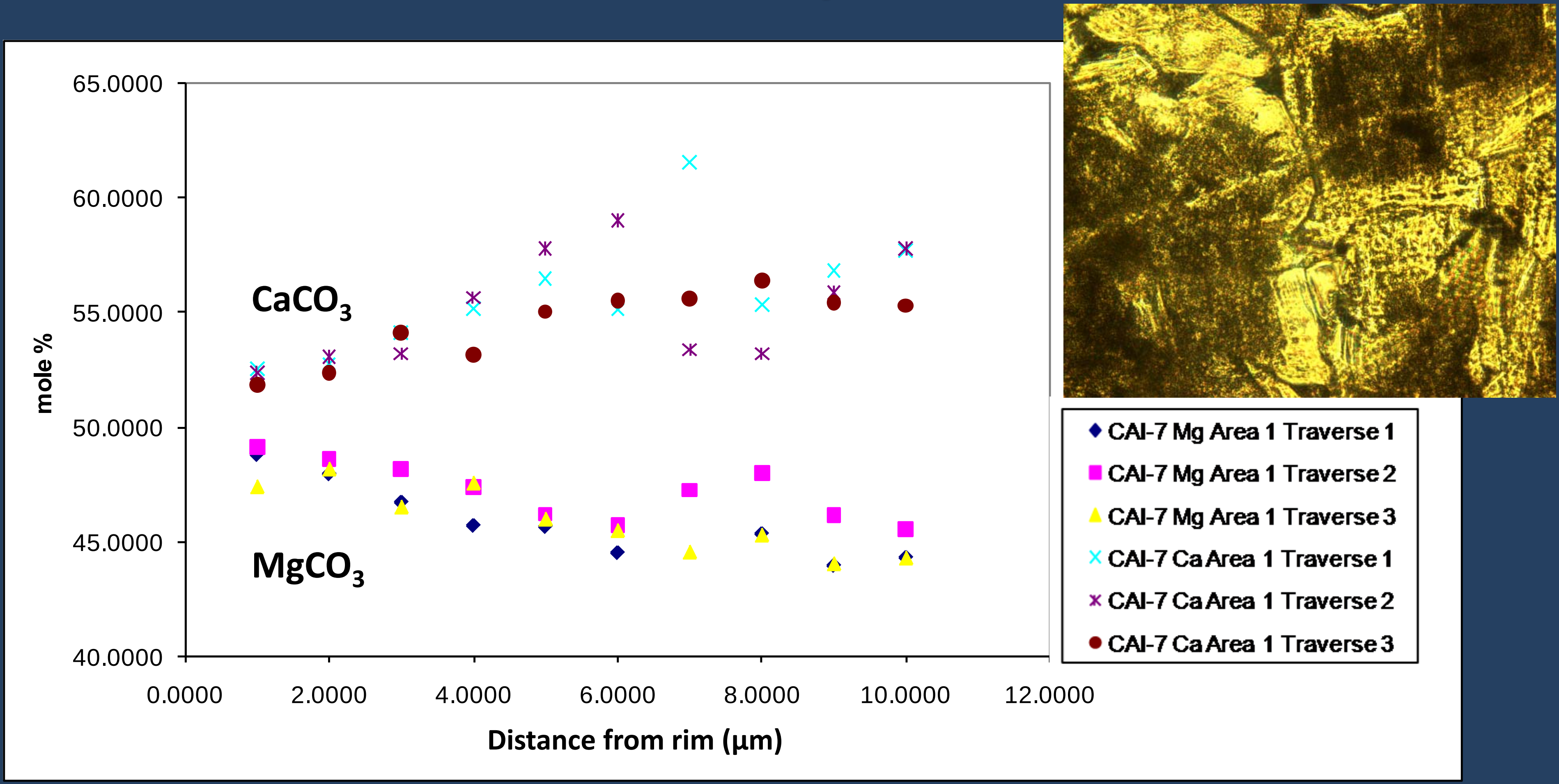
Inner Platform

Closer to Margin



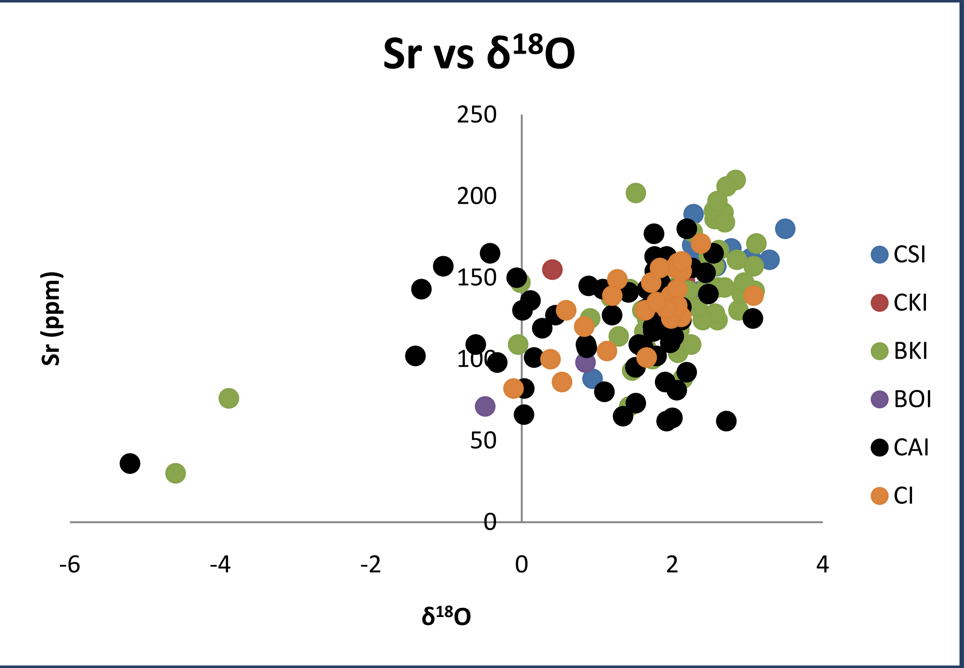
- Mud matrix of Late Jurassic limestone is similar to deeper water Late Jurassic
- Oxygen isotopes of dolomite whole rock 2 to 4‰ heavier than limestone, suggesting they are not altered. Most of the dolomite carbon isotopes are rock buffered
- Outliers suggest some modification by meteoric waters or sulfate reduction

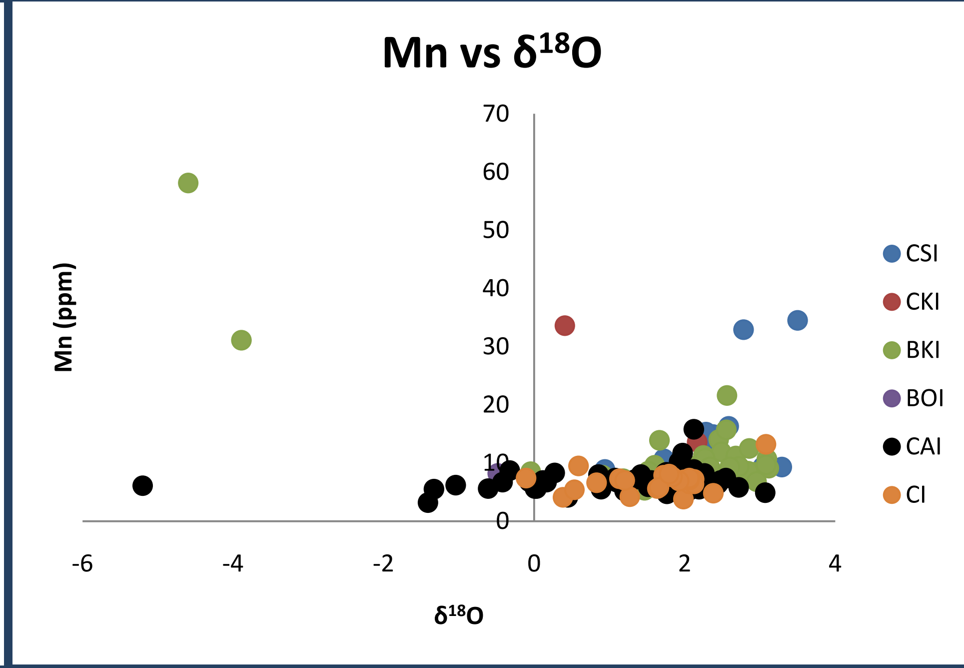
Dolomite Stoichiometry



- Dolomites show Ca-rich cores that become more stoichiometric toward clear rim
- Cathodoluminescence shows a single non-luminescent generation of dolomite

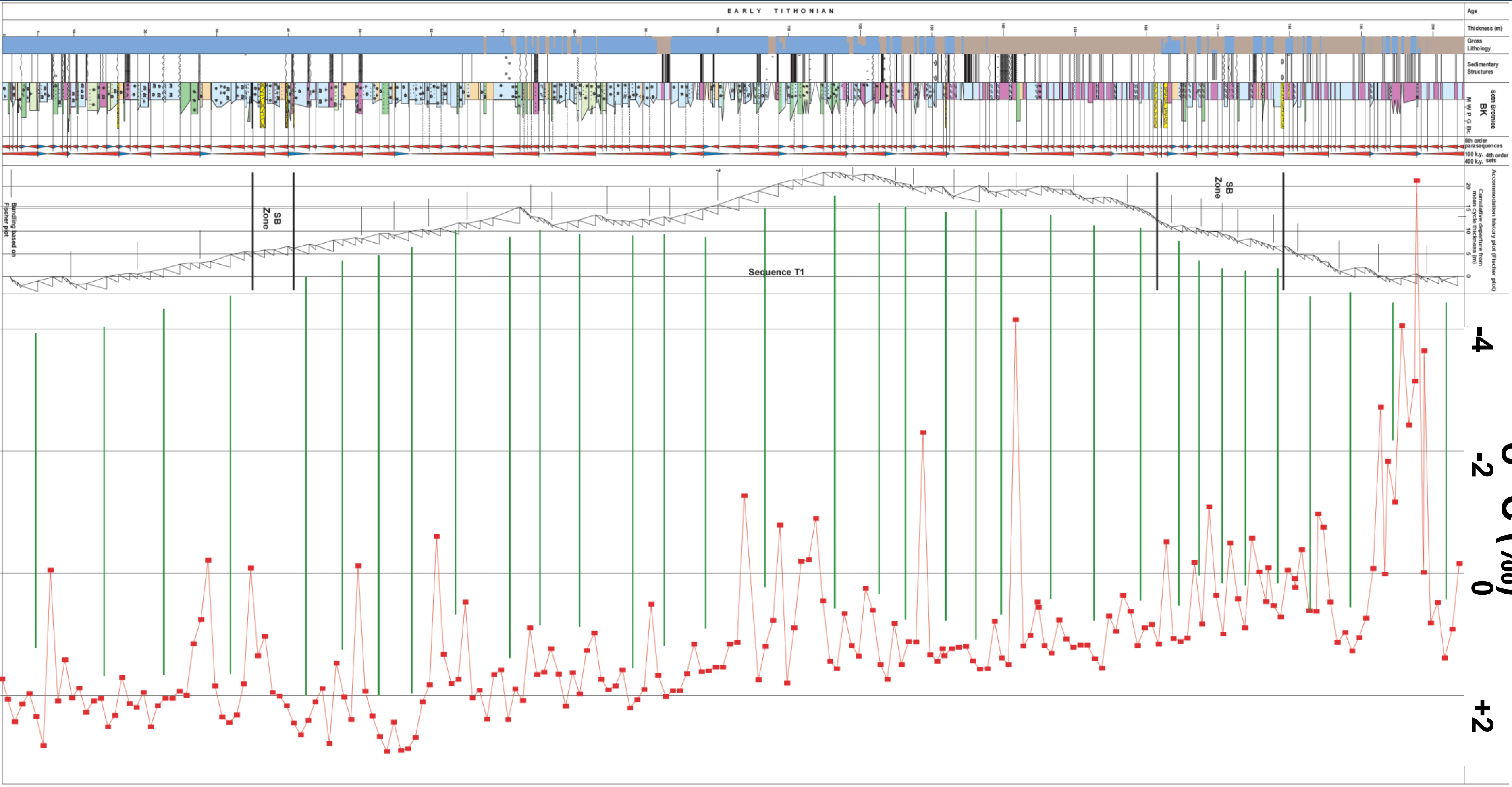
Strontium and Manganese versus $\delta^{18}O$ in dolomites





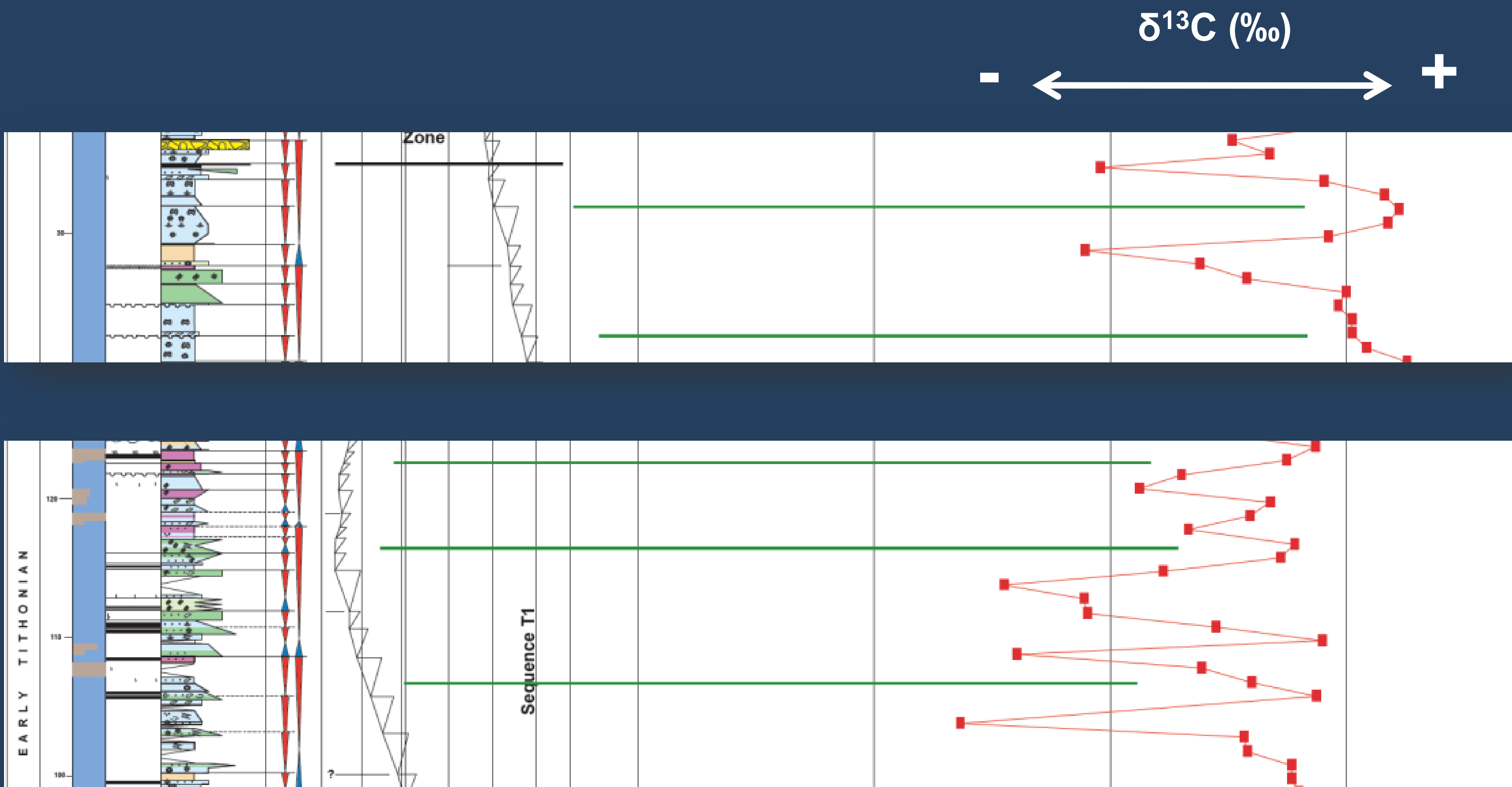
- Sr is low. Maybe due to stabilization of dolomite or may reflect low Sr/Ca precursor limestone of calcite seas
- Very low Mn suggests oxidizing near-surface marine phreatic waters (in tidal flats and by reflux on the open platform)
- CL shows dolomite is single generation and non-luminescent

Carbon isotopes within parasequence sets



- Within parasequence bundles some positive C-excursions appear to be in highstands; may be related to increased productivity shoreward
- However, some positive C-excursions are within the overall transgressive part; may be related to local or global sequestration of light carbon
- Light C-values in some caps may be due to sulfate reduction within mats

Carbon isotopes within parasequence sets



Conclusions

- Kimmeridgian supersequence 5-6 m.y., two 3rd order sequences. Tithonian supersequence 5-6 m.y., four 3rd order sequences
    - Match Haq and Al-Qahtani (2005) sea-level curve
- Parasequences ~precessional; supersequence TST → subtidal cycles, supersequence HST → peritidal cycles
- Parasequence sets (~100 k.y. bundles) commonly show positive $\delta^{13}C$ excursions near tops
- Dolomites: some are tidal flat, but most are related to reflux of slightly more saline marine waters
- Parasequences typical of greenhouse conditions, within Lower Jurassic-Early Cretaceous cool mode of Frakes et al. 1992

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