Interwell-Scale Heterogeneity in an Upper Jurassic Carbonate Ramp*

Mahmoud H. Alnazghah[1] , Luis Pomar[2], Marc Aurell[3], and Beatriz Bádenas[3]

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[1]Reservoir Characterization Department, Saudi Aramco, Dhahran,Saudi Arabia (mahmoud.hasan@live.com)
[2]Departament de Ciencies de la Terra, University of the Balearic Islands, Palma de Mallorca, Spain
[3]Departamento de Ciencias de la Tierra, University of Zaragoza, Zaragoza, Spain

Abstract

The well-exposed Upper Kimmeridgian carbonate ramp between Jabaloyas and Arroyo Cerezo, Iberian Basin, Eastern Spain, provides an excellent analog to stratigraphically equivalent subsurface reservoirs, such as the carbonate ramps of the Arab-D of the Middle East and Smackover of the Gulf of Mexico. Critical questions regarding interwell-scale heterogeneity and correlation motifs for low-angle ramp systems can be addressed using continuous exposures that encompass a full range of inner to outer ramp facies. Outcrops in this area provide complete and extensive (> 10 km) 3D exposures of the ramp succession in both depositional dip and strike directions.

At Arroyo Cerezo, a 40 m thick and 2 km long, dip-oriented continuous section has been studied in detail. Lithofacies and bounding surfaces have been mapped on a continuous photomosaic and were complimented by five measured sections (500 m spacing) and petrographic analysis. Facies recognized (in down-dip direction) include: 1) low-energy oncolitic rudstone-floatstones and peloidal-skeletal wackestones-packstones, 2) moderate-energy packstones-grainstones with different proportions of peloids, bioclasts, ooids and oncoids, and 3) high-energy ooid-peloid-oncoid and intraclast grainstones that pass down-dip into wackestone-packstones of the offshore proximal environment. Coral-microbial mounds commonly occur in mid-ramp settings.

Detailed interwell-scale mapping of continuous dip-oriented exposures documents distinct prograding ramp clinothems with transitions from inner- to middle-ramp settings occurring within 2 km, where maximum depositional dips are less than one degree. This facies transition compares closely to that observed in many time-equivalent reservoir settings, where relatively short-length facies dimensions and steep depositional dips differ significantly. The Arroyo Cerezo outcrop indicates that the apparent ramp-facies

continuity, when based on a 5 km well log correlation, is most likely a lithostratigraphic perspective. Use of detailed spatial and temporal analysis of high-quality outcrop analogs promotes more realistic models for understanding the interwell, meter-scale heterogeneity governing reservoir fluid movement, and may help optimize and enhance hydrocarbon production.

Reference

Markello, J.R., R.B. Koepnick, L.E. Waite, and J.F. Collins, 2008, The carbonate analogs through time (CATT) hypothesis and the global atlas of carbonate fields; a systematic and predictive look at Phanerozoic carbonate systems: Special Publication Society for Sedimentary Geology, v. 89, p. 15-45.

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*(1) Reservoir Characterization Department, **Saudi Aramco,** Dhahran, Saudi Arabia.*
*(2) University of the Balearic Islands, **Palma de Mallorca,** Spain.*
*(3) University of Zaragoza, **Zaragoza,** Spain.*

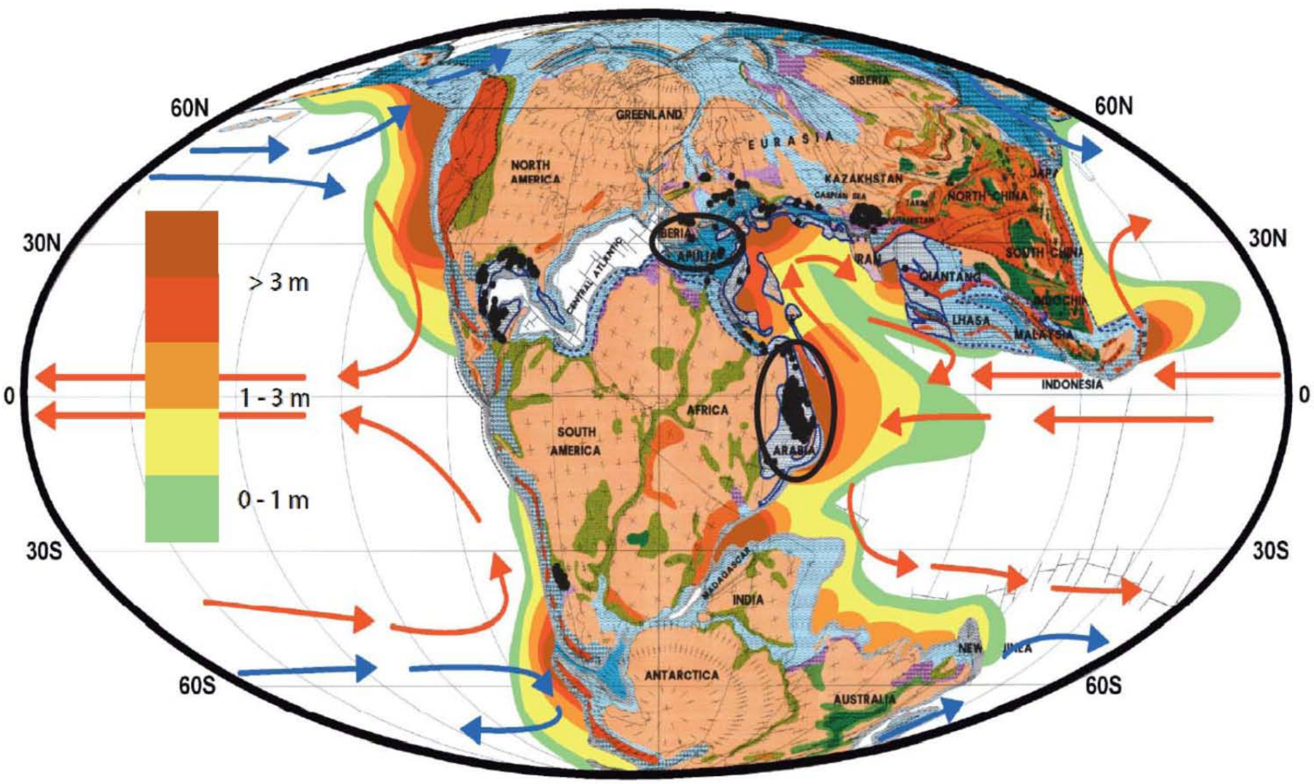
Introduction

- Importance of defining reservoir-scale facies architecture within the framework of high resolution sequence stratigraphy.
- Outcrop analogues are needed to address spatial and temporal distribution.
- Torrecilla Formation as facies and time equivalent.
- Detailed mapping of the facies belts.
- Five measured section at interwell spacing (~250 m apart).

Notes by Presenter:
As part of the Jurassic sequence stratigraphy program in Saudi Aramco, we identified importance of defining reservoir-scale facies architecture within the framework of high resolution sequence stratigraphy.
- This called for an outcrop analogue to address the spatial and temporal distribution of key facies, to help understand the Jurassic and specifically, Arab D.
-To this end, we identified the Torrecilla Fm in Spain as facies and time equivalent to the Arab D.
-The purpose: To document the facies and the architecture of the upper Kimmeridgian ramp outcropping in Arroyo Cerezo in a continuous . To resolve a reasonable scale of facies continuoity versus diachronoity.

Late Jurassic Setting Comparison

Late Jurassic Palaeo-Tidal Range



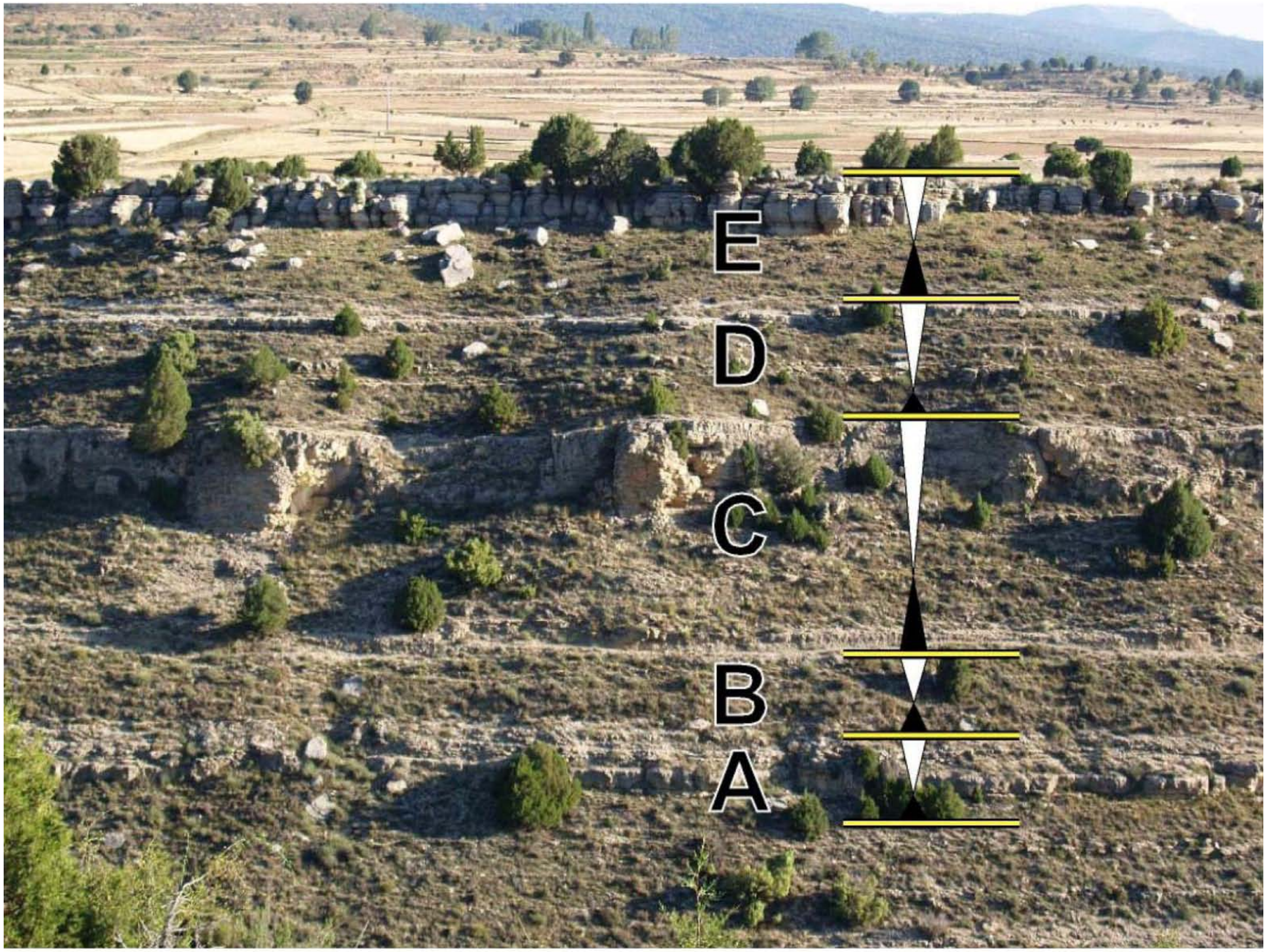
Modified from Markello et. al (2008)

Notes by Presenter:

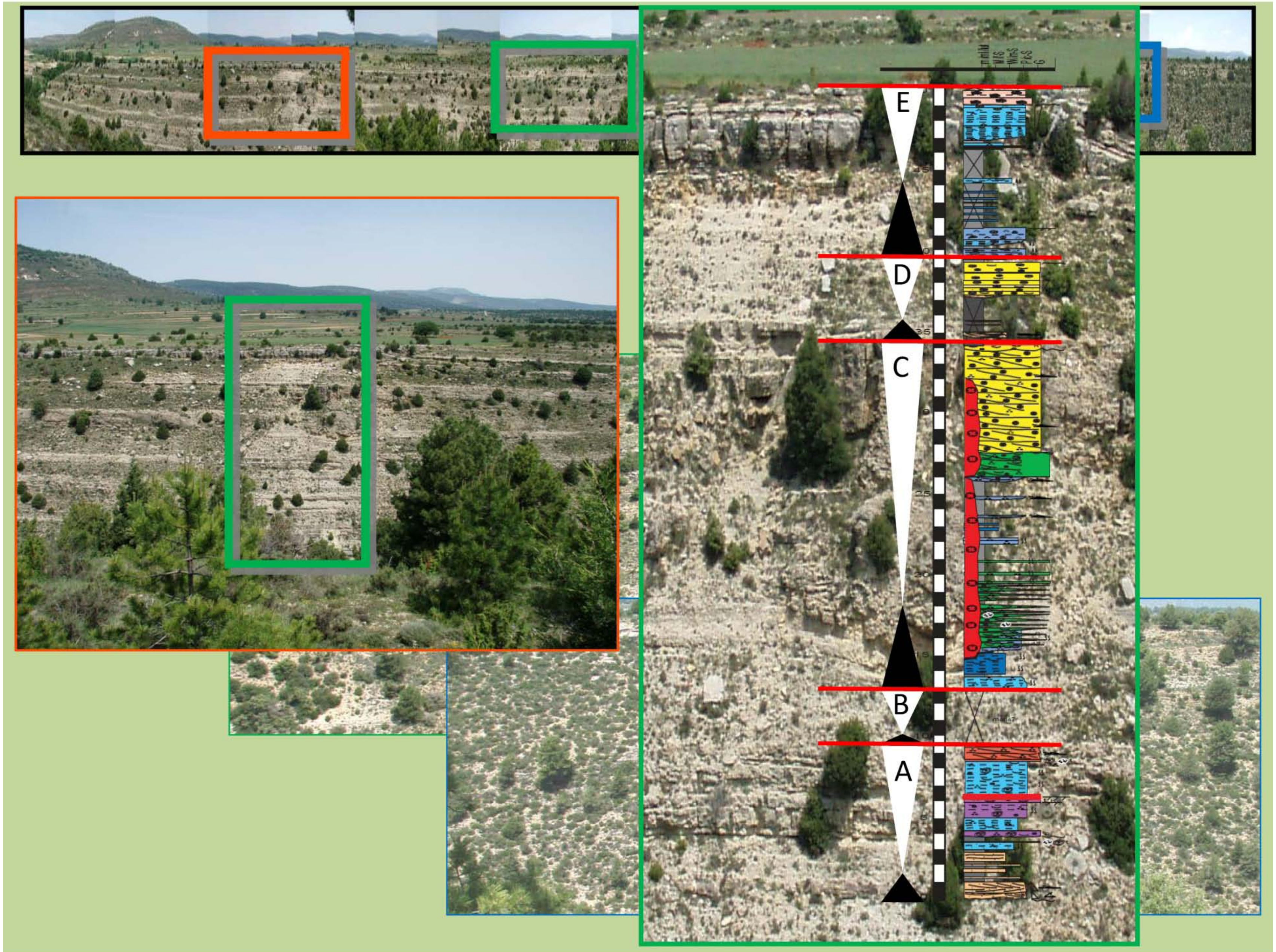
-This is a quick comparison between the Arabian and the Iberian basins – both are in intra-cratonic basins that have been filled with Mesozoic, greenhouse, shallow marine deposits, and both were open to the Tethys from the east. The palaeo-latitude of the Arabian basin was located at the equator, while the Iberian basin is located at 25 – 30° N of the equator.

- This map shows the palaeo-oceanic surface temperatures . We can see that both basins exhibit the same range.

- This map shows the palaeo-tidal range and both basins appear to be in the same range, more or less, even the though the Arabian basin is slightly higher.

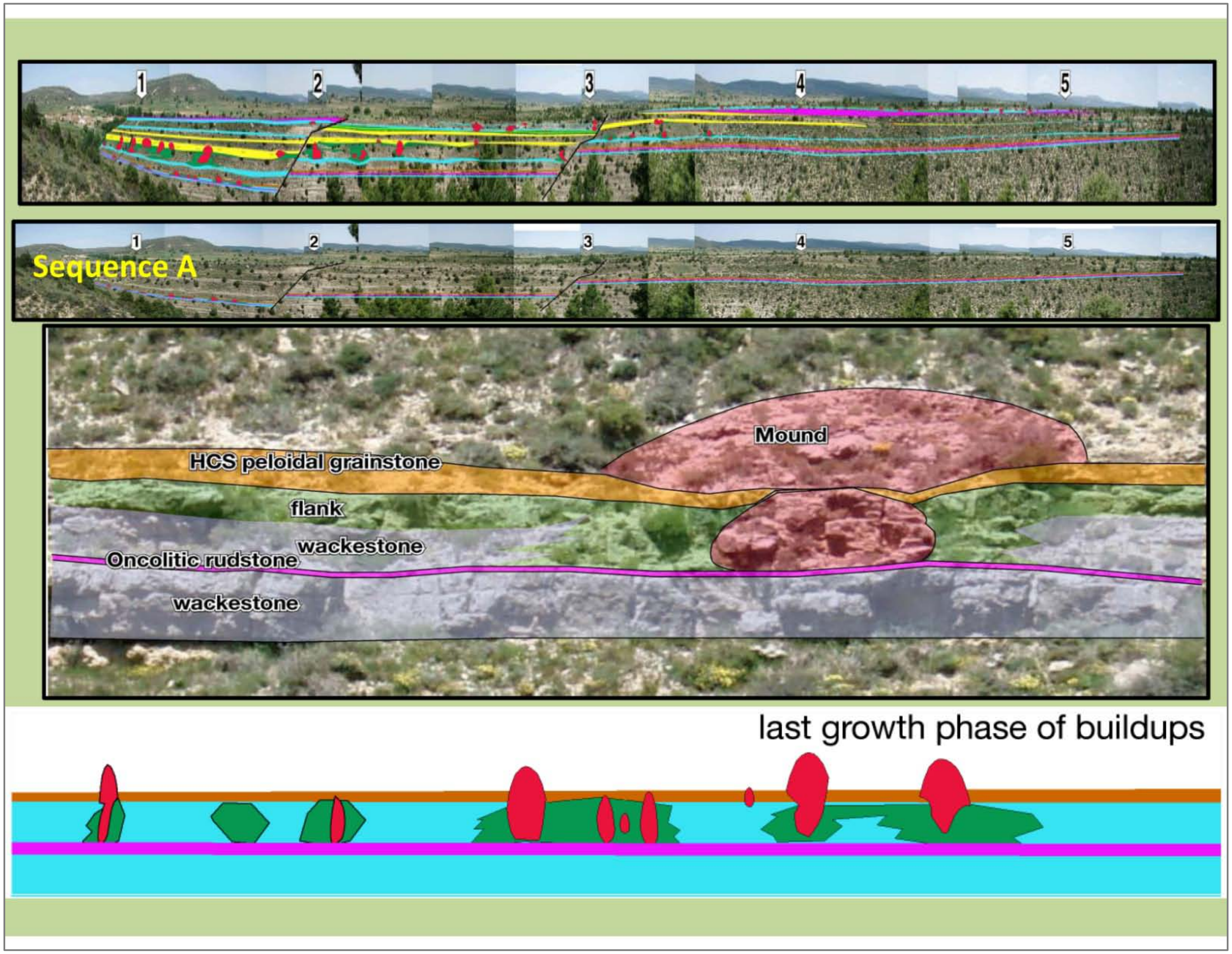


Notes by Presenter:
-This is a late Kimmeridgian map of the Iberian basin showing our study area in the red square focusing in Kim 2 composite sequence deposited in middle ramp.
THIS IS THE STRATIGRAPHY OF THE UPPER JURASSIC rocks in the studied area
1 – these rocks accumulated on a wide carbonate ramp, facing the Tethys Ocean to the east.
2 - We worked the Torrecilla Fm, Time-equivalent and with some Facies-similarities to the Arab-D
3 - Aggrading and prograding carbonate ramp –at 10's km scale, log correlation provides a "layer-cake" stratigraphy
3A- Shows the studied area which is correlated across using meausred section spaced at roughly 5 km. They show aggradation and progradation.
4 – the studied area, is 2 km section in dip direction.
5 – previous works have differentiated up to 5 high-frequency sequences within the Late Kimmmeridgian sequence.



Notes by Presenter:

- This shows the outcrop from West to East! And this is a measured section that we will go each high frequence sequence, except B because it is not well exposed in our study area.

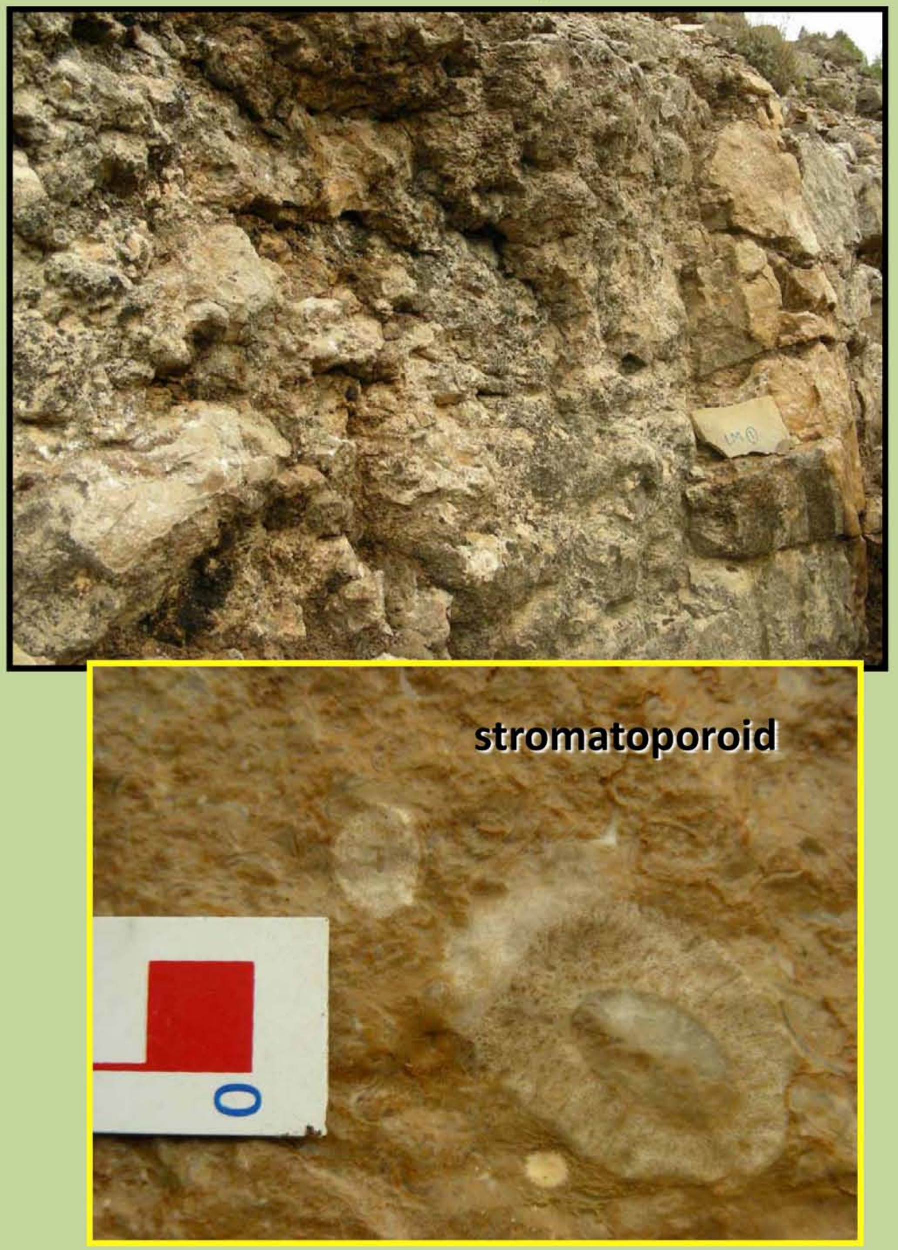


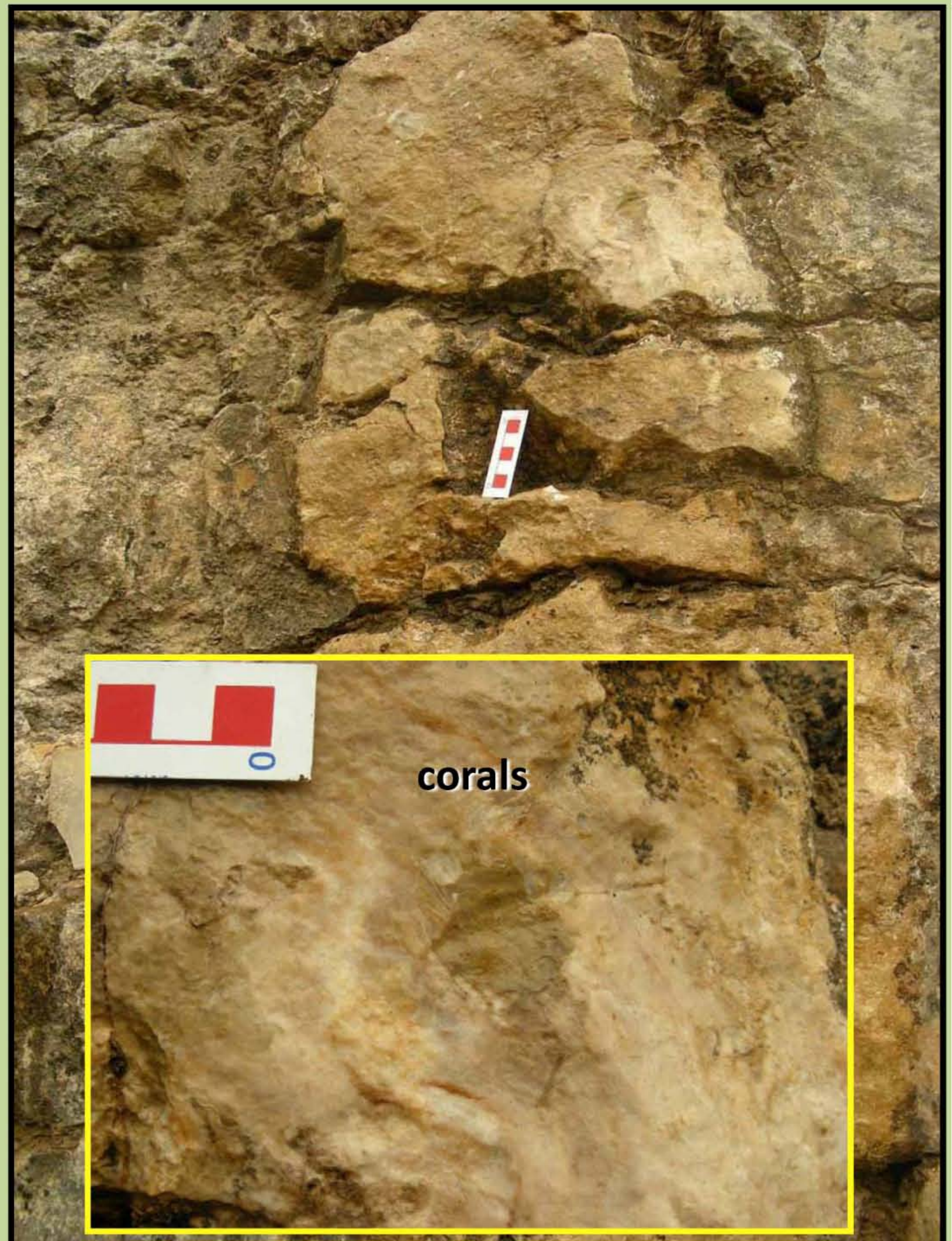
Notes by Presenter:
This is the outcrop with all HFS mapped, and we will start with Sequence A.
SEQUENCE A: Only a small part of sequence A has been mapped in detail, because bad outcrop quality and we will go through the details we collected.

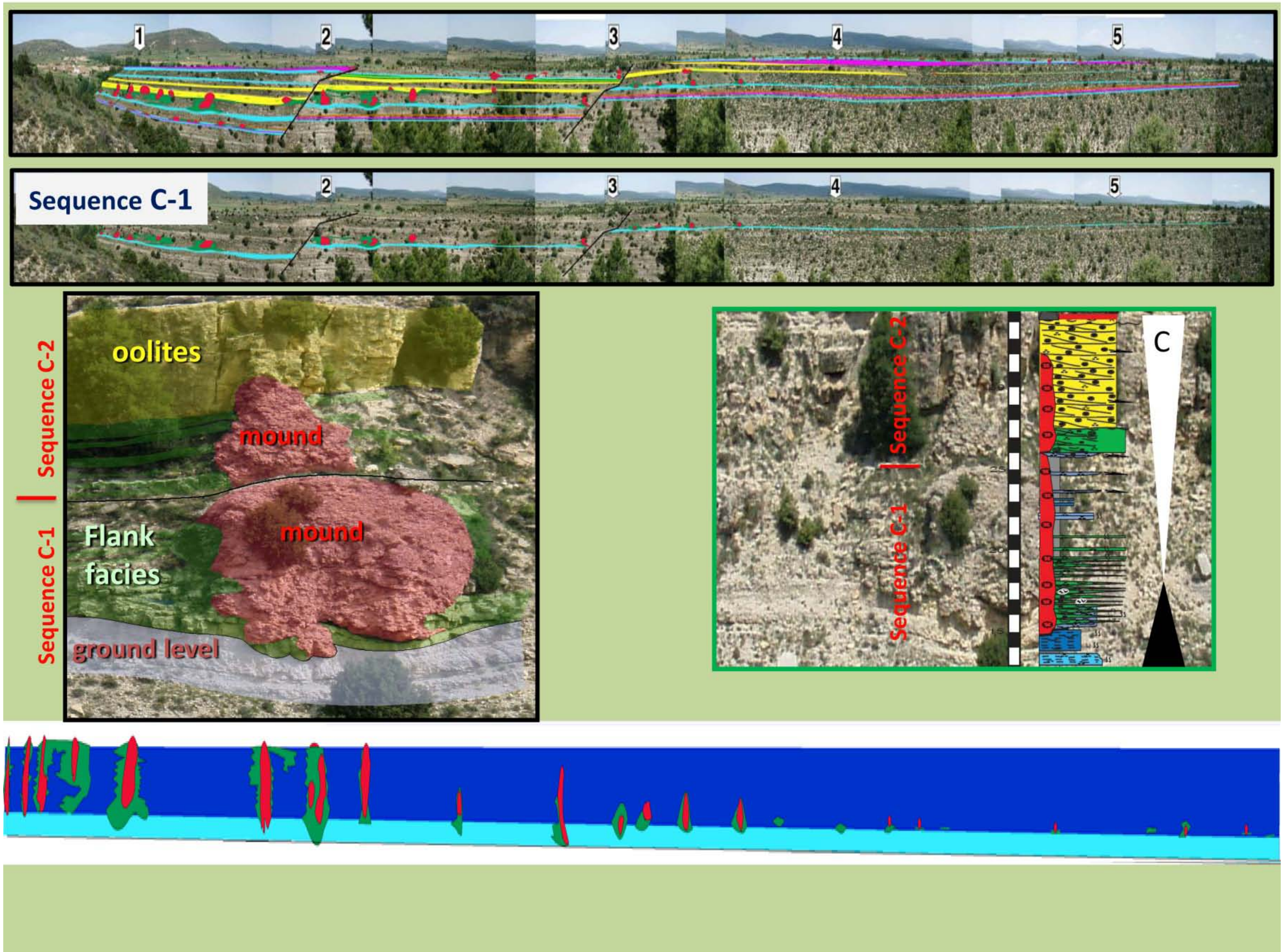
This is a cartoon showing the depositional episodes of the sequence. Starting with the deposition of the ground level, oncolitic rudstone, buildup growth and development of flank facies. Followed by the deposition of HCS Pelo Grst and another stand of buildup growth occurred preferring the position of previous buildup.
Similarly, sequence B, has not been mapped because the bad quality of outcrop
(in fact, I cannot see the reason for this sequence to be differentiated)

Sequence A – Ground Level

Sequence A - Reef







Notes by Presenter:

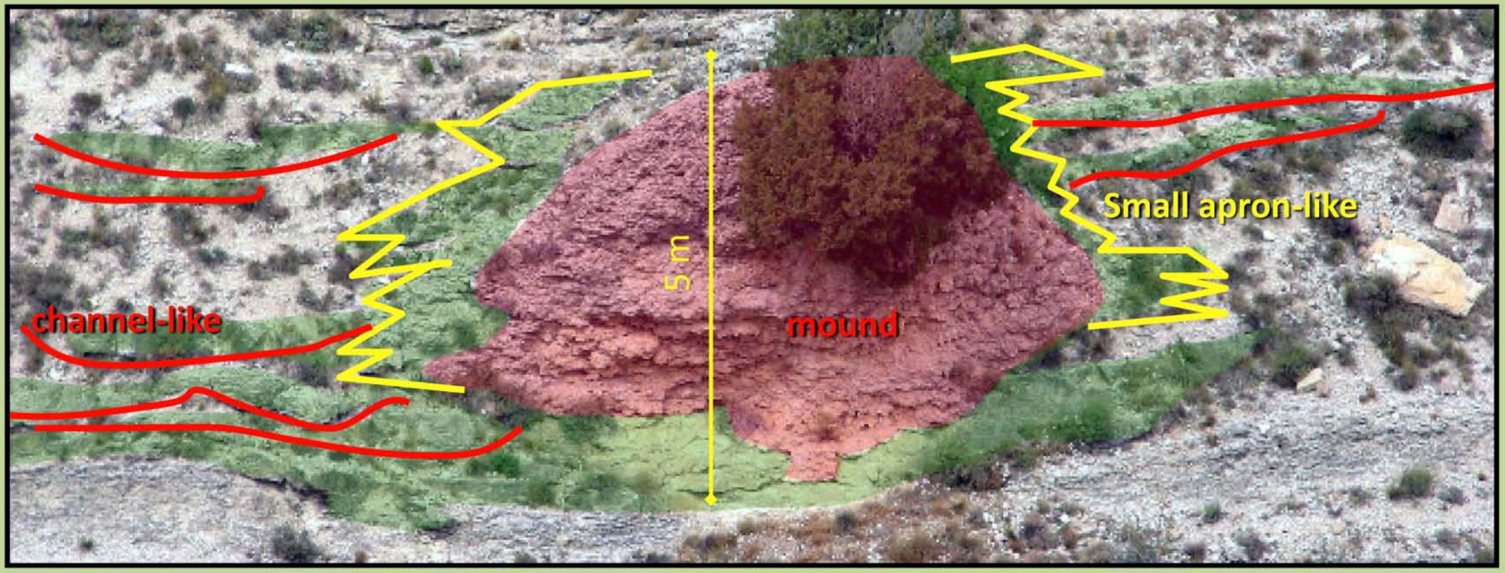
Sequence B has not been worked out due to the bad quality of outcrop.

1 - Sequence C: Good outcrop quality allow to differentiate 2 subsequences, within sequence C

The lower subsequence, consists of coral-stromatoporoid-microbial buildups, with flank facies,

2- to -5: That started growing onto a Wkt ground level layer, but continued to grow along with clay accumulation

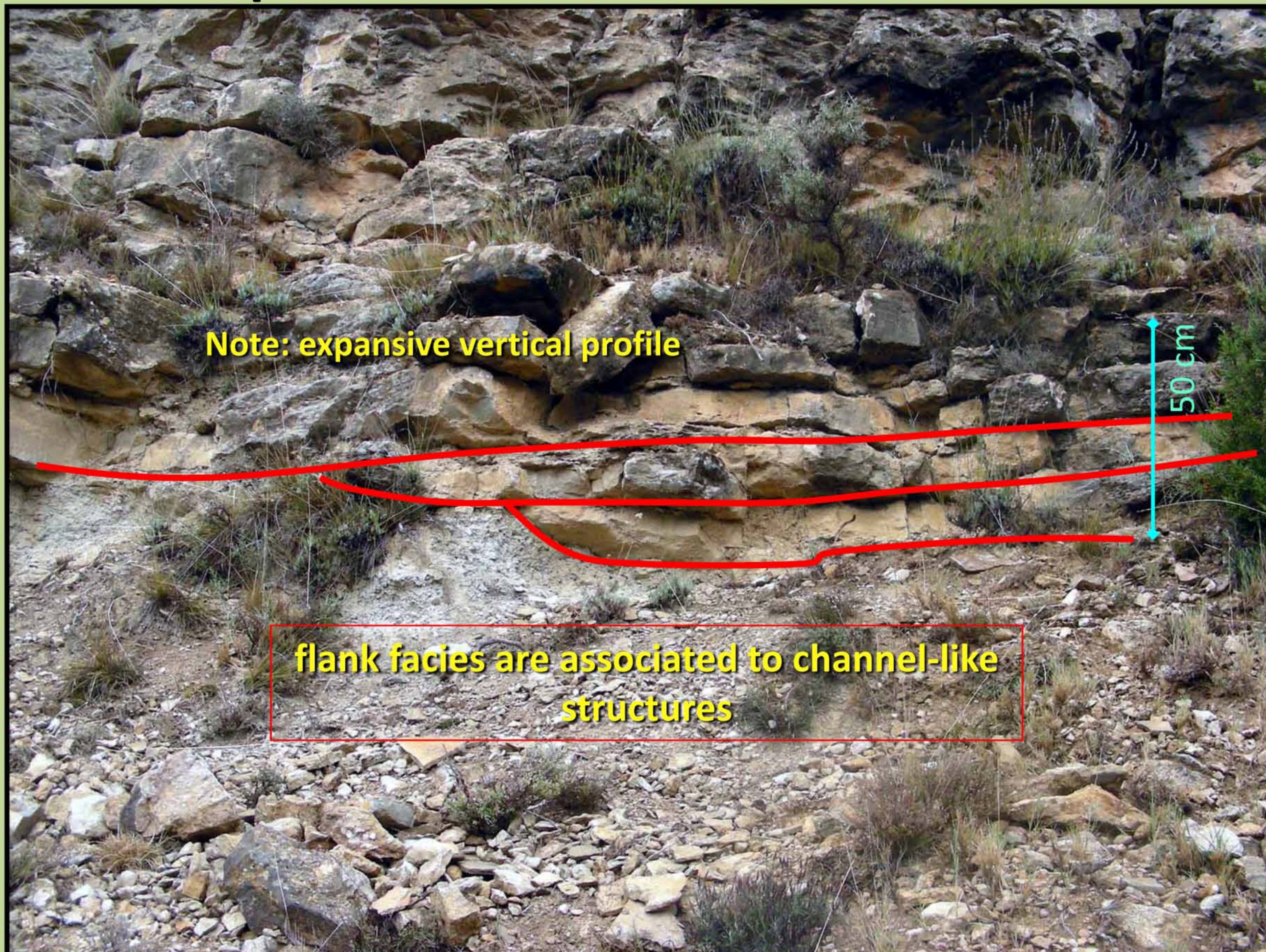
Sequence C –1 Flank Facies



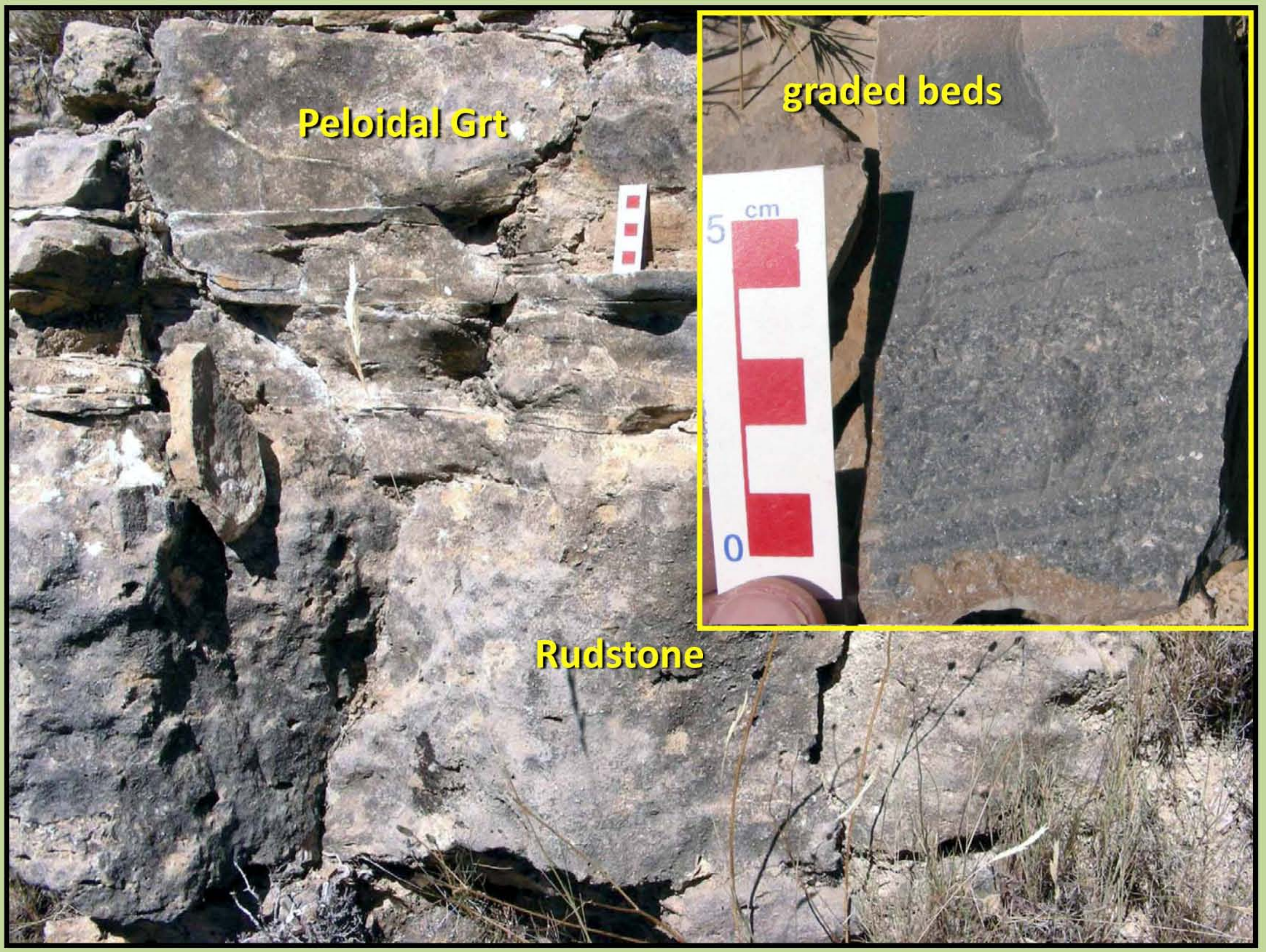
Notes by Presenter:
Flank facies are interbedded with clay and organized in two styles: apron like and channel like.

Normally they consist of graded beds with mud intra-clasts (suggest being erosional related to storm activity).
These accumulate near the storm wave base, but not above it, as you get clay and mud.
Hit episodically by storms generating density currents depositing these graded beds.

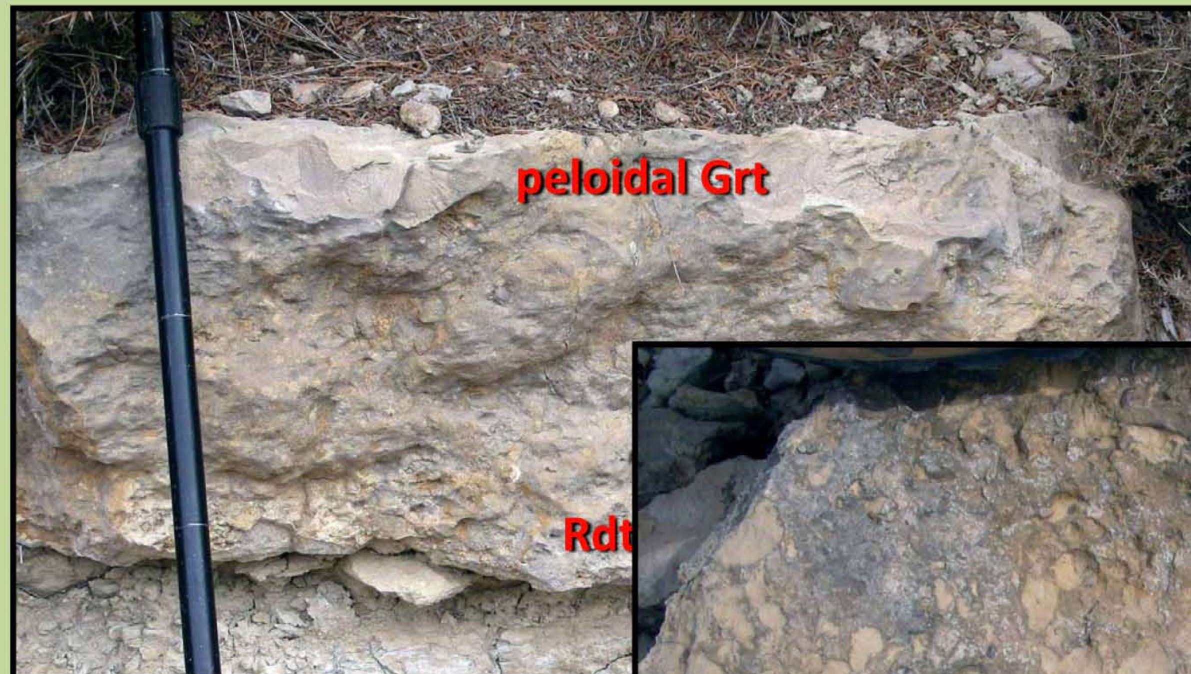
Sequence C – 1 Flank Facies



Sequence C – 1 Flank Facies



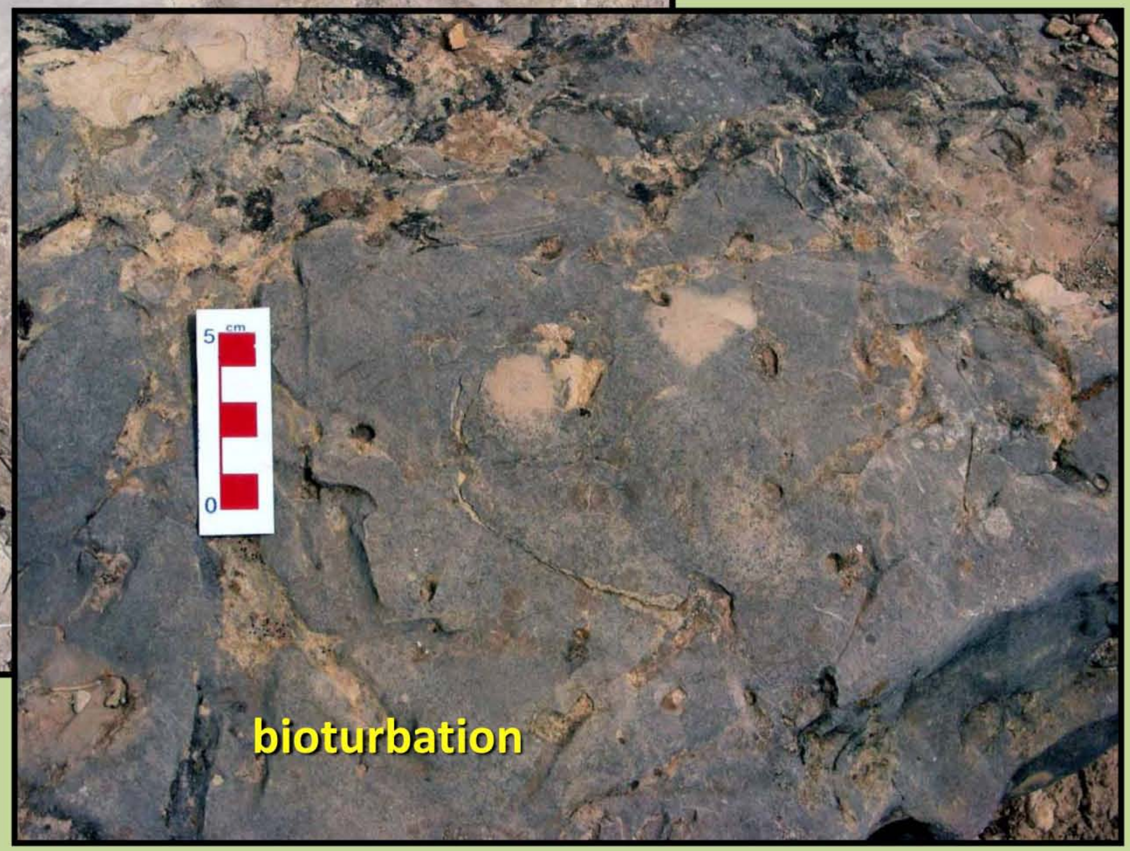
Sequence C – 1 Flank Facies

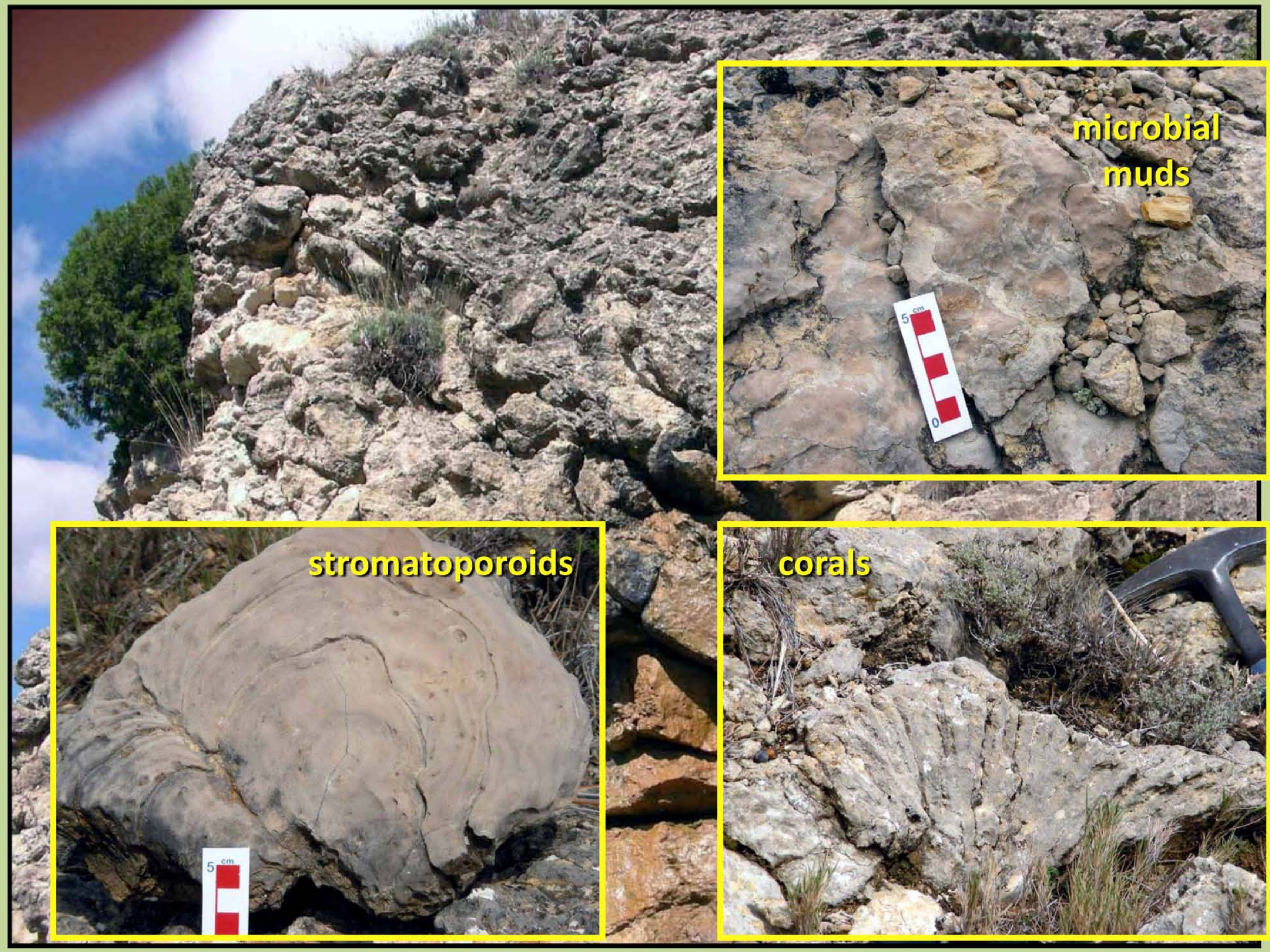


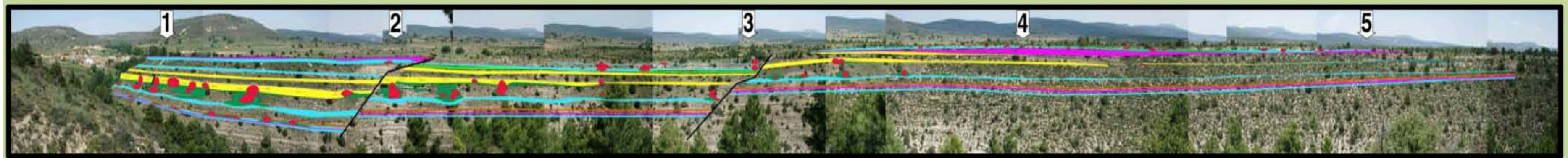
Sequence C – 1 Flank Facies

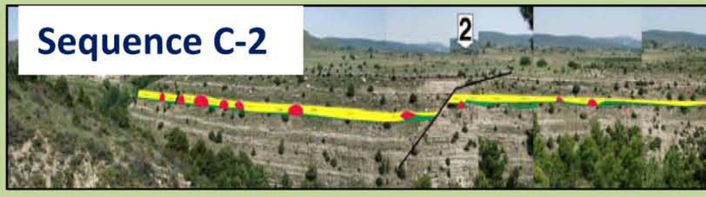
In more distal position, channel-like structures mostly consist of peloidal grainstone with subordinate rudstone textures.

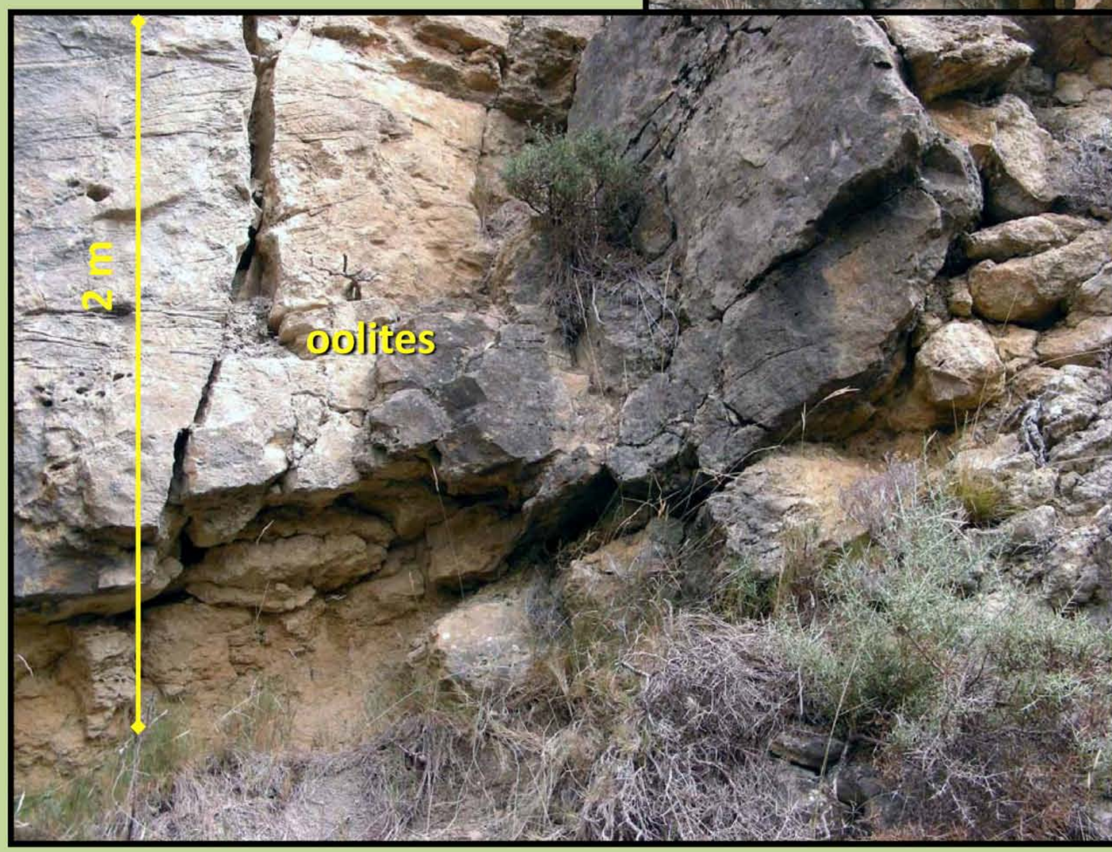
Sequence C – 1 Flank Facies




microbial
muds
stromatoporoids
corals







In sequence C-2, flank facies interfinger with oolitic grainstone (early stage)

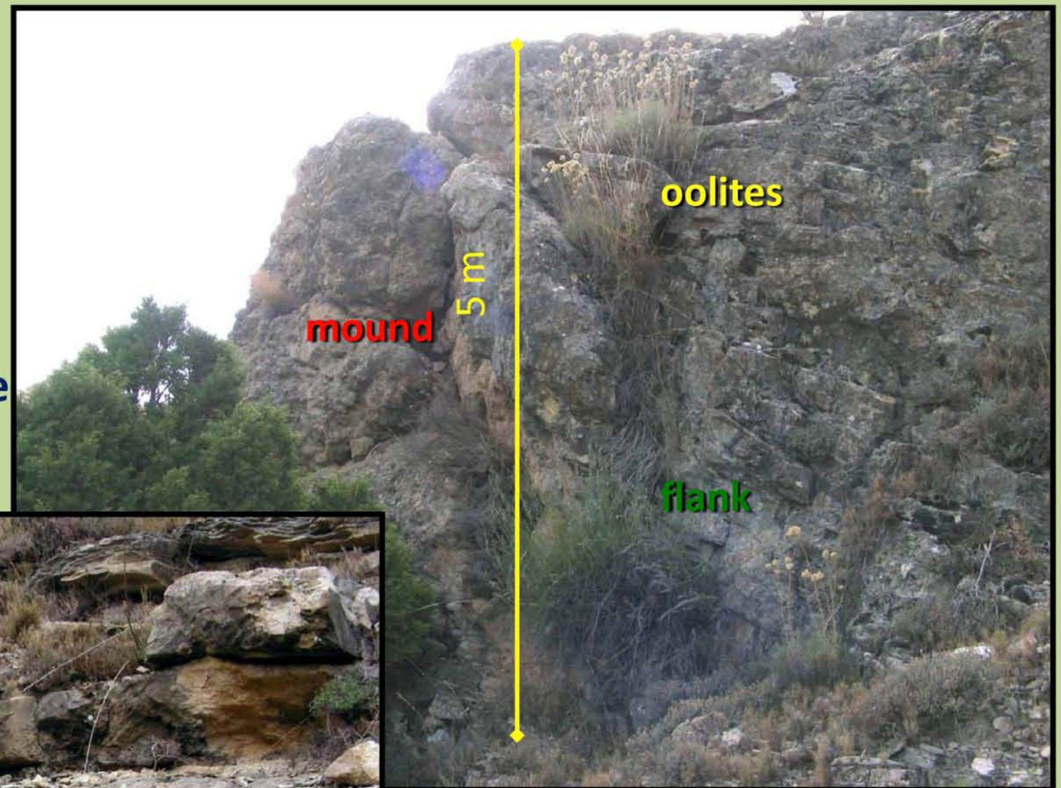
Sequence C – 2

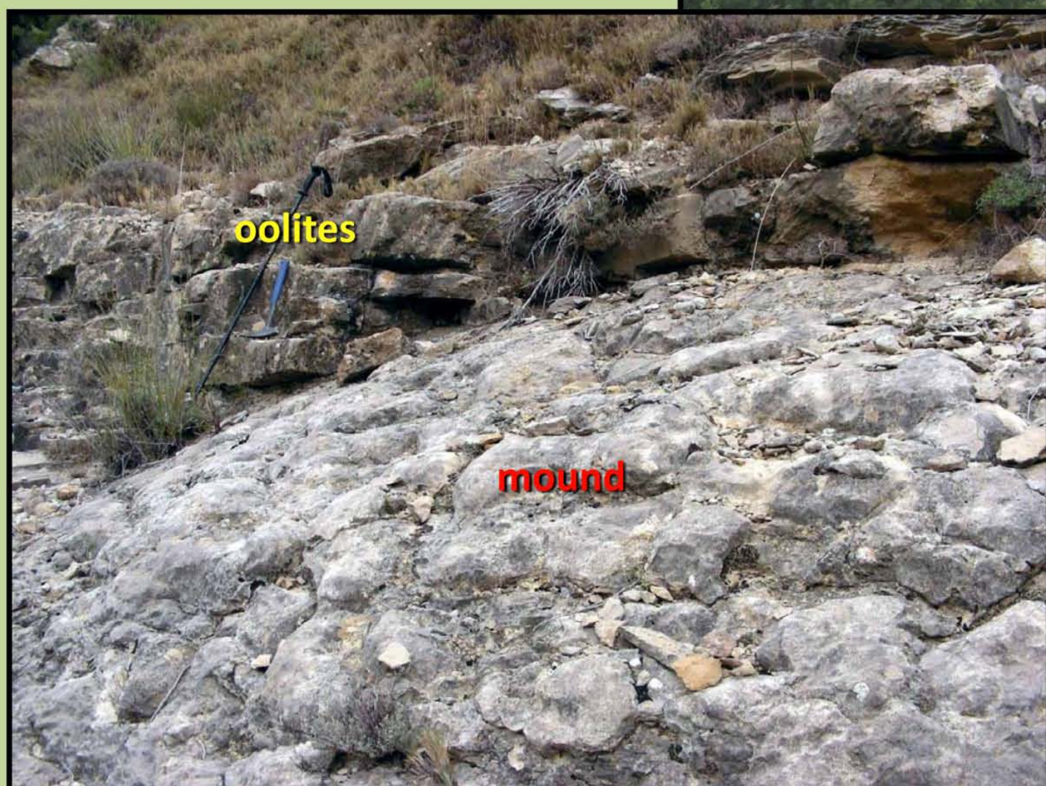
Trough X-stratification in oolitic grainstone

Lamination associated with troughs

Sequence C – 2

Oolitic grainstone onlap onto the buildups (late stage)

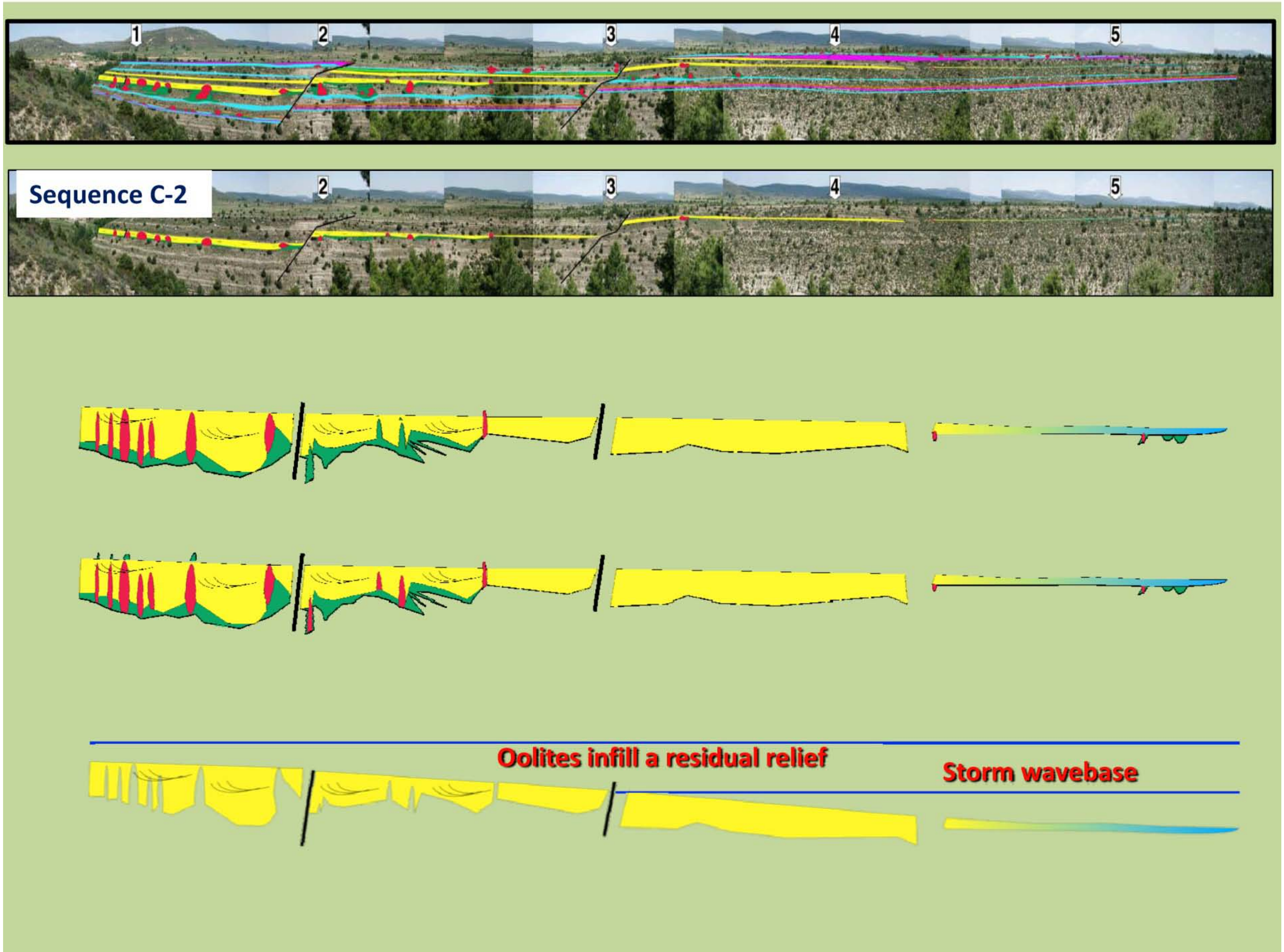




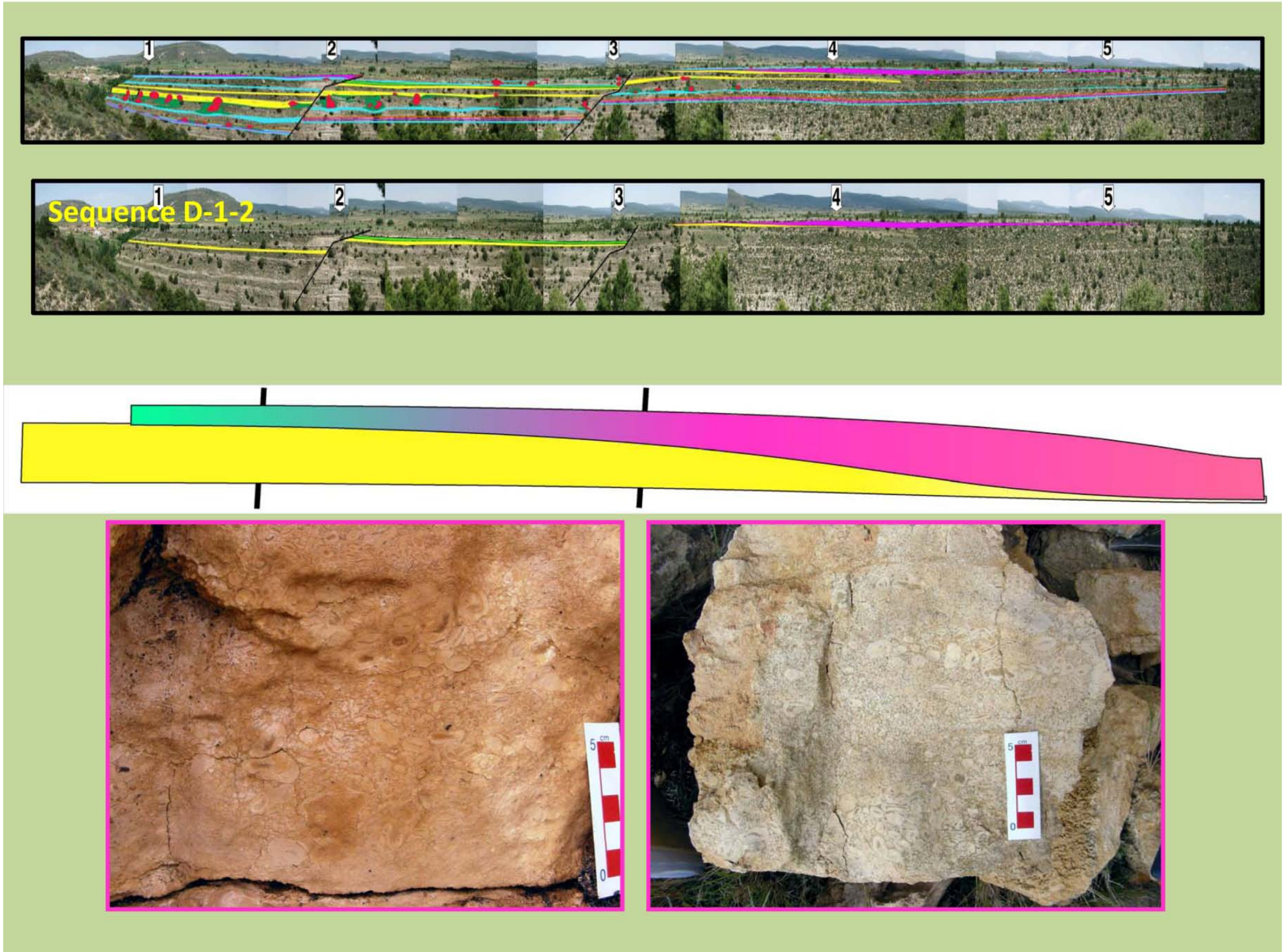
Notes by Presenter:
The rudstone flank facies derived from the mound are inter-figgering with the oolitic unit above.

Sequence C – 2

Upper oolitic grainstone pass, basinward, into fine-grained oolitic packstone – wackestone.

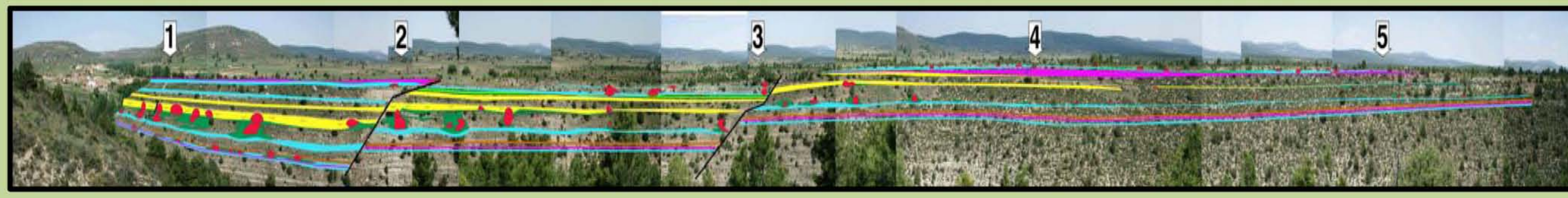


Notes by Presenter:
This represents a reconstruction of the sequence. It is apparent that the density of the mounds and flank facies is reduced eastward to the basin. The thick oolite pass into oolitic packstone and wackestones in less than 2 km.

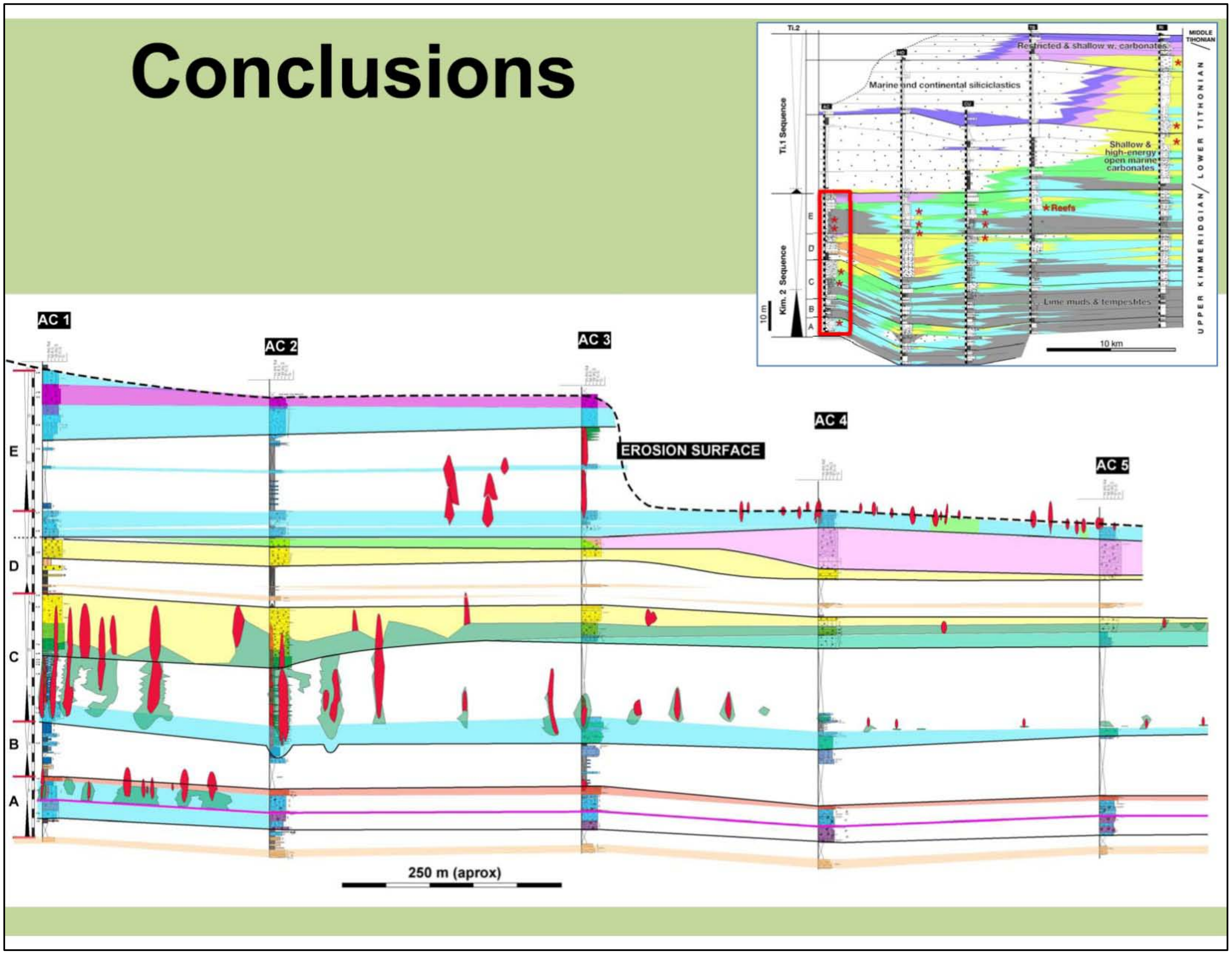


Notes by Presenter:
Good quality exposures allow to differentiate 3 subsequences within sequence D
In the lower interval, two subsequences are stacked in shingling configuration
- Oolitic grainstone, thins out basinward, passing into thin oolitic wackestone
-- bioclastic graisntone passes basinward into a thick oncolitoc-oolitic rudstone

Notes by Presenter:
The upper interval consists of two subsequences (although the uppermost one has mostly been removed by erosion. In the lower sequence, a clear facies differentation can be seen in dip direction.
This is a reconstruction of the profile and note the abundance decrease of the buildups.



Sequence E: wackestone and oncolitic rudstone.



Notes by Presenter:

The well-exposed upper Kimmeridgian carbonate ramp at Arroyo Cerezo, Iberian Range, provides an excellent analog to stratigraphically equivalent subsurface reservoirs.

The apparent continuity when correlating at 5 km spaced logs disappears, when compared to correlation at shorter scale. And the heterogeneity become dramatic when complete mapping of the section is done in dip direction. Which is below the resolution of any subsurface tool but this is the nature of the record.

So for enhanced recovery, such small scale heterogeneities have to be addressed and considered when modelling fluid flow in reservoirs.


Thanks for your attention …