UNIL | Université de Lausanne
Faculté des géosciences
et de l'environnement

Universität Zürich[UZH]

Complementary and additional text

The basal Triassic microbialites, between reef building and red ammonoid limestone

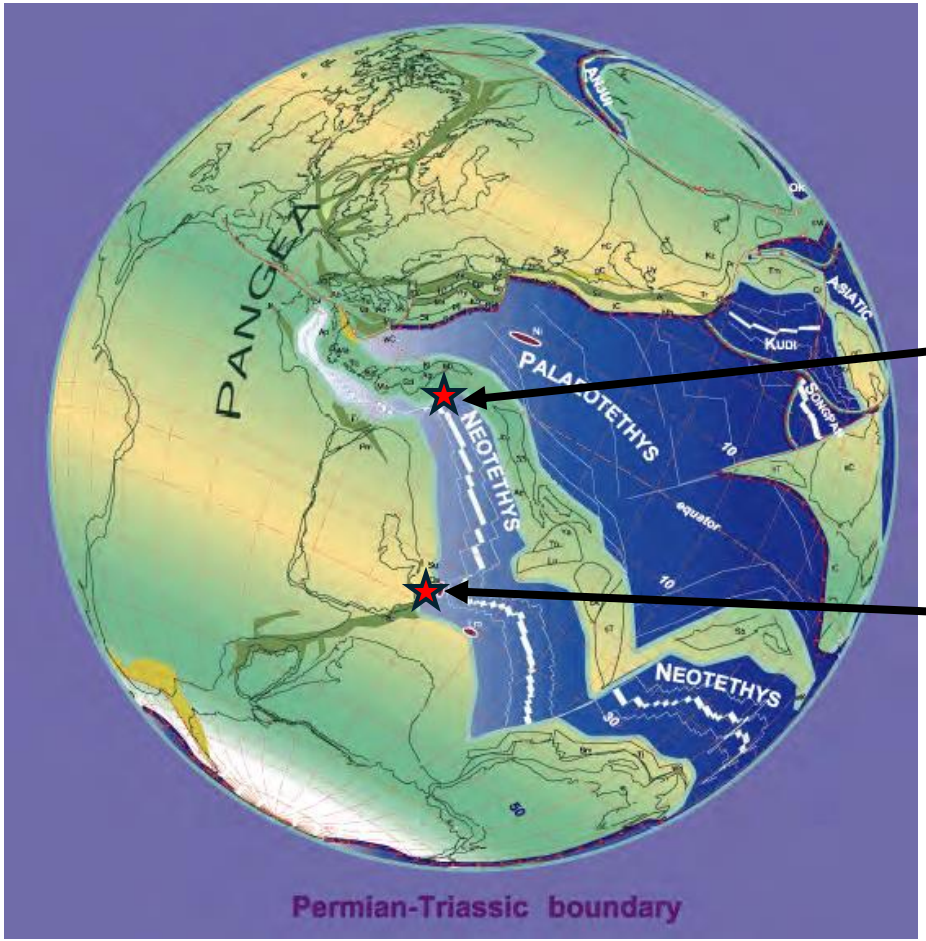
By Aymon Baud[1] and Hugo Bucher[2]

1- Geological Institute, Lausanne University, Switzerland

2 Paleontological Institute and Museum, University Zurich, Switzerland

1- Introduction to Paleogeography
2- The Induan sponge-microbial reef building in Armenia
-Look at the Permian-Triassic Chanakhchi lithological section and description
3- The newly discovered Induan sponge-microbial red ammonoid limestone in Oman
-Look at RAA red ammonoid limestone block and description
-The Permian-Triassic boundary part of the RAA limestone block
-The Griesbachian part of the RAA limestone block
-The Dienerian part of the RAA limestone block
4- The Olenekian sponge-microbial red ammonoid limestone in Oman
-The Smithian part of the RAA limestone block
5- The still known Olenekian sponge-microbial red ammonoid limestone in Oman
6- To resume

1- Introduction to Paleogeography



The Permian opening Neotethys separated the two examined basal Triassic microbialite sections.

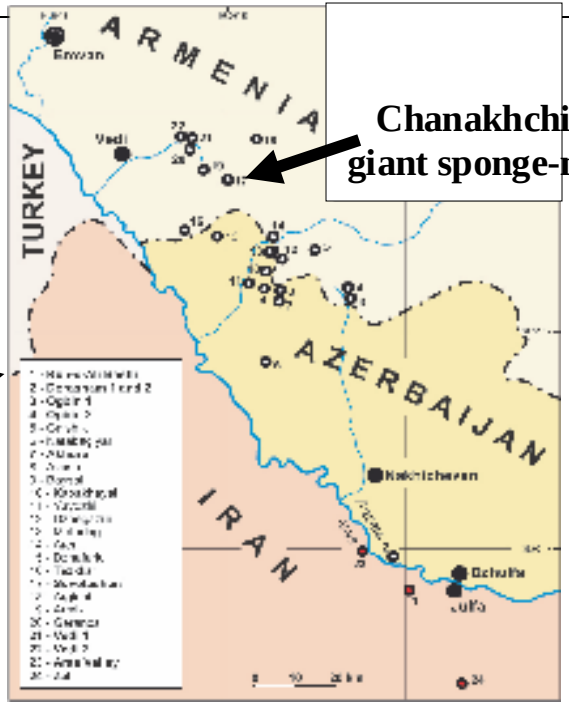
One the north side of the Neotethys, with the giant sponge –microbial buildups overlying latest Permian red ammonoid limestone and

The other on the Gondwana, south side, with the sponge –microbial factory work to red ammonoid limestone deposition.

2- The Induan giant sponge-microbial reef building (GSMB) in Armenia

The Transcaucasia region is one of the places in the world where continuous sections of Upper Permian and Lower Triassic strata with marine faunas can be observed. The boundary beds are exposed in the SE of Armenia, the NW Iran, the Nakhichevan and the adjacent part. Interesting to note that in these area the main end-Permian carbonate facies is a well dated red ammonoid limestone!

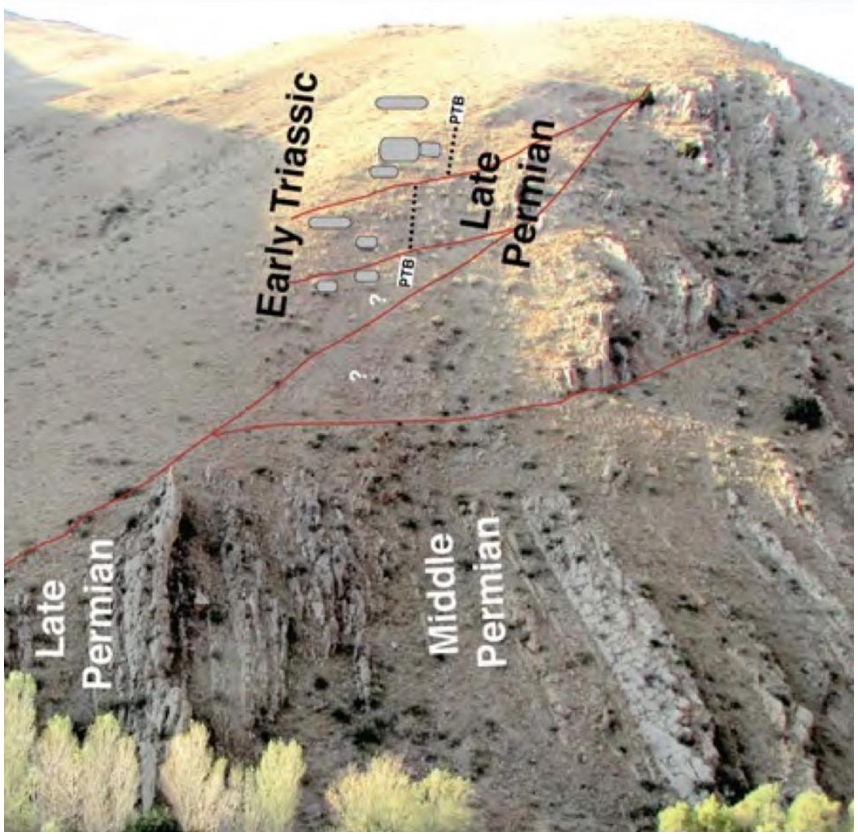
Transcaucasia area with the map showing 24 Permian-Triassic sections all along.



Chanakhchi, an outcrop with giant sponge-microbial buildups.

2- The Induan giant sponge-microbial reef building (GSMB) in Armenia

-Look at the Permian-Triassic Chanakhchi lithological section



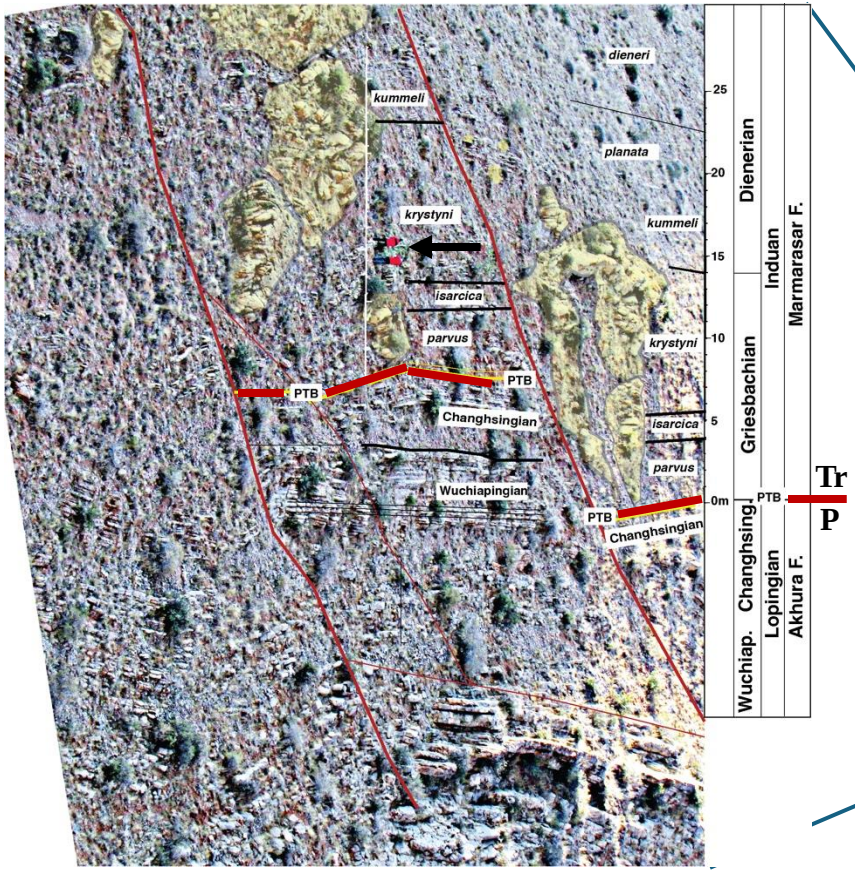
In the S Armenia, the Chanakhchi profile called Sovetachen during Soviet time, is situated about 60km SE of the country's capital Yerevan.

Continuous sections of upper Permian and lower Triassic strata with marine faunas, and basal Triassic giant sponge-microbial buildups can be observed.

Fine lower Triassic biochronology is based on Conodont succession as shown in next slide.

Face view of the Chanakhchi PTB section from the opposite side.

2- The Induan giant sponge-microbial reef building (GSMB) in Armenia



Detailed stratigraphy of the Chanakhchi PTB section, view turned at right-angle from the opposite side.

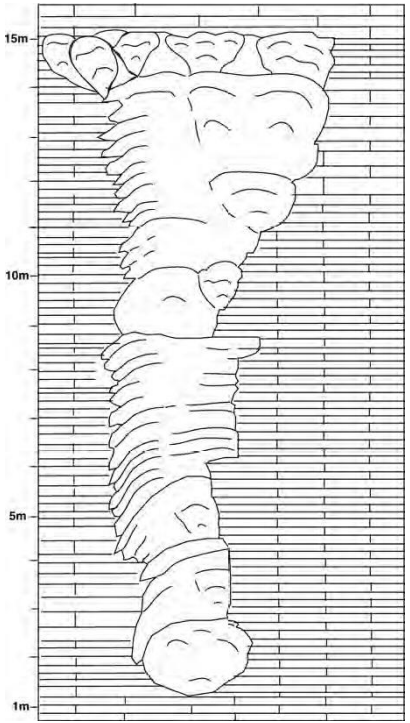
Giant sponge-microbial buildups (GSMB: early growth in light purple: main buildups in light yellow).

Stratigraphic data across the Permian-Triassic Boundary (PTB: thick red line); fine red line: fault. Scale given by 2 geologist with red jacket (arrow), above horizontal white scale. Beds are dipping vertically

Chanakhchi PTB section from the opposite side.

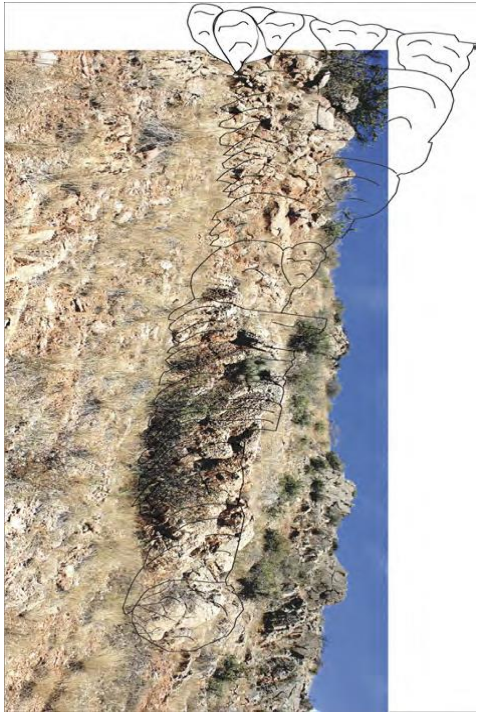
2- The Induan giant sponge-microbial reef building (GSMB) in Armenia

The overturned cone-shaped geometry and a 8-m top head diameter, is built by thrombolite domes associated with keratose sponges as published by Friesenbichler et al., 2018.
The growing duration from basal Griesbachian up to lower Dienerian is about 500'000 years.



GSMB sketch according to field observations

Field view of platy grey limestone, 0.1m thick beds



Verticalized view of a GSMB, 15m high

2- The Induan giant sponge-microbial reef building (GSMB) in Armenia

An early growth phase consists of vertical fan structure made of branching digitate stromatolite with pseudomorphs or aragonite crystals. The lime mud microbial matrix of leiolite type is reinforced by calcified Keratose sponge fibers.

Field view of the so called "calcite crystal fan structure" (CCFs).

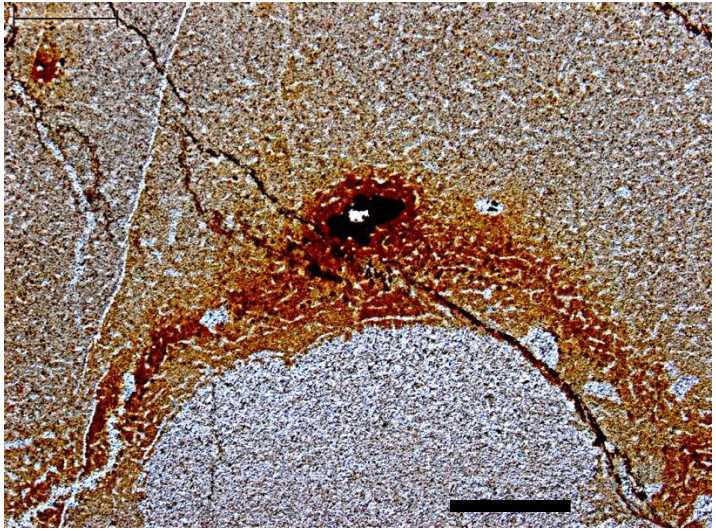
Thin section of the digitate stromatolite in lime mud with calcified sponge fibers. Bar scale = 1 cm.

2- The Induan giant sponge-microbial reef building (GSMB) in Armenia

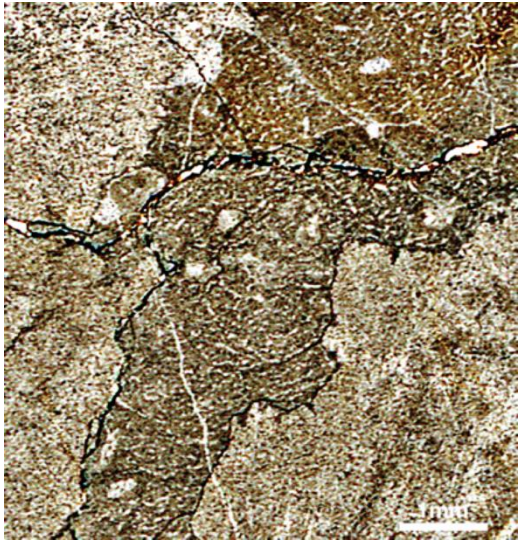
-A look at thin sections

The organic skeletons of keratose sponges can be preserved in the same way as the rapidly calcified siliceous sponges found in Phanerozoic carbonates (Luo & Reitner , 2014). Due to calcium carbonate oversaturated seawater, the spongin skeleton has been preserved as a calcified fiber or tissue network within lime mud, within thrombolite or within spar spheroid (sponge body?).

It is likely that the sponge tissue stabilized the overall framework.



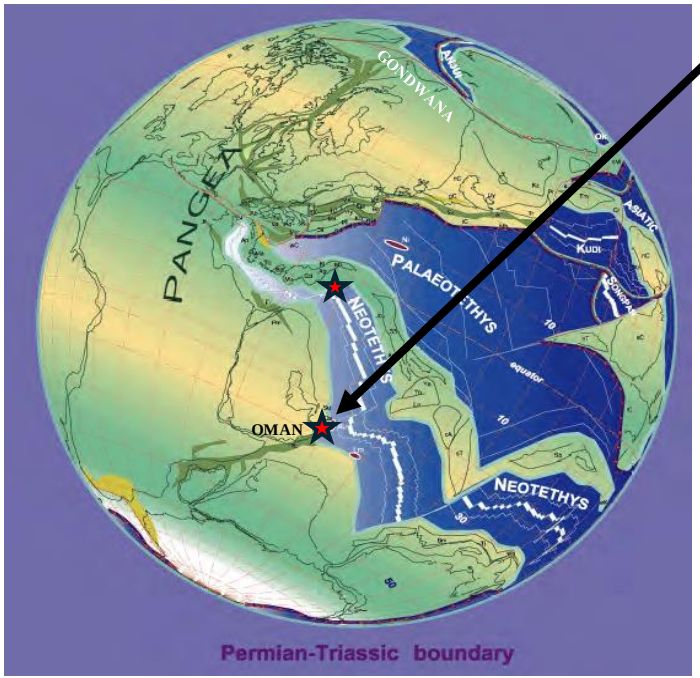
Thin section scan view of the calcified keratose sponge fiber tissue in lime mud with preserved sponge shape spheroid (Bar scale=1 mm).

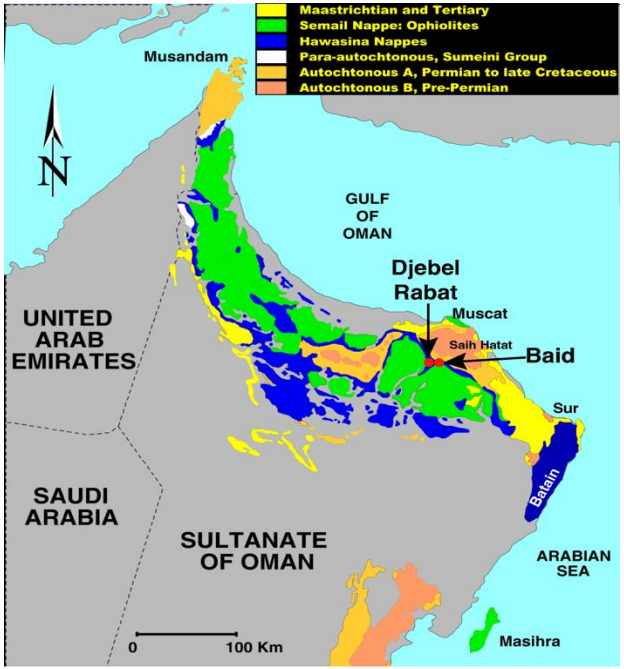


Thin section scan view of the preserved framework of calcified keratose sponge fiber in a dark lime mud matrix (Bar scale=1 mm).

3- The newly discovered Induan sponge-microbial red ammonoid limestone in Oman

On the southern, Gondwana side of the Neotethys in Oman, this new discover by one of us, HB, of red ammonoid limestone succession, basal Triassic in age is unique in the world and fills the gap of the red ammonoid limestone deposition during Induan time.





Map of Oman with the Djebel Rabat position S of Muscat.

3- The newly discovered Induan sponge-microbial red ammonoid limestone in Oman

This discover consits of one large boulders (RAA), issued of a past dismantle Hallstatt-type pelagic platform at apparently 80-100-m water depth, and crops out (arrow) left of the top of Djebel Rabat Range about 80-km South of Muscat (Oman).

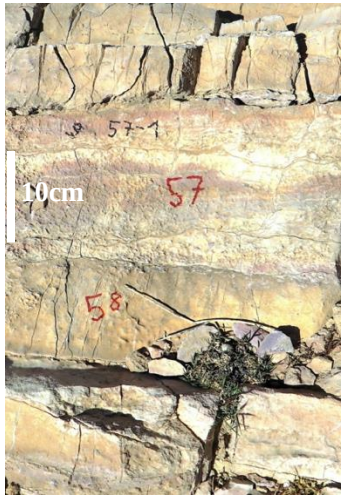
View from the East to the Djebel Rabat crest. The RAA block is behind the crest on the left (arrow).

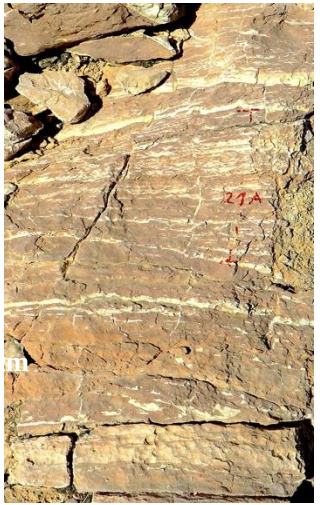
3- The newly discovered Induan sponge-microbial red ammonoid limestone in Oman

-Look at Induan RAA red ammonoid limestone block

Outcrop views: Griesbachian succession,

This block, the Djebel Rabat RAA limestone succession, 30 m thick is unique and the only known of well-preserved basal Triassic ammonoid-bearing, pelagic Hallstatt-type limestone deposited on an isolated carbonate platform.
With Conodonts and Ammonoids, the lower Triassic succession is well dated up to middle Smithian.





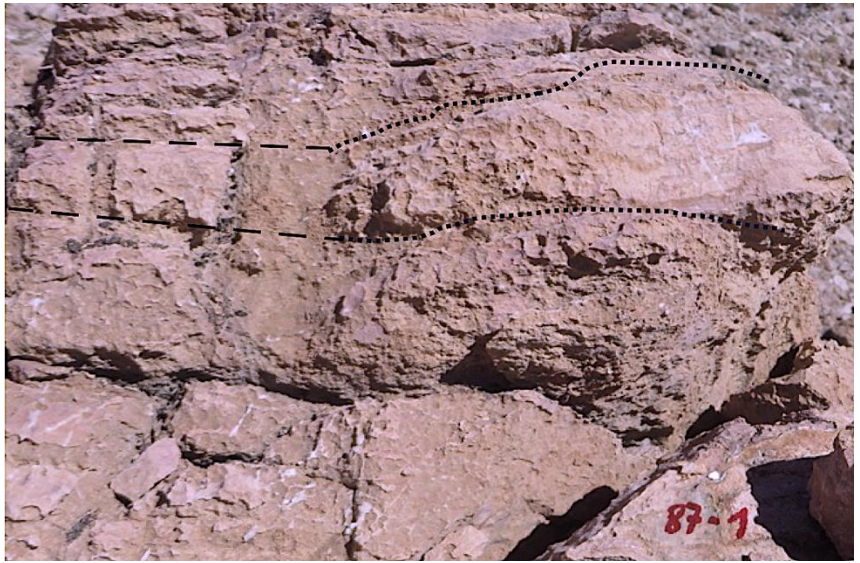
Dienerian and Smithian carbonate beds with domal structures

3- The newly discovered Induan sponge-microbial red ammonoid limestone in Oman

According to outcrop analysis, the tabular thrombolite can forms centimetric to metric large mound with very low angle flanks and low elevation, as it's the case in many levels.

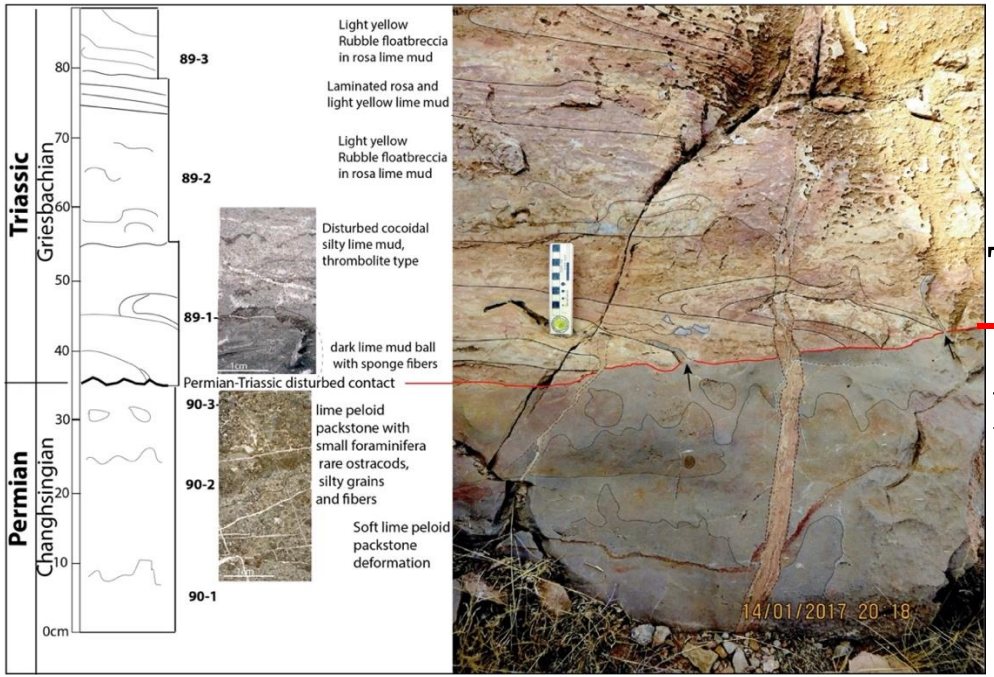
Mamet and Préat, 2006 and Préat et al., 2006, working on red ammonoid-bearing limestone, such as the "Griotte" during the Devonian, the "Han Bulog" and the "Hallstatt" during the Triassic and the "Ammonitico Rosso" during intervals of the Jurassic, have shown that dysoxic conditions favoured the spread of iron bacteria and fungal biofilms inducing the precipitation of iron hydroxydes, leading to the red-rosa pigmentation of the micritic matrix finally by hematite.

Outcrop views of Griesbachian beds 86, 87/1-2 with a 10cm thick mound.



3- The newly discovered Induan sponge-microbial red ammonoid limestone in Oman - The Permian-Triassic boundary part of the RAA limestone block (Baud, 2023)

Overlying a 35cm thick latest Permian dark limestone substratum, it is the unique known red ammonoid limestone with deposition starting at Griesbachian time.



The Permian-Triassic disturbed contact at the base of the RAA limestone succession.

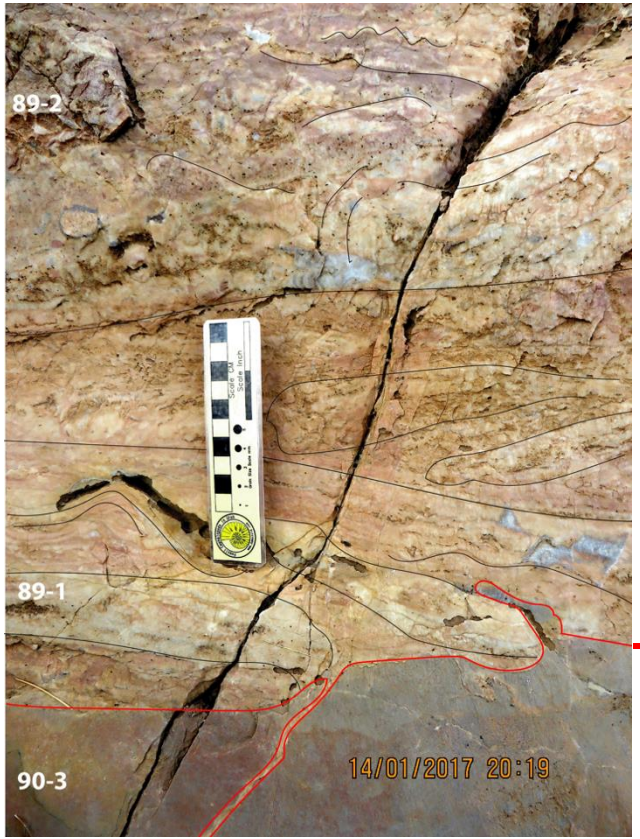
Tr

P

Sedimentological study shows that the overlying Griesbachian rosa silty-lime mud consists in coccoidal thrombolite type of microbialite with centimetric dark lime mud ball showing keratose sponge fibers and small calcite filled vugs

This late Permian base of the RAA limestone succession consist of 35 cm of grey lime peloid packstone with silty grains and fibers, showing a strong contrast with the light rosa yellow overlying basal Triassic limestone.

3- The newly discovered Induan sponge-microbial red ammonoid limestone in Oman
- The Permian-Triassic boundary part of the RAA limestone block (Baud, 2023)



Tr

P

This Permian-Triassic disturbed contact (red line) with sediment injection and sedimentary micro dikes. The basal Triassic of rosa lime mud units 89- and 89-2 is showing low angle cross faults, boudinage, micro-folds and rubble float breccia.

The origin can be trigger by earthquake shakes, as the boudinage, intraformational deformations, decimetric folds, both in the underlying late Permian succession and the overlying Griesbachian rosa silty-lime mud.

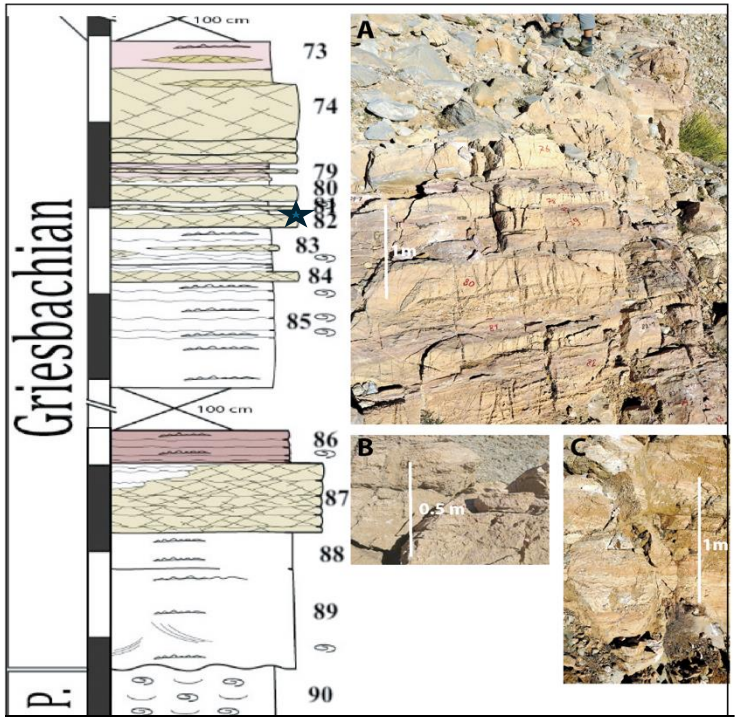
It is interesting to note that similar soft deformations occur at the Permian-Triassic transition succession of the near autochtonous beds on the Saiq Plateau (Baud et al., 2015).

Detailed view on Permian-Triassic disturbed contact

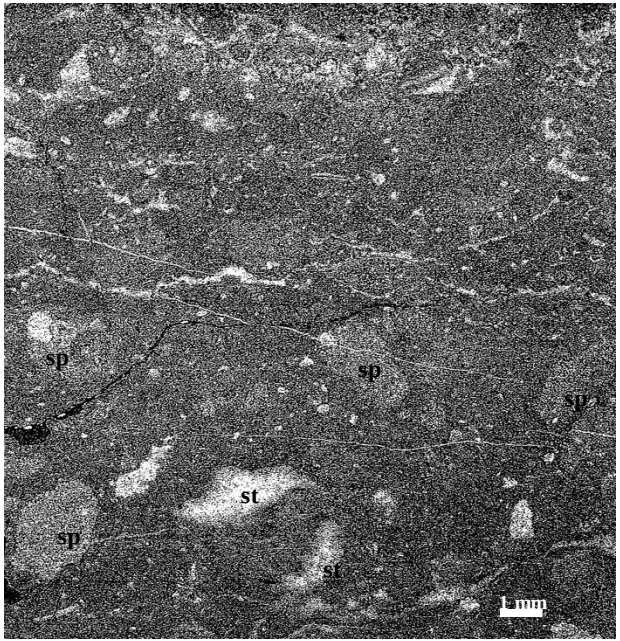
3- The newly discovered Induan sponge-microbial red ammonoid limestone in Oman

The Griesbachian part of the RAA limestone block

The about 7 m thick Griesbachian Hallstatt limestone succession is overlying, as shown before the late Permian one.



Griesbachian Hallstatt limestone section (black-white meter scale) with outcrop views (A,B,C)

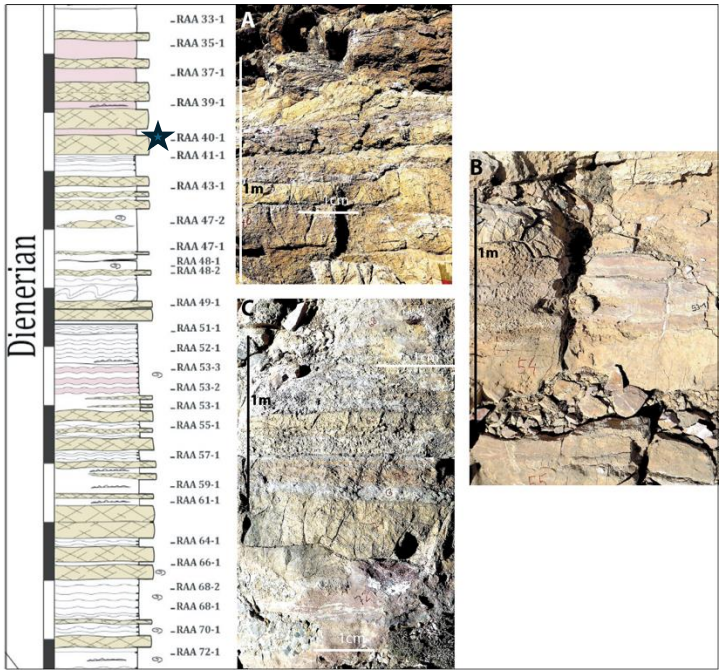


RAA 82-1 thin section: succession of coccoidal lime silt microbial bindstone with filament sheath, stromatactis (st) with sponge phantoms (sp) filled with sponge fibers (keratose?).

3- The newly discovered Induan sponge-microbial red ammonoid limestone in Oman

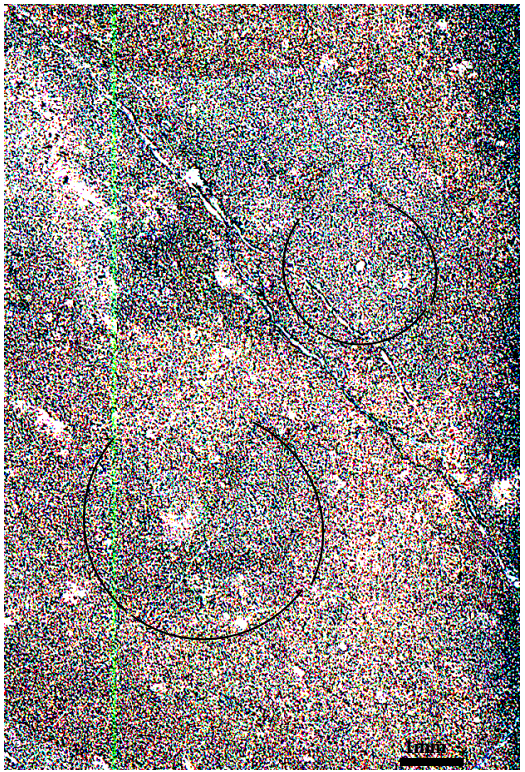
The Dienerian part of the RAA limestone block

The 11 m thick Dienerian Hallstatt limestone succession overlain the Griesbachian one with very similar features of thrombolites made of coccoidal lime silt, lime mud, filaments and keratose sponge fibers accumulation. Numerous fenestral structure and stromatactis of possible sponge decay origine.



Dienerian Hallstatt limestone section (black-white meter scale) with outcrop views (A,B,C).

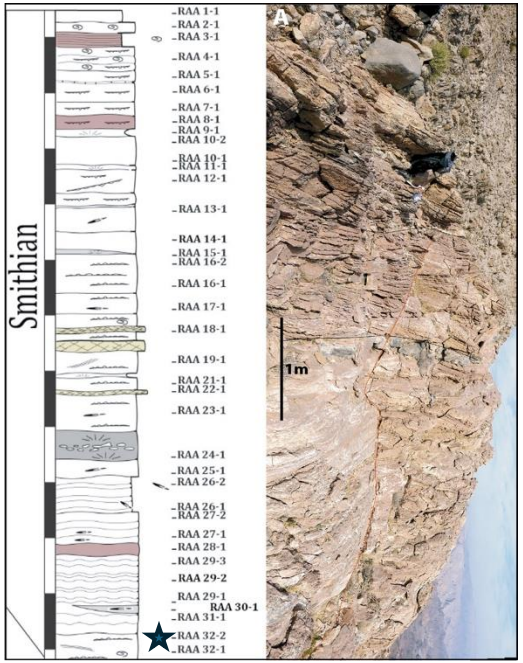
★ **A=RAA 40-1 thin section: network of keratose sponge fibers in red lime coccoidal siltite; the black line outlines the shape of a possible sponge sections.**



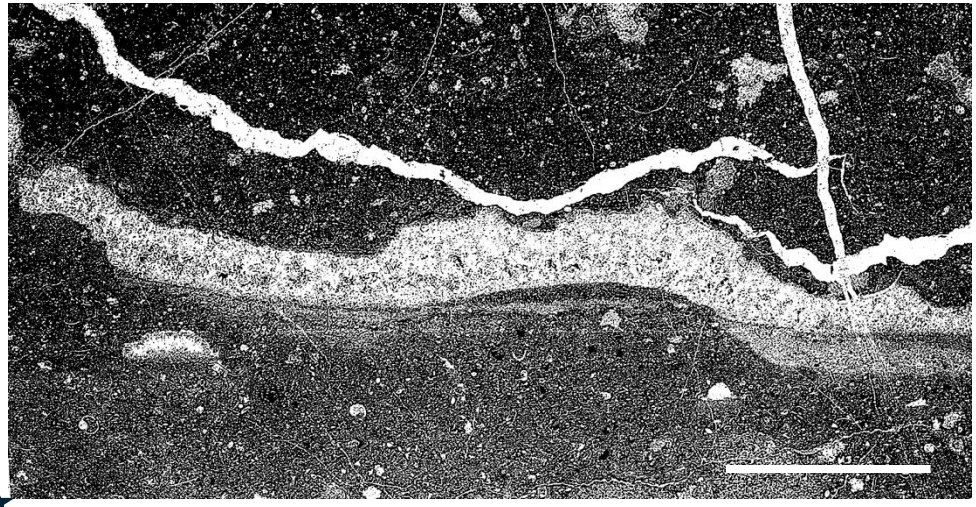
4- The Olenekian sponge-microbial red ammonoid limestone in Oman

-The Smithian part of the RAA limestone block, -similar to previously published Olenekian sponge-microbial red ammonoid limestone in Oman

This 11 m. thick red ammonoid limestone, lower-middle Smithian in age is similar to the near lower Alwa Formation outcrop. As shown by the outcrop view this part is mainly red colored with irregular thin to thick bedding and abundance of stromatactis.



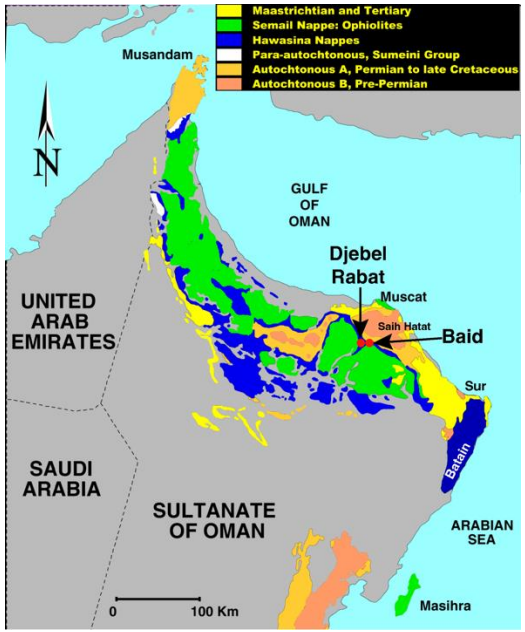
Smithian red ammonoid limestone section (black-white meter scale) with verticalized outcrop views.



RAA 32-1 thin section: lower fiber layer overlain by centimetric long stromatactis partly filled by the same fiber accumulation and overlain by microbial coccoidal lime mud with silty debris of keratose sponge fibers and filament sheaths (Bar scale=1 cm). .

5- The still known Olenekian sponge-microbial red ammonoid limestone in Oman

Previously published Olenekian sponge-microbial red ammonoid limestone in Oman concern Ba'id Exotic along the Wadi Alwa river (Oman Mountains). This cited Olenekian outcrops have been presented in the A01 fieldtrip and field guidebook (Baud et al. 2001) of the Oman 2001 Geological Congress and worked on Woods & Baud, 2008, Baud & Richoz, 2013 and Baud & Bucher 2019.



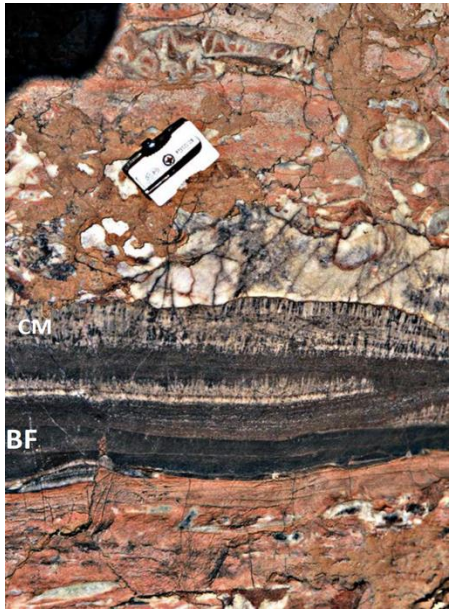
Map of Oman with the Ba'id locality close to Djebel Rabat.

On the south side crops out the Olenekian red ammonoid limestone.

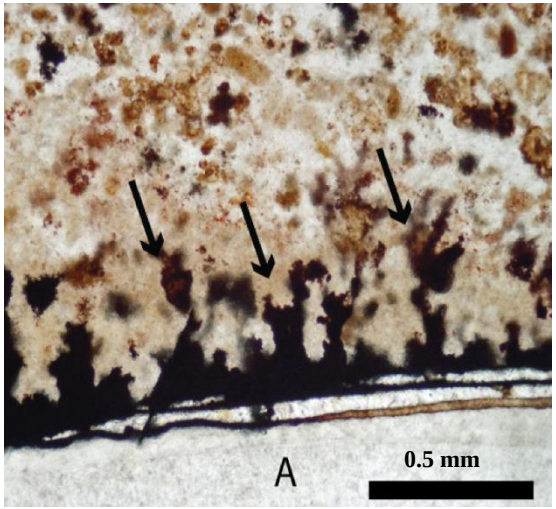
5- The still known Olenekian sponge-microbial red ammonoid limestone in Oman

According to Woods & Baud, 2008, large botroidal cement, bacterial sheaths, coccoids and frutexites-bearing microbialites have been illustrated, in this Smithian deposit of the Alwa Formation (Ba'id Exotic).

Red limestone ammonoid cimetery bed.



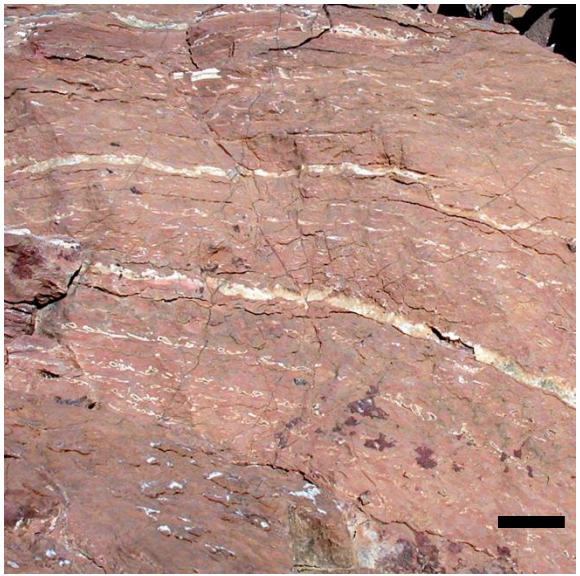
The black, Frutexites-bearing microbialites (BF) often contain cements crusts (CM).



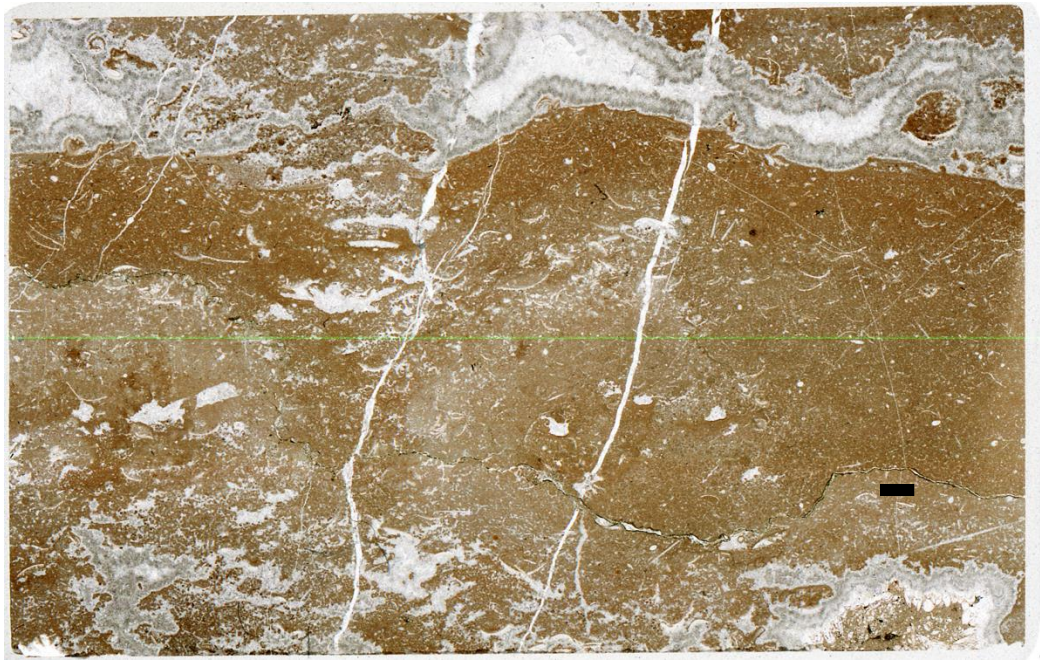
Frutexites grew perpendicular from growth surfaces, such as the base of the Frutexites–bearing microbialites, individual laminae within the microbialites, or from other substrates, such as ammonoids (A).

5- The still known Olenekian sponge-microbial red ammonoid limestone in Oman

According to Baud & Richoz, 2013, Linked with thrombolites, numerous stromatactis cavities locally occur with a spicular meshwork shown by microphotographs, indicating the collapse of soft sponge bodies.



Outrcrop view of stromatactis in red limestone with mound forming, framed by stromatactis levels built by small sized sponge collapse. Scale bar = 5 cm.



Photomicrographs of the stromatactis surrounded by micrite with sponge spicule meshwork. Scale bar = 1mm.

6- To resume

With same post-extinction starting age and similar 80-100-m water depth in dysoxic environment, microbialites carbonate factory developped with sponges two strategies:

- In the equatorial belt, the first one consisted-on branching digitate stromatolite followed by thrombolite domes with keratose sponges that they continuously build during about 500'000 years inside platy limestone deposition, up to lower Dienerian time, forming apparent giant buildups.

- At Southern latitudes, the second one, following improved oxidation and upwelling development, contributed to the microbial coccoidal red lime mud deposition with keratose sponge fibers and filament sheaths and recorded refuges for ammonoides and other mollusks. This unique record in the world, of a red ammonoid limestone deposition from Griesbachian to middle Smithian time is showing a continuous growth of post-extinction microbialites associated with sponges during more than 2 million's years.

-During the late Olenekian time, the pattern in time-space distribution of these red ammonoid limestones changed onward and have been described from western Neotethys under the name "Han Bulog". Described also from Central Himalaya (Nepal and Tibetan side) it is known up to the middle Spathian part of the Luolou Formation in the Nanpanjiang Basin (Yangtse Block, S. China).

Acknowledgments

In Yerevan, many thanks to **Professore of Armenian Academy of Sciences Lilit Sahakyan** for her help in the field. With **Evelyn Friesenbichler** and **Sylvain Richoz** we discussed a lot on the Chanakhchi section, thanks to them.

In Oman, Hugo Bucher get the precious help of **Dr Thomas Bruehwiler** in the field, **Dr Edward Oluwaseun** prepared all thin sections photos and **Dr Louis Dudit** digitized the field section drawed by Hugo Bucher, thanks to all.

We are grateful to the **Directors of the Ministry of Mines of the Sultanate of Oman** for important administrative support.

References

Baud, A., 2023. Six main facies in the post-extinction basal Triassic (Griesbachian) of Oman, from deep to shallow and from euxinic to well oxygenated. In Baud A., (Editor). Across the end Permian « Great Extinction »: from field studies to scientific results. Mém. Géol. (Lausanne), n° 50, 121-122.

Baud, A., Béchennec, F., Cordey, F., Krystyn, L., Le Métour, J., Marcoux, J., Maury, R., Richoz, S., 2001. Permo-Triassic Deposits: from the Platform to the Basin and Seamounts, International Conference on the Geology of Oman, Muscat, Oman, Field guidebook A01, 54 p.

Baud, A. & Richoz, S., 2013. The Smithian (Early Triassic) red ammonoid limestone of Oman, refuge for sponge–microbial build-ups during a recovery phase. In 2013 GSA Annual Meeting in Denver. GSA Abstracts with Programs. Vol. 45, No. 7, p.883

Baud A., Friesenbichler E., Krystyn, L. Sahakyan L. Richoz S., 2015. Proterozoic-like/type basal Triassic microbial build-ups of unusual height in Armenia. Goldschmidt Conference, Prague August 16-21, 2015, Abstract book, 06i session, Poster 2074

Bruehwiler, T., Bucher, H., Goudemand, N., Galfetti, T., 2012. Smithian (Early Triassic) ammonoid faunas from Exotic Blocks from Oman: taxonomy and biochronology. Palaeontographica Abteilung A-Palaozoologie-Stratigraphie, 296, 3-107.

Friesenbichler E., Richoz S., Baud A., Krystyn L., Sahakyan L., Vardanyan, S., Peckmann, J., Reitner, J., Heindel, K., 2018. Sponge-microbial build-ups from the lowermost Triassic Chanakhchi section in southern Armenia: Microfacies and stable carbon isotopes. PPP 490, 653-672.

Luo, C., & Reitner, J. (2014). First report of fossil “keratose” demosponges in Phanerozoic carbonates: preservation and 3-D reconstruction. Naturwissenschaften, 101, 467-477**.**

Mamet, B., & Préat, A. (2006). Iron-bacterial mediation in Phanerozoic red limestones: state of the art. Sedimentary Geology, 185(3-4), 147-157.

Préat, A., Morano, S., Loreau, J.-P., Durlet, C., Mamet, B., 2006. Petrography and biosedimentology of the Rosso Ammonitico Veronese (middle-upper Jurassic, north-eastern Italy). Facies 52, 265-278.

Sahakyan, L., Baud, A., Grigoryan, A., Friesenbichler, E. & Richoz, S., (Eds) 2017. The Permian-Triassic transition in Southern Armenia. 5th IGCP 630 Conference, Yerevan, Field Guidebook, 1-53.

Woods, A.D., Baud, A., 2008. Anachronistic facies from a drowned Lower Triassic carbonate platform: Lower member of the Alwa Formation (Ba'id Exotic), Oman Mountains. Sedim. Geol. 209, 1-14.