

Sequence Stratigraphic Characterization of a Microbially-Influenced Carbonate Ramp: Khufai Formation, Sultanate of Oman*

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Abstract

The Khufai Formation is a thick, microbially-influenced carbonate ramp preserved within the Ediacaran to earliest Cambrian age Huqf Supergroup. The Khufai ramp is exposed in two major areas in Oman including the Huqf-Haushi High where inner- to outer- ramp facies are preserved, and in the Oman Mountains that feature correlative distal ramp deposits. Here we present the results of detailed sequence and litho- stratigraphic analysis of the Khufai Formation.

The Khufai Formation spans one and a half 3rd order depositional sequences and exhibits extensive cyclic depositional patterns at finer scales. A maximum flooding surface occurs in the basal Khufai Formation within outer- and mid-ramp intraclast wackestones and packstones. Much of the deposition occurs above this surface as the ramp prograded, forming a highstand system tract. A type 2 sequence boundary is located within the upper microbially-dominated peritidal facies and is marked by a systematic increase in parasequence thickness. The transition into the overlying Shuram Formation is marked by a transgressive oolite, micritic microbial bioherms, and rapid flooding of the ramp surface.

Significant facies variability is observed both laterally along a given depositional profile and through time as the ramp profile evolved. Microbially-dominated facies were particularly responsive to changes in relative accommodation and wave energy. These facies range from the deep water crinkly laminites observed in the Oman Mountains to the heavily silicified irregular laminites and domal to tufted stromatolites that comprise much of the peritidal deposits in the Huqf. Within the later facies group, higher relative accommodation corresponds to increased synoptic relief on microbial accumulations. Additional depositional variability appears to reflect the influence of syn-sedimentary faulting and influx of clastic material into particular parts of the basin. The presented sequence stratigraphic model will allow for greater understanding of the nuances of Khufai Formation deposition, along with its potential as a target for hydrocarbon exploration.

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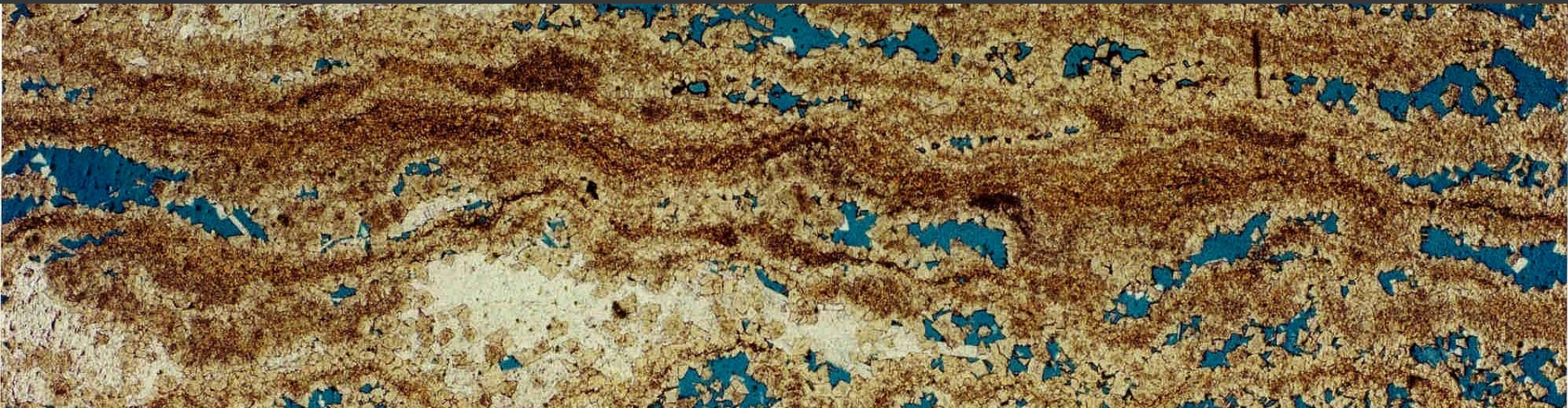
California Institute of Technology



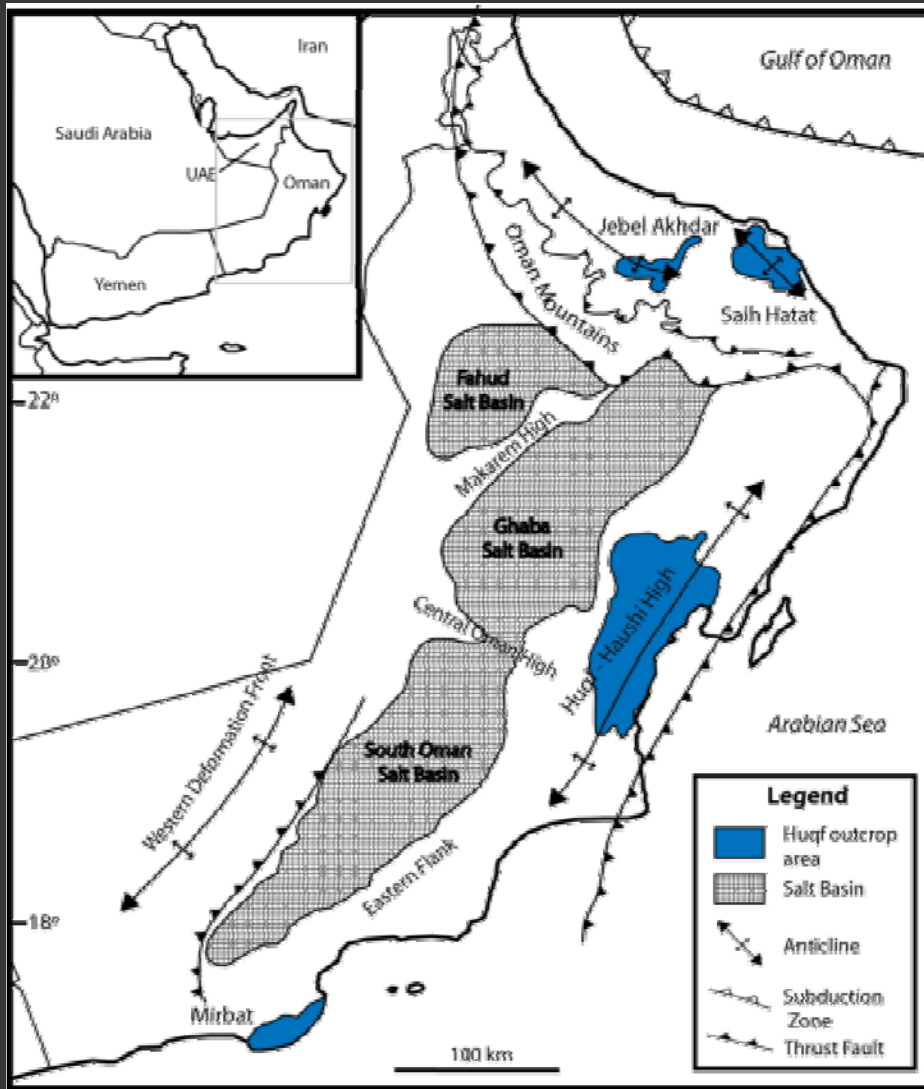
Motivation



- Microbial reservoirs are a frontier in global exploration
- In Oman, producing from a Precambrian microbial reservoir since 1970
- Principles of Precambrian microbialites apply in the Phanerozoic in times of reduced metazoan predation (i.e. mass extinction, lacustrine)
- Need to understand these microbialites with a predictive framework

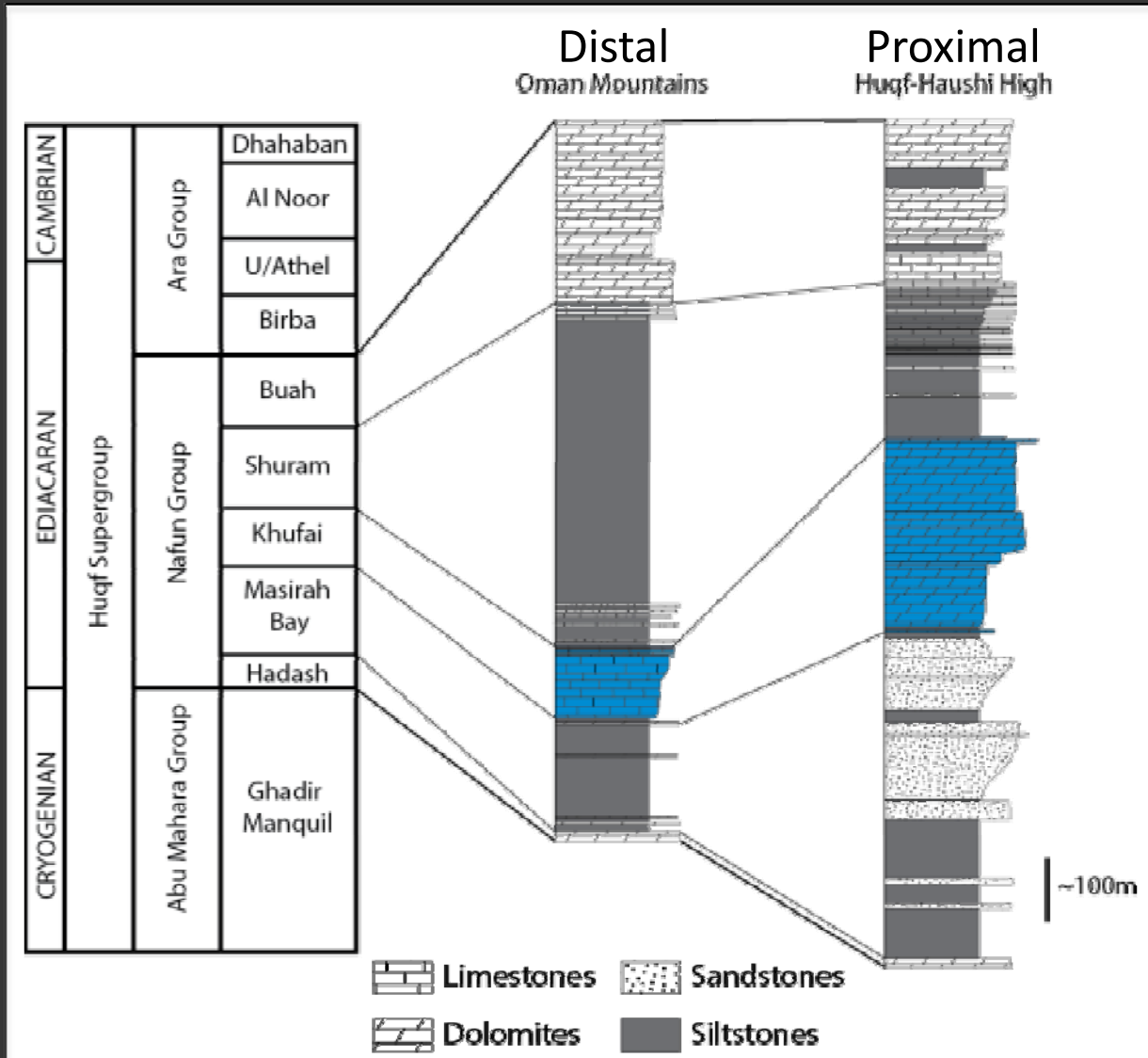


The Huqf Supergroup



- Latest Precambrian to early Cambrian time
- Carbonates, siliciclastics, and evaporites
- Exposed in four main outcrop areas across Oman and in numerous subsurface penetrations
- Previously work by Gorin, Wright, McCarron, Allen, and Bowring

The Khufai Formation

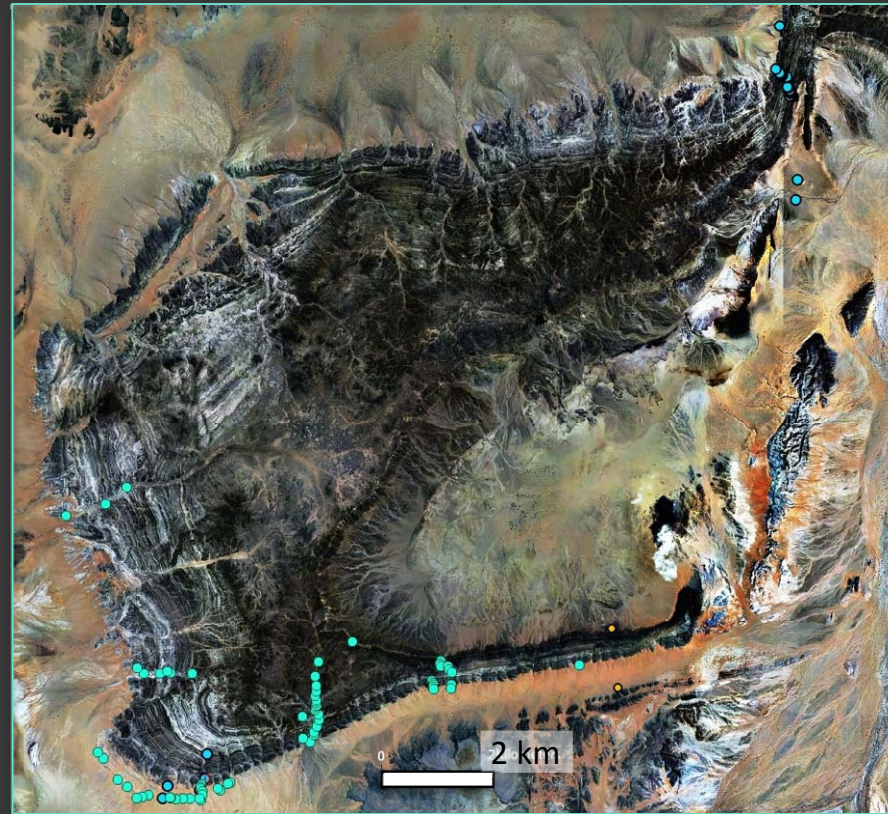


- First major carbonate of the Huqf Supergroup
- Bounded above and below by siliciclastics
- Distal facies preserved in the Oman mountains
- Platform facies preserved in the Huqf Area

The Khufai Formation



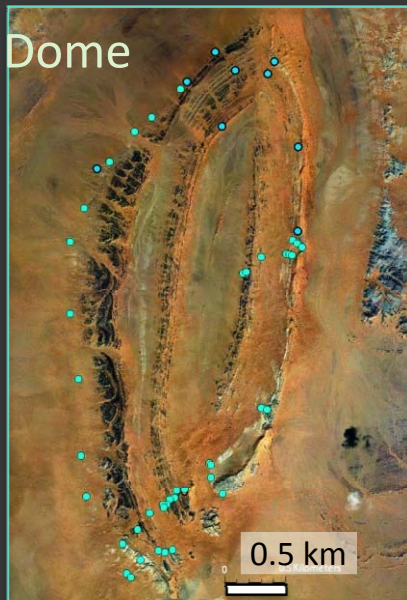
Khufai Dome



Mukhaibah Dome



Buah Dome



Lithostratigraphic Overview



Lithostratigraphic Overview



- At the largest scale the Khufai Formation records the progradation of a large carbonate ramp
- Facies range from outer-ramp deposits at the base, through grainstone shoals, into a large sequence of subtidal to supratidal parasequences
- The upper boundary is marked to a transgressive surface flooding into the overlying Shuram Formation

Outer- and middle-ramp



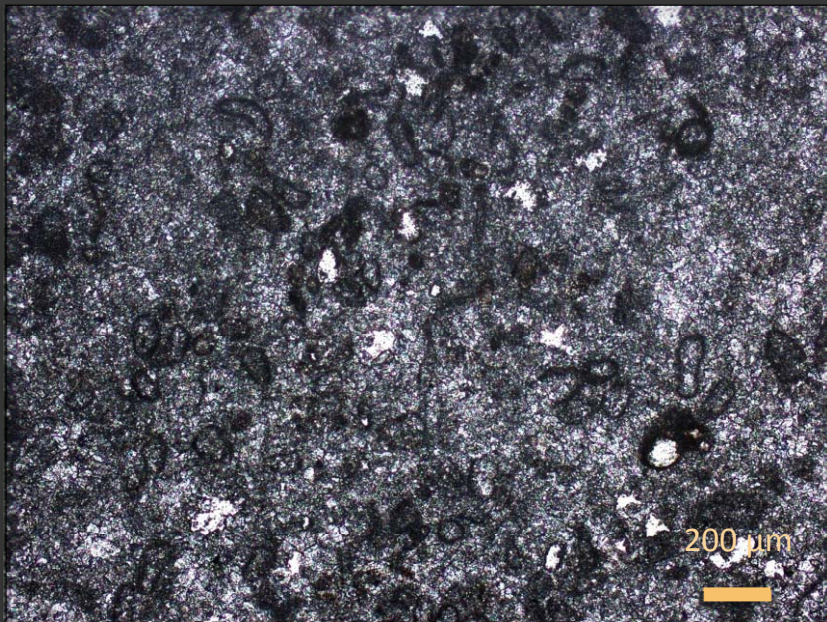
- Fetid thick laminated mudstone
- Peloidal intraclast wackestone/packstone
- Hummocky cross-stratified packstone
- Argillaceous planar laminated mudstone



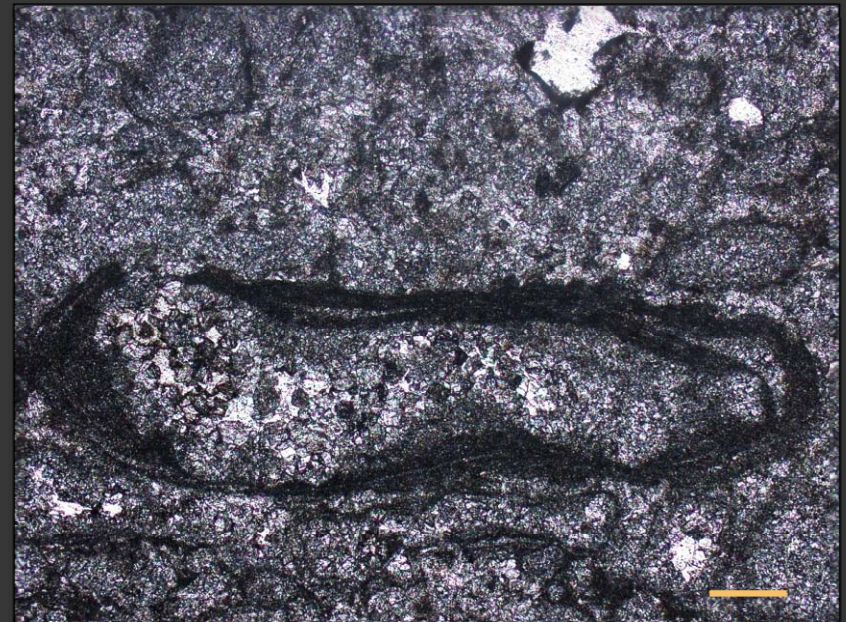
Inner-ramp: Subtidal



- Peloidal grainstones



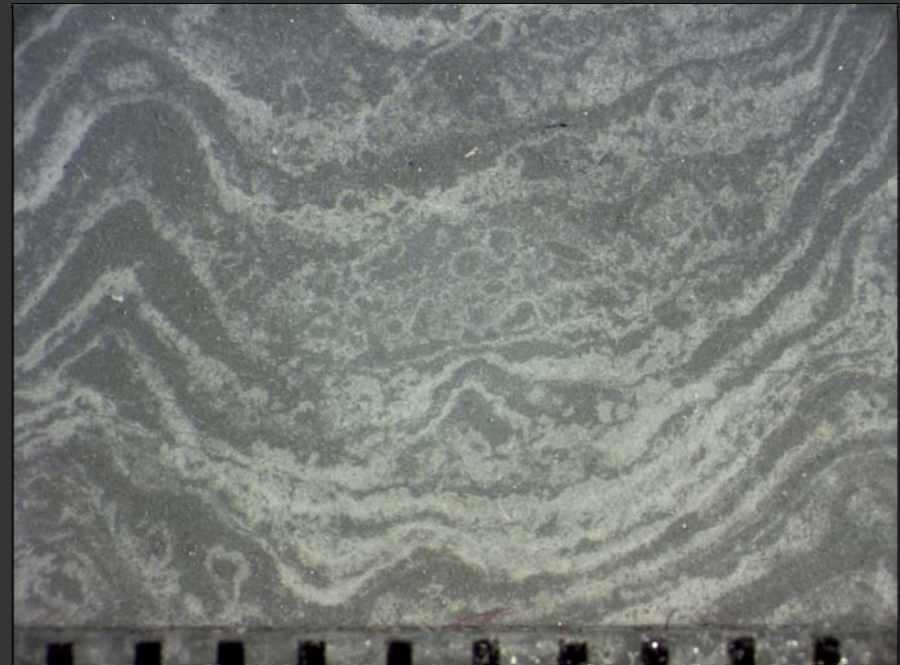
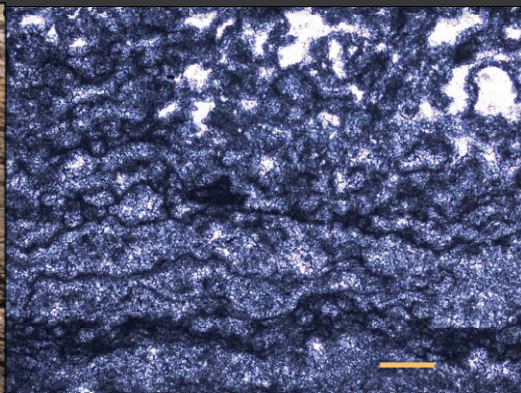
- Oncolite grainstones



Inner ramp: peritidal microbialites



- Oncolite grainstones/ boundstones
- Irregular laminite/ stromatolite
- Tufted laminite/ stromatolite



Inner ramp: parasequences



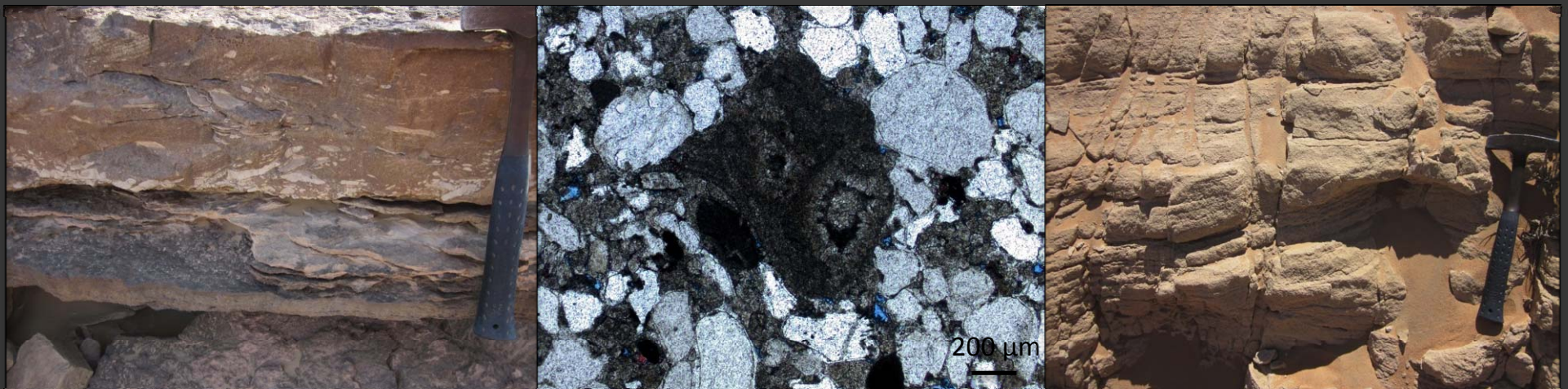
- Smooth-laminated stromatolite
- Tepee associated facies
- Intraclast conglomerate
- Fenestral mudstone
- Peritidal grainstone



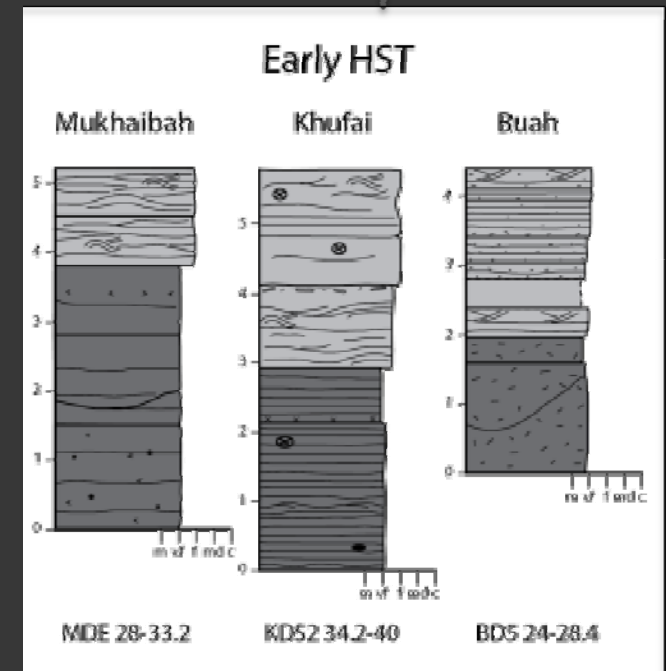
Inner ramp: siliciclastics



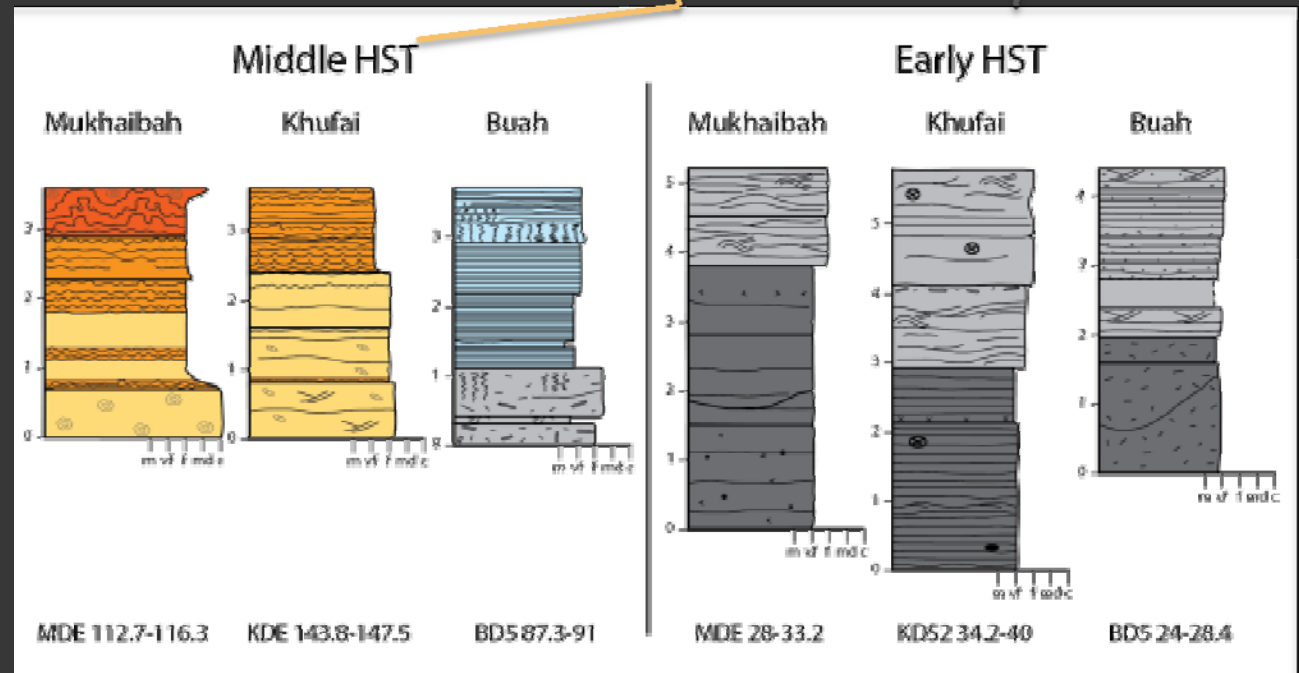
- Quartz arenites
- Mixed calc to quartz arenites (Buah)



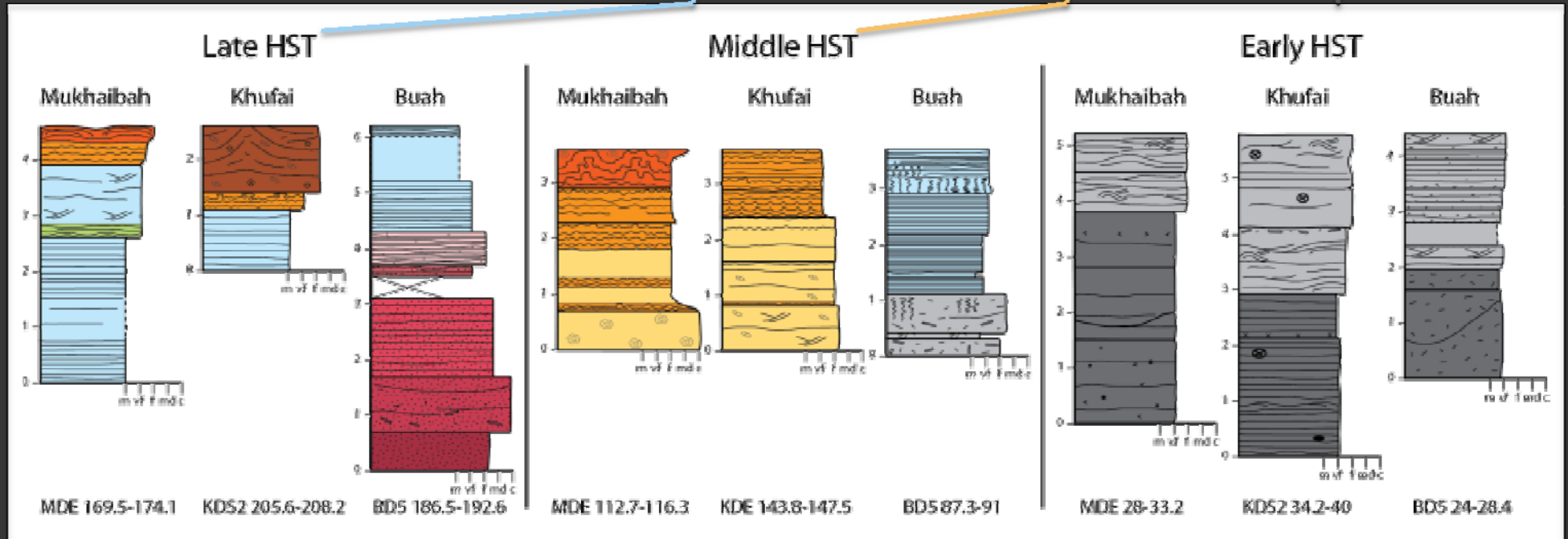
Parasequence definition



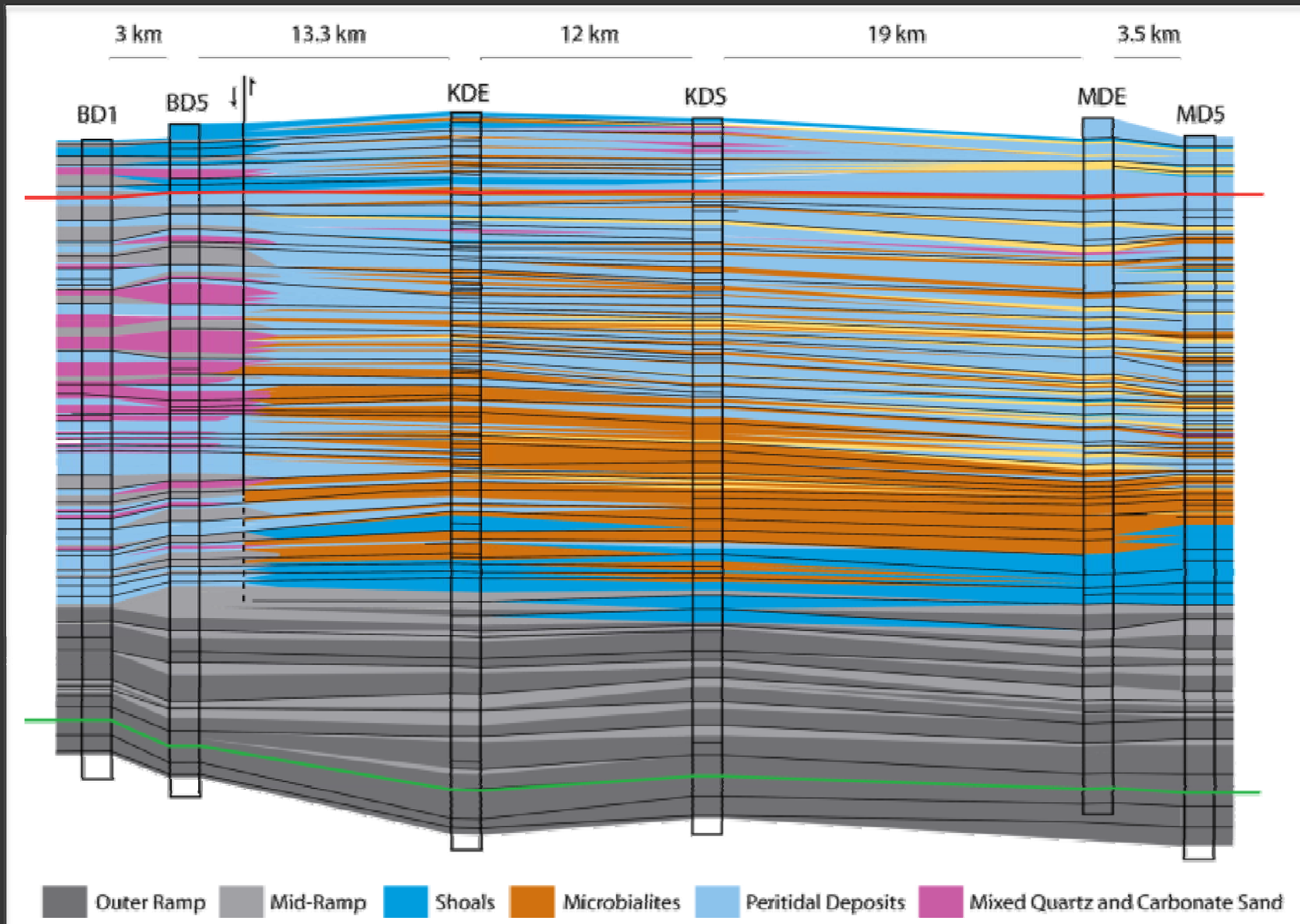
Parasequence definition



Parasequence definition



Correlation

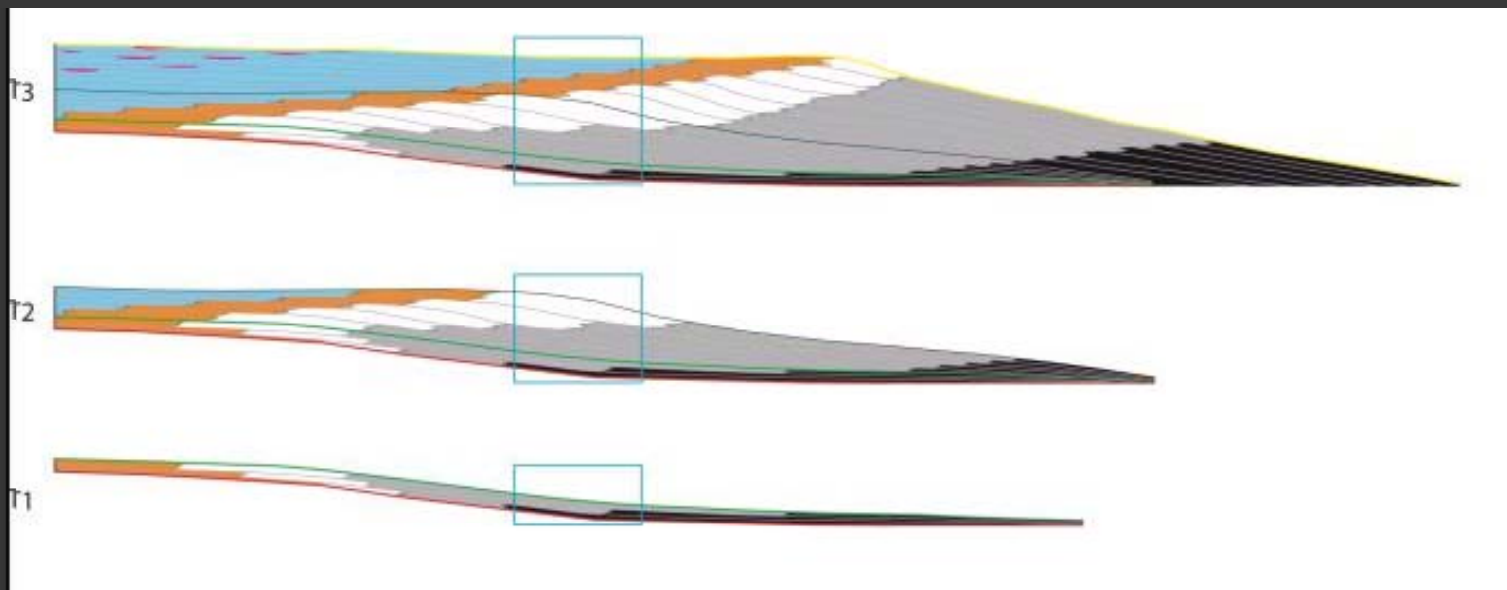


Depositional model

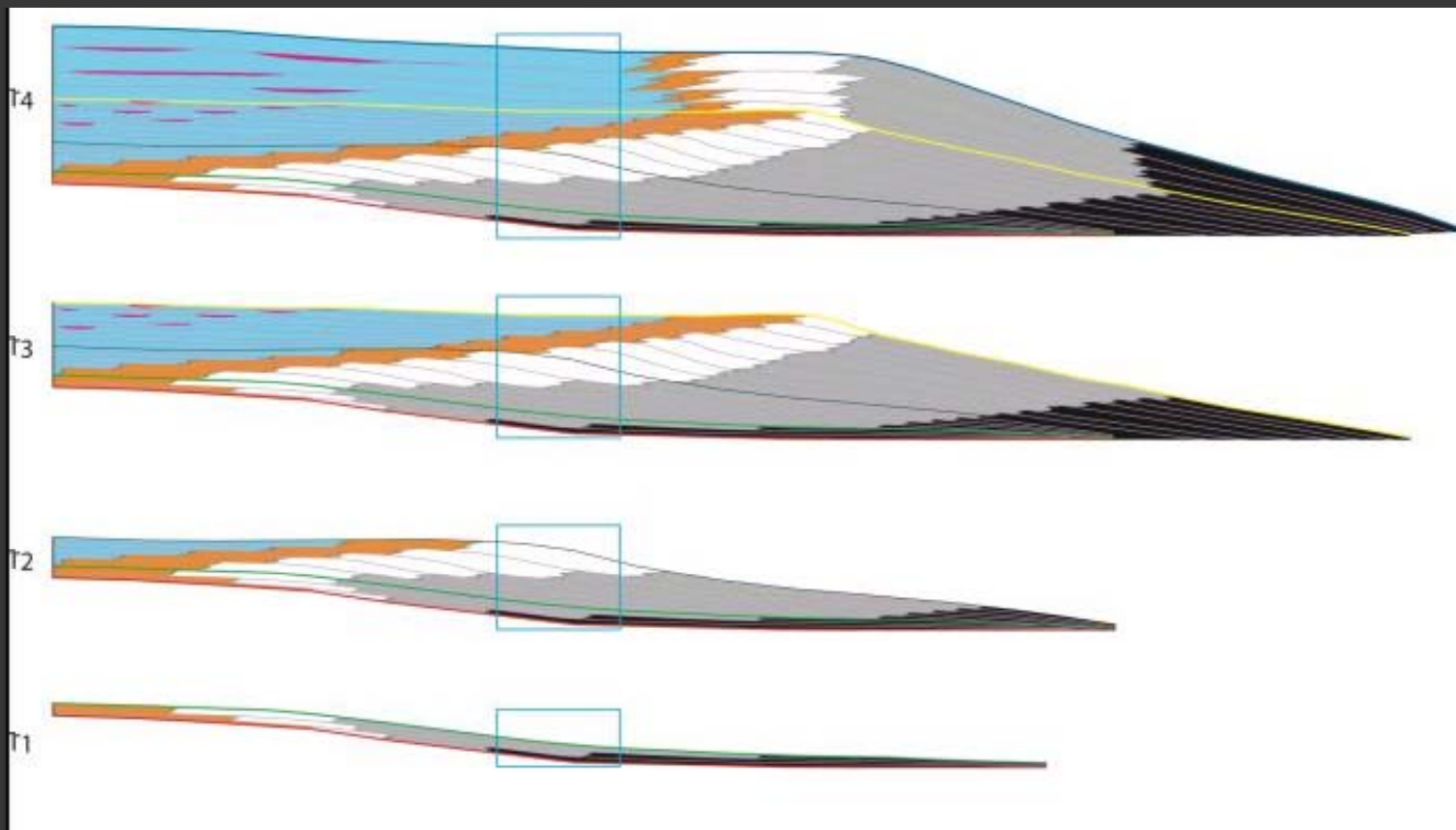


- quartz sand
- cyclic peritidal facies
- microbial flats
- grainstone shoals
- intraclast packstone/wackestone
- silt
- SB1
- MFS
- SB2
- TS

Depositional model

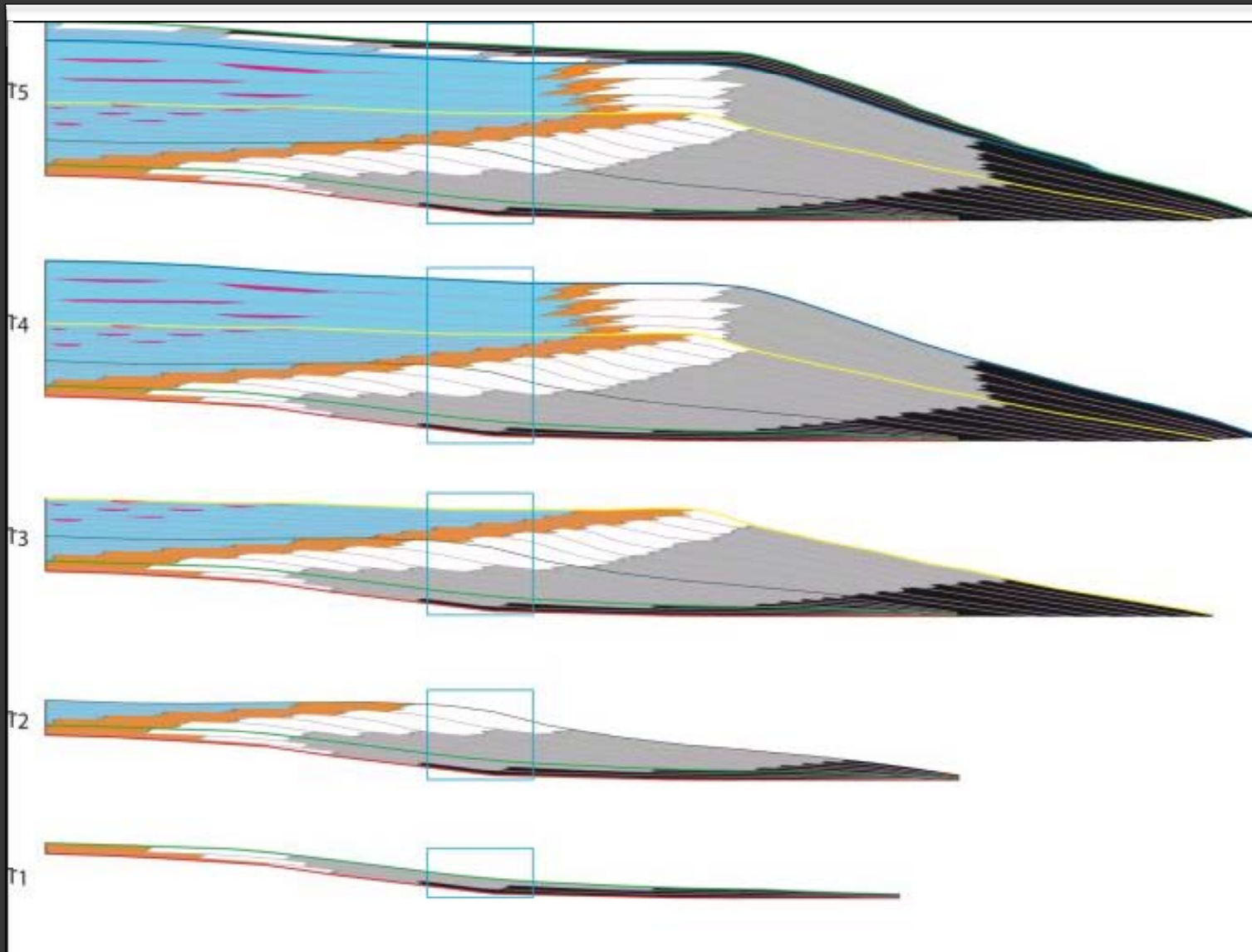


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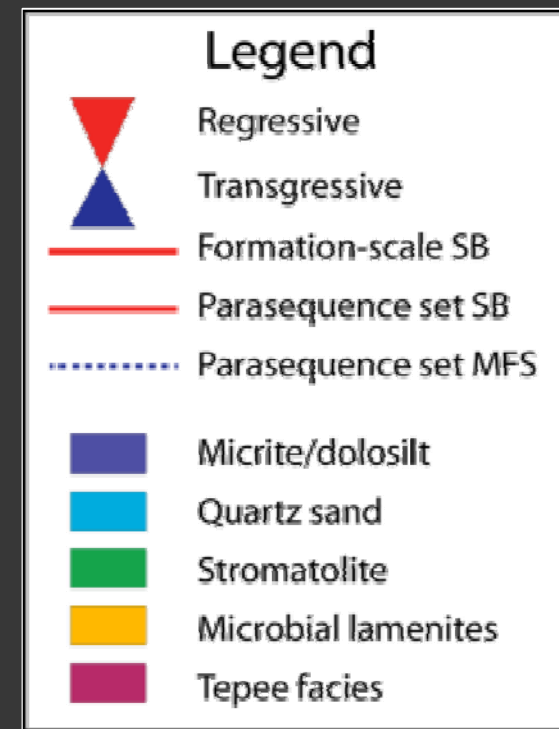
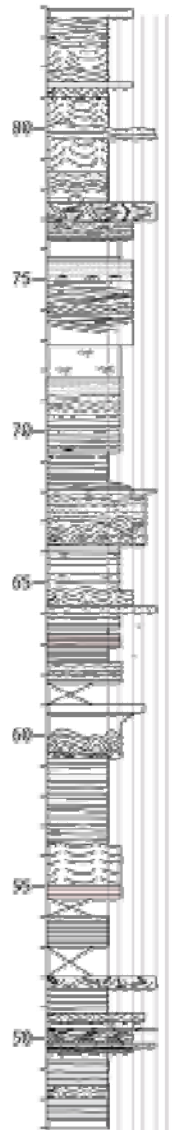


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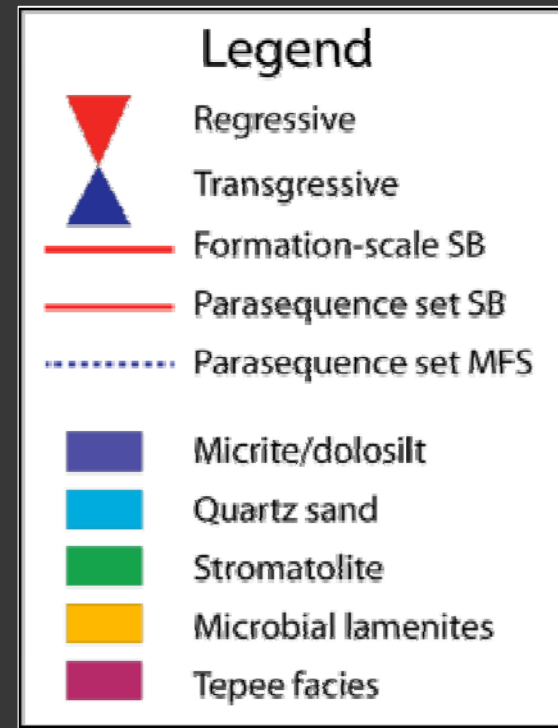
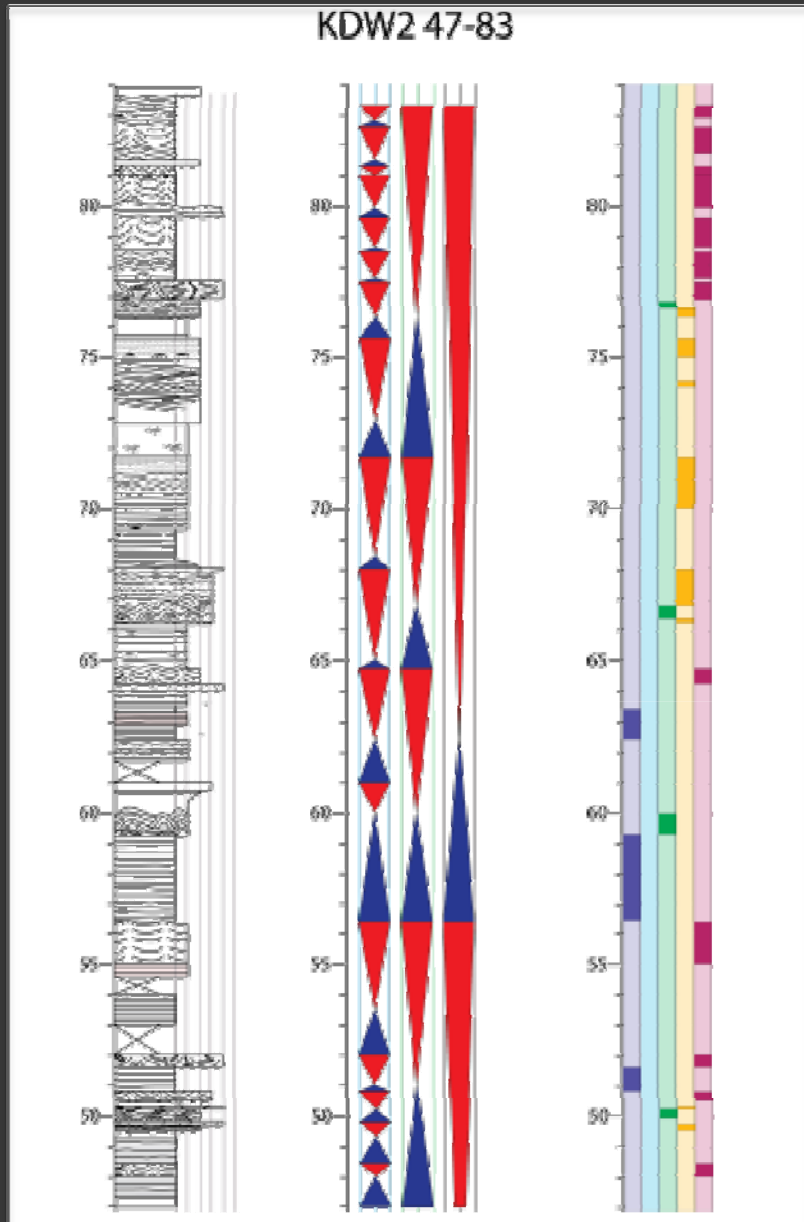
High resolution stratigraphy



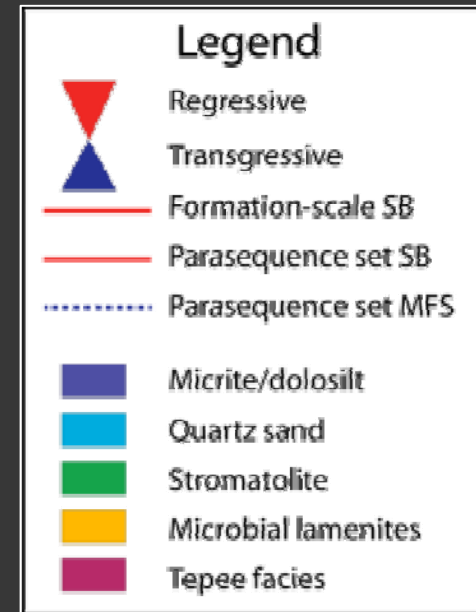
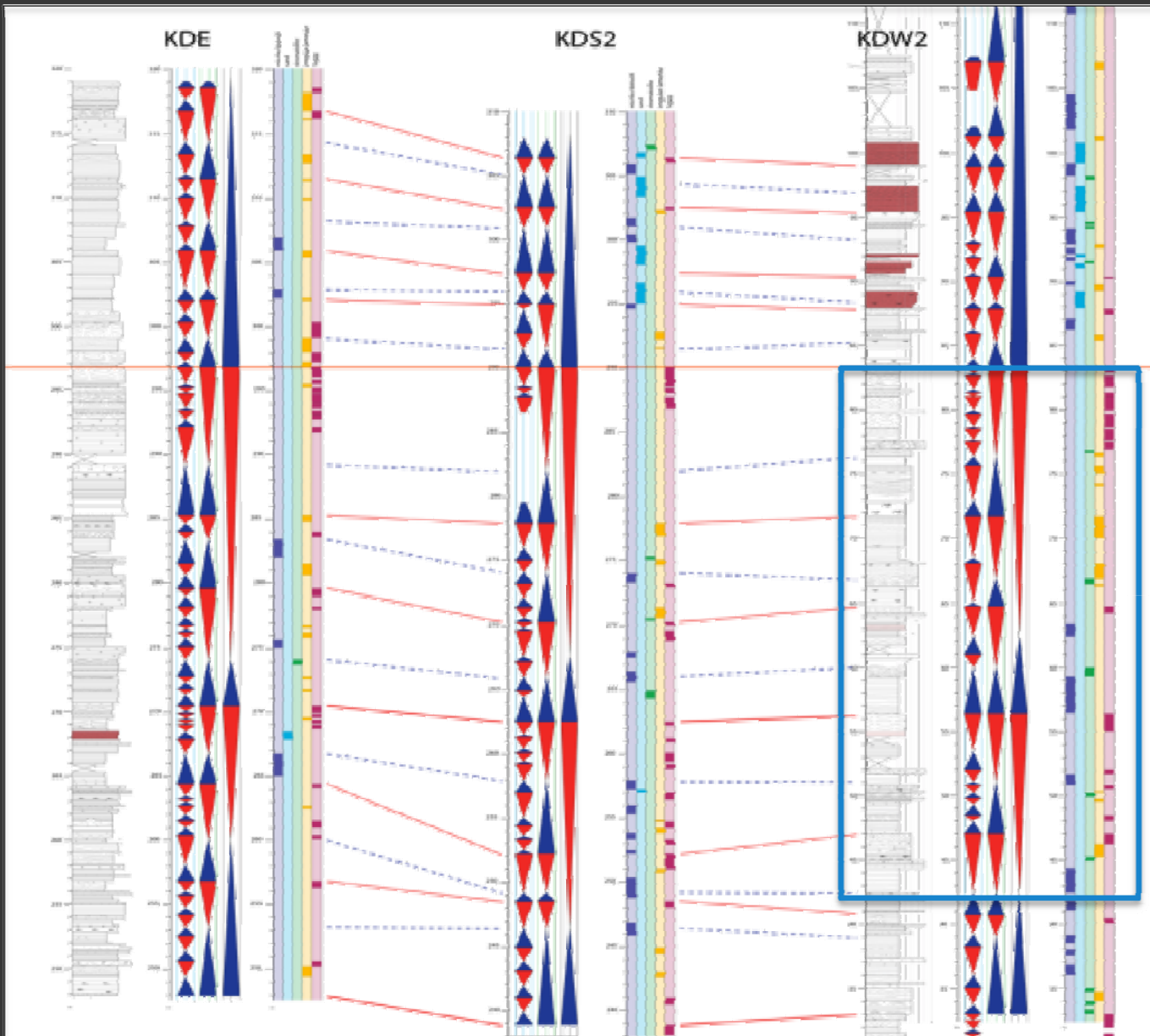
KDW2 47-83



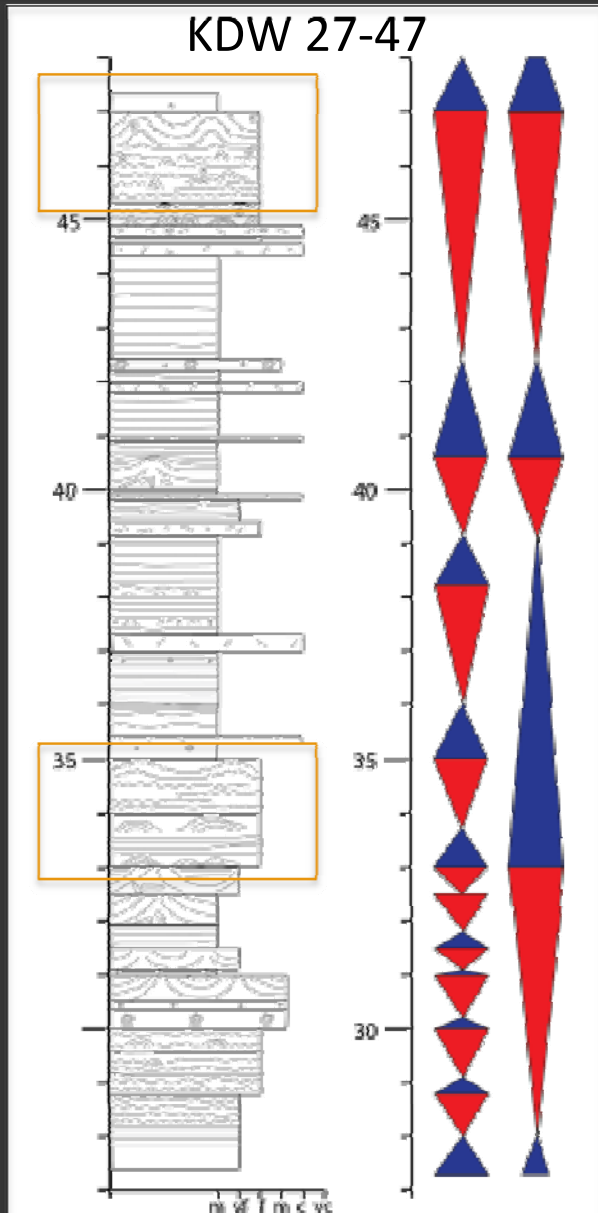
High resolution stratigraphy



High resolution stratigraphy



Cycle-capping Microbialites



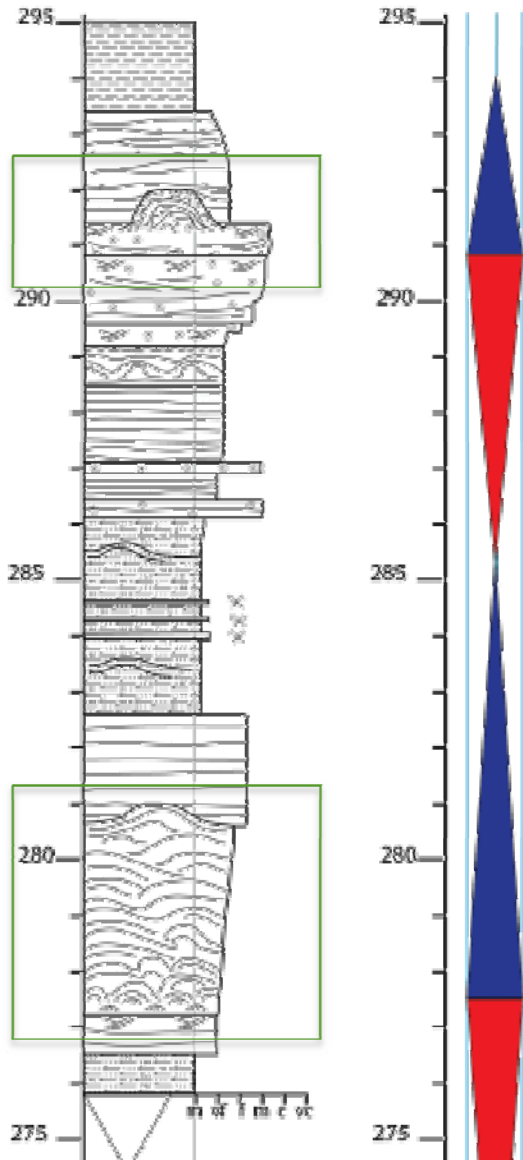
- Low amplitude
- Patterns of decreasing accommodation
- Tend to be heavily silicified, low porosity



Transgressive Microbialites



MDE 276-295



- Large, high amplitude
- Build during flooding events in a “keep-up” style, similar to modern coral
- Retain significant original porosity



Main Points



- The Khufai Formation records the development of a large scale carbonate ramp in the Ediacaran
- Significant facies variability is observed both through time as the ramp evolved and laterally along a given depositional profile
- Detailed sequence stratigraphic analysis records at least 4 scales of cyclicity ranging from the parasequence to formation scale
- Microbial facies vary in response to stratigraphic, depositional, and lithological environments

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- Coauthors:



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