IPC 6
THAILAND

FROM GONDWANA TO LAURASIA

THE 6TH INTERNATIONAL PALAEONTOLOGICAL CONGRESS

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KHON KAEN, THAILAND

ABSTRACT BOOK

The Oman-Madagascar seaway source of the unsuspected Permian-Early Triassic palaeontological richness of the Batain (SE Oman)

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Located in eastern Oman, south of the town of Sur, the Batain Plain extends about 40km west-east and 130km northeast-southwest and is bounded to the south by the Indian Ocean. Due to the relatively scattered outcrops of the different lithologies and apparently chaotic structural situation, they were previously interpreted as "Batain Melange" with the same sedimentary succession as recorded in the N Oman Hawasina basin transported to the SW from the Neotethys. After a detailed geological mapping Peters et al. (2001), structural data, indicate a WNW directed nappe emplacement, in contrast to the south to south-west thrusting direction of the Hawasina nappes of the Oman Mountains. As strong lithological differences appear comparing to the Hawasina succession, these authors defined a Batain Group, and described four new formations, all coming from an Oman-Madagascar seaway, a boundary between Western and Eastern Tethys. Following the geological mapping, sedimentological and palaeontological research revealed an unsuspected palaeontological richness of some level of the Permian Qarari limestone. Some lower, marly light part cropping out in the central Bu Fashiqah area is very rich in pyritic ammonoids of Wordian age comprising at least fifteen genera. NE outcrops in the Wadi Khawr al Jaramah (S of Ras al Haad) are fossiliferous rich beds contain brachiopods, crinoids, blastoids, corals, trilobites, bryozoans, ammonoids, nautiloids and fusulinids. The foraminifera have been studied by Leven and Hewward (2013) showing older fusulinid assemblage than those found in the N Oman. Fortey and Hewards (2014) studied and illustrated extremely well-preserved trilobite fauna, with five new species including one new genus and new brachiopods are studied by Viaretti et al. (work in progress). Until now, in the sedimentary succession of the Batain area, the Induan time was considered as a sedimentary gap (Hauser et al., 2001). Our finding of more than forty reworked boulders of lower Triassic to basal Anisan coquina and buildup limestone brought new views on the Paleozoic to Mesozoic evolution of this peculiar area and on Early Triassic recovery. Fossil richness of these Lower Triassic boulders with accumulation of ammonoids, bivalves and brachiopods is unexpected and all of these new occurrences display well-oxygenated depositional environments. Basal Triassic crinoidal meadows are described by Brosse et al. (2018) from an Asselah boulder, showing abundant holocrinids, gastropods, bivalves and five ammonoid taxa, two of which are only known in East Siberia and NE Greenland. One of the largest boulders issued of a dismantle Lower Triassic seamount consists of a 30 m high Olenekian reefal succession, partially made of up to 9 m thick continuous metazoan (bivalves, brachiopods) accumulation (Leu et al., submitted). Another ultra-condensed limestone boulder 1.2 m thick, contains more than 60 superposed ammonoids divided into 16 ammonoid zones without gap between Late Induan to Early Olenekian time (Brühwiler et al., work in progress). This boulder concerns also exceptional basal-body preservation of earliest Olenekian conodont (Souquet and Goudemand, 2019).

Brosse. M., Bucher, H., Baud, A., Frisk, Å.M., Goudemand, N., Hagdorn, H., Nützel, A., Ware, D., Hautmann, M. 2018. New data from Oman indicate benthic high biomass productivity coupled with low taxonomic diversity in the aftermath of the Permian-Triassic Boundary mass extinction. Lethaia 52(2), 165-187.
Hauser, M., Martini, R., Burns, S., Dumitrica, P., Krystyn, L., Matter, A., Peters, T., and Zaninetti, L. 2001. Triassic stratigraphic evolution of the Arabian-Greater India embayment of the southern Tethys margin. Eclogae geologicae Helvetiae 94, 29-62.

Leven, E. J., Heward, A. P. 2013. Fusulinids from isolated Qarari limestone outcrops (Permian), occurring among Jurassic-Cretaceous Batain Group (Batain Plain, eastern Oman). Rivista Italiana di Paleontologia e Stratigrafia 119(2), 153-162.
Peters, T., Batashi, M., Bläsi, H.R., Hauser, M., Immenhauser, A., Moser, L., Rajhi, A.S. 2001. Explanatory Notes to the Geological Map of Sur and Al Ashkharah, Sheet NF 40-8F & 12C, Scale 1:100,000. Muscat, Oman, in Directorate General of Minerals, 1-95.
Souquet, L., Goudemand, N. 2019. Exceptional basal-body preservation in some Early Triassic conodont elements from Oman. Palaeogeography,Palaeoclimatology, Palaeoecology 549, 109066.

Keywords: S Tethys seaway, Permian, Lower Triassic reef, ammonoids accumulation, bioherme, biostrome

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Palaeobiogeography of the Western and Eastern Tethys - migration routes (IGCP 710)

Suplementary material

The Oman-Madagascar seaway source of the unsuspected Permian-Early Triassic palaeontological richness of the Batain (SE Oman)

by Aymon Baud[1] and Hugo Bucher [2]
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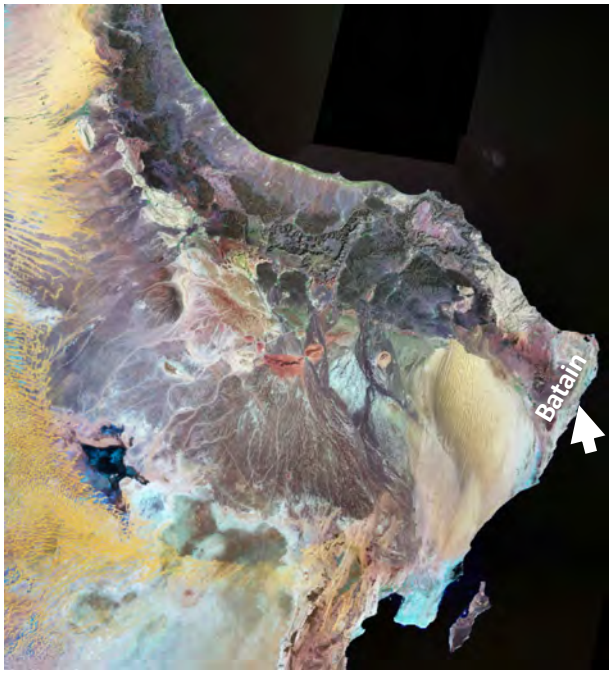
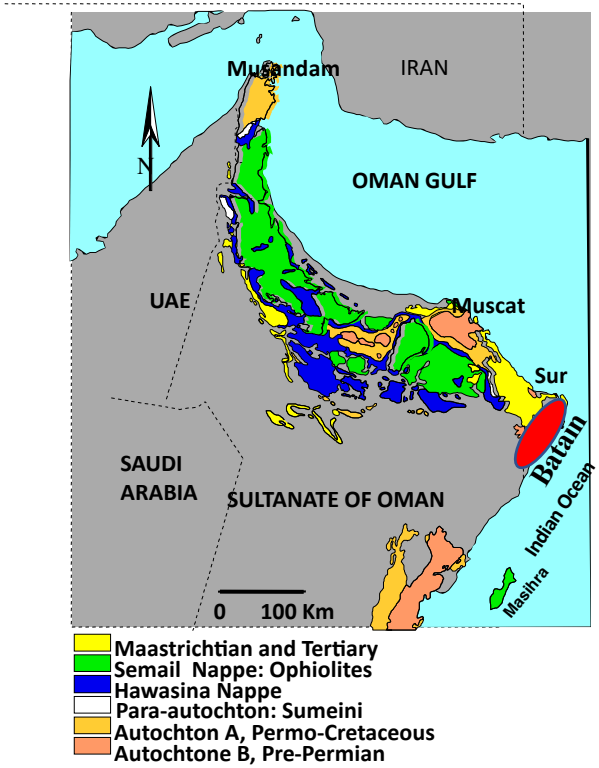
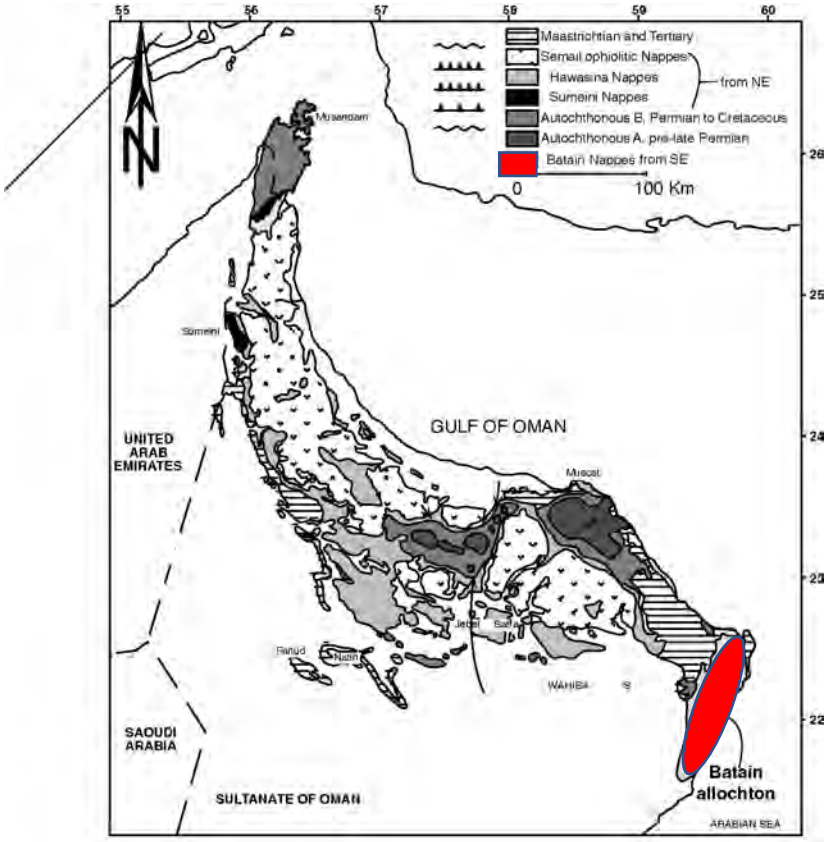
1 Introduction: geological setting of the Batain

Located in eastern Oman, south of the town of Sur, the Batain Plain extends about 40km west-east and 130km northeast-southwest and is bounded to the south by the Indian Ocean.





1 Introduction: geological setting of the Batain

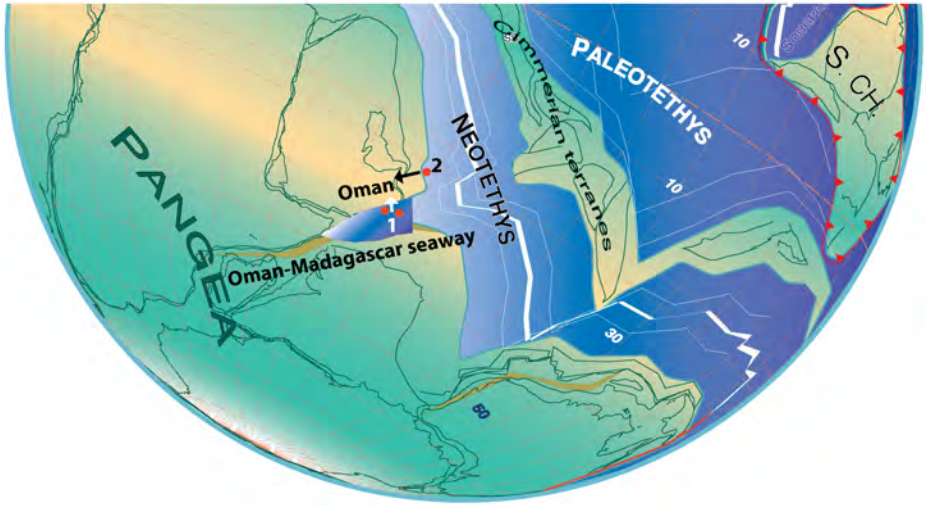


Due to the relatively scattered outcrops of the different Formations and apparently chaotic structural situation, they were previously interpreted as "Batain Melange" with the same sedimentary succession as recorded in the N Oman Hawasina basin transported to the SW from the Neotethys.

As marked lithological differences appeared with the Hawasina nappes, a Batain Group was subsequently described with four new formations, all originating from the Oman-Madagascar seaway.

2: The Gondwana margin and the Oman-Madagascar seaway

After a detailed geological mapping Peters et al. (2001), structural data, indicate a WNW directed nappe emplacement of the Batain (1), in contrast to the south to south-west thrusting direction of the Hawasina nappes of the Oman Mountains (2).

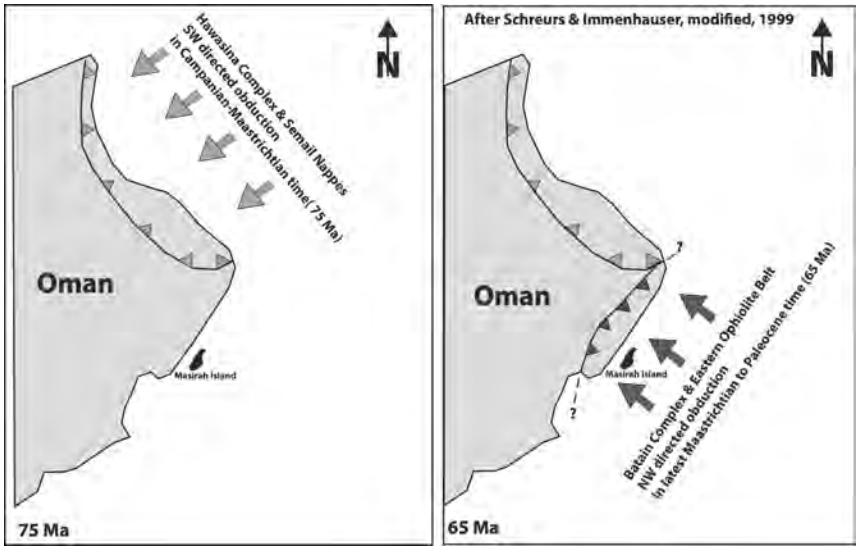


Lower Triassic Paleo-map

(largely modified from Stampfli et al., 2002) :

1 WNW directed nappe emplacement of the Batain

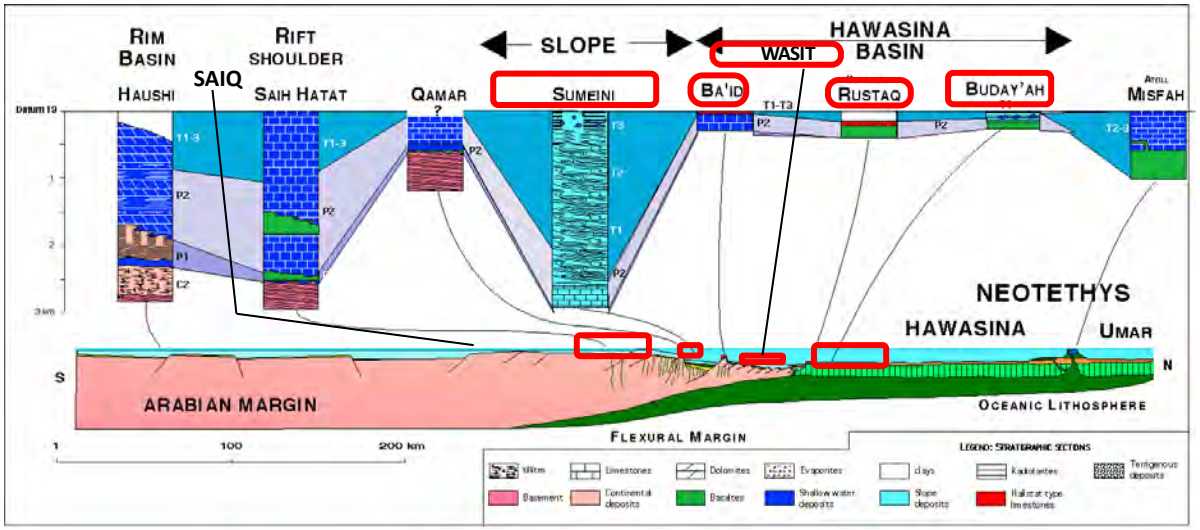
2 South-west thrusting direction of the Hawasina nappes



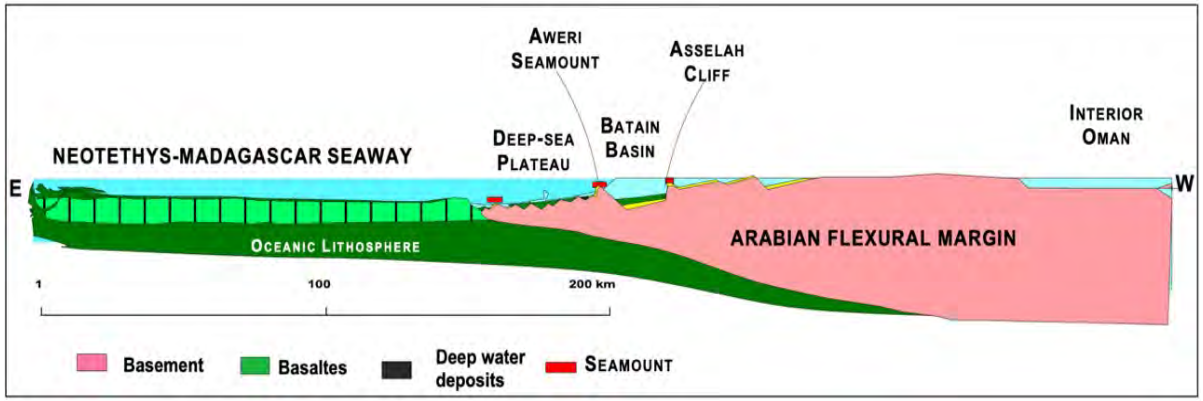
After Schreurs & Immenhauser, modified, 1999

2: The Gondwana margin and the Oman-Madagascar seaway

Autochtonous Formations **Allotochtonous Formations**

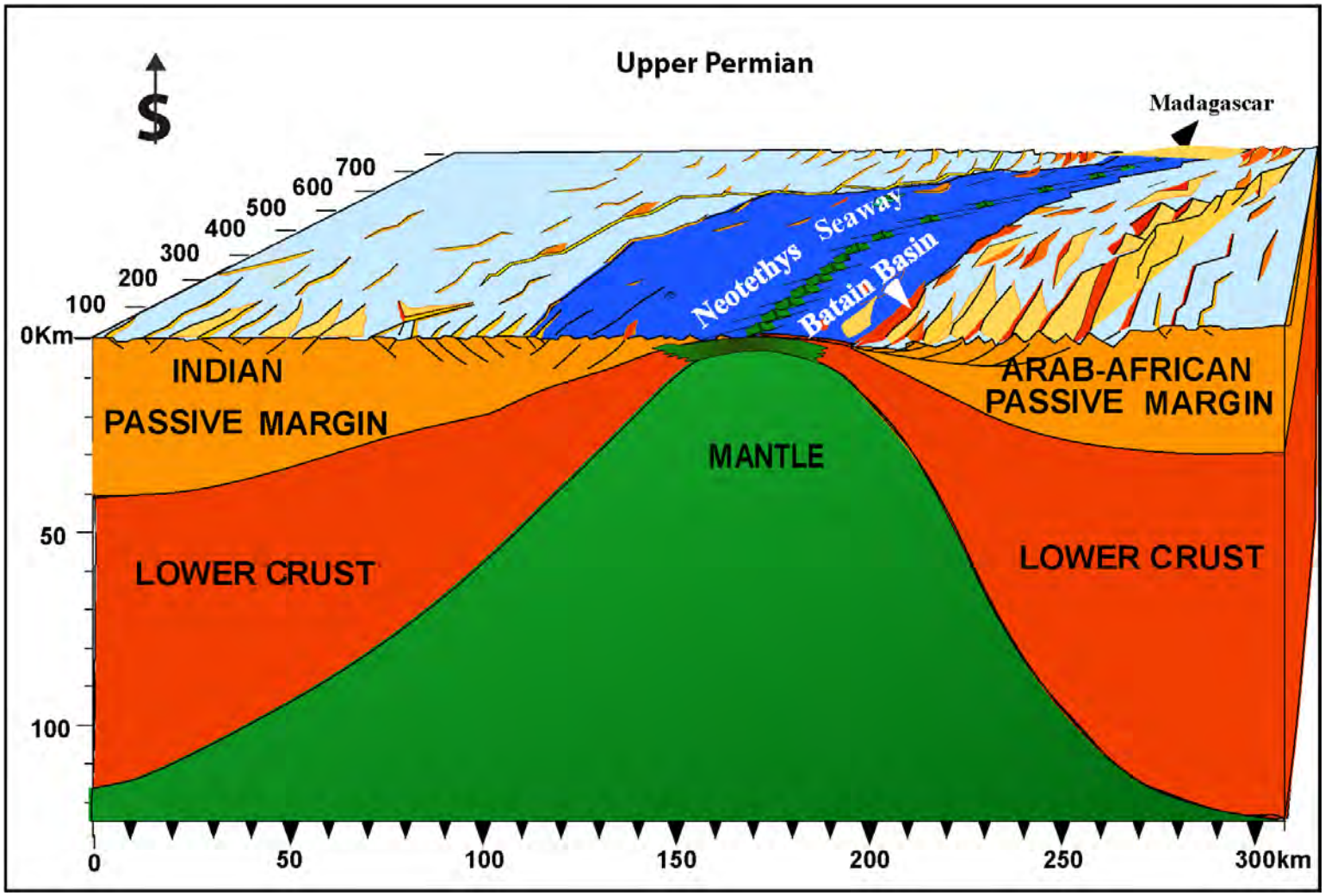


Paleoposition of the Hawasina Formations



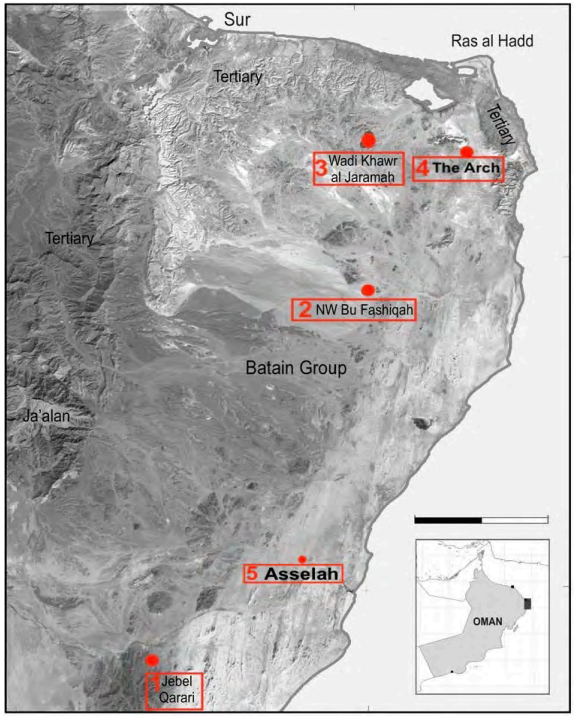
Paleo-emplacement of the Batain Formations

2: The Gondwana margin and the Oman-Madagascar seaway

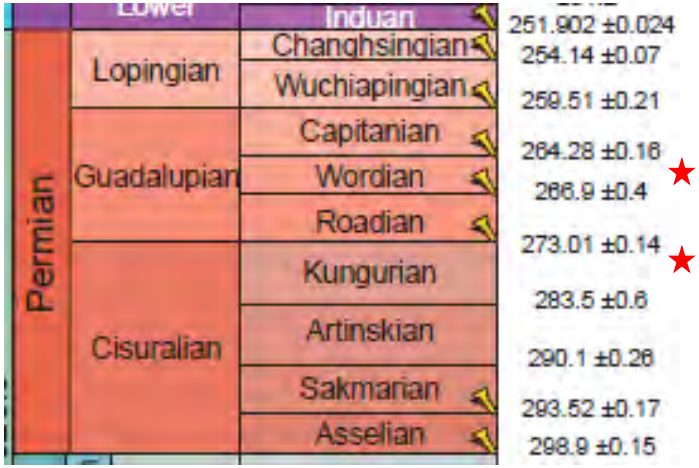


3- The Permian Qarari Formation

The middle to Late Permian of the allochthonous sequence is recorded in the Qarari hemipelagic dark limestone Formation followed by the late Permian quartzitic sandstones and the debris flow Asselah Formation.
In the next pages, we will look at five main Qarari outcrops



The five examined Qarari sections



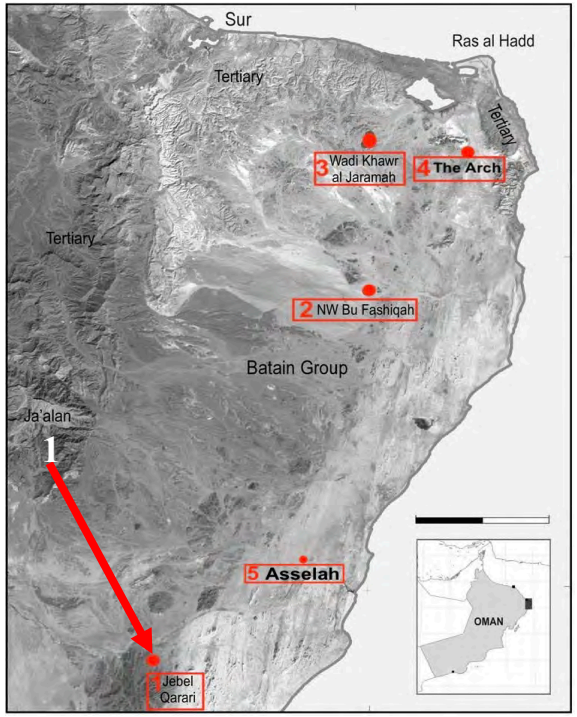
Late Permian deep water Qarari limestone NE of Bu Fashika

Stratigraphic range Known of the Qarari Formation

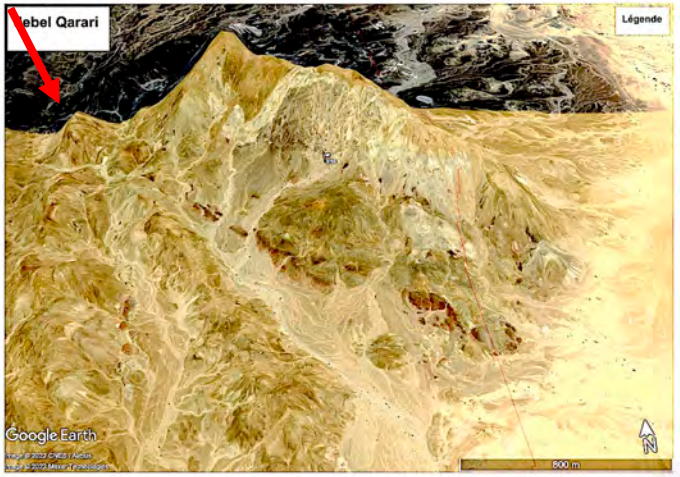
★ **Fossil rich outcrops**

3-1 The Permian Qarari Formation: Jebel Qarari and Qarari limestone, Lower-Middle Permian

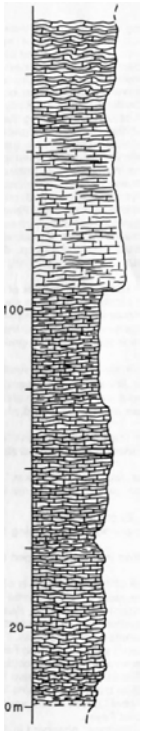
According to Shakelton et al., 1990 and Béchenec et al., 1992, a rich late lower to middle Permian fauna of Brachiopods, crinoids, with some Ammonoids and foraminifera occurs at the base of the Qarari limestone section of the Jebel Qarari.



The five examined Qarari sections:
1 - Jebel Qarari

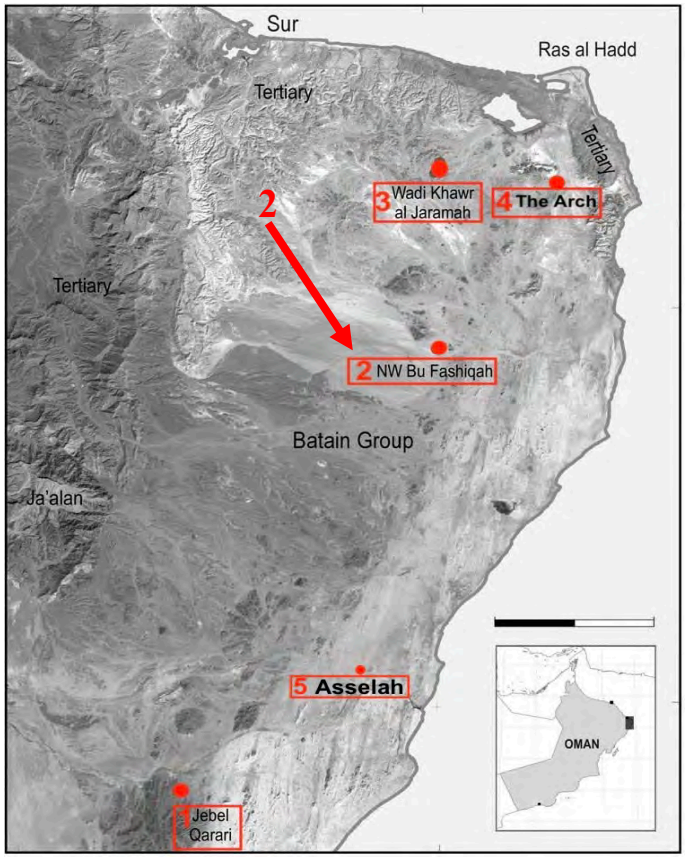


Google Earth view on the Jebel Qarari crest from SW.



The 170m thick section of Qarari limestone studied by Béchenec et al., 1992, at the foot of the Jebel Qarari

3 -2 The Permian Qarari Formation: Bu Fashiqah area, Wordian



The five examined Qarari sections:

2 - Bu Fashiqah.

Lower, marly light part cropping out in the central Bu Fashiqah area is very rich in pyritic ammonoids of Wordian age comprising at least fifteen genera according Peters et al. (2000).

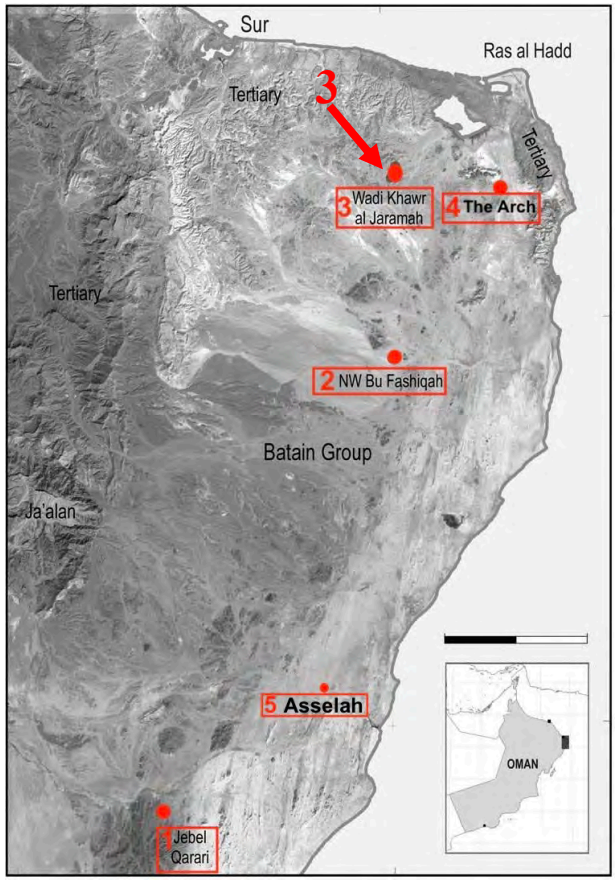
Pseudogastrioceras sp. **giving a Wordian age.** ***Tauroceras scrobiculatum*** **Gemmellaro,** ***Mongoloceras omanicum*** **Glenister & Furnish,** ***Stacheoceras meditteraneum*** **Gemmellaro,** ***Stacheoceras cf. tietzei*** **Gemmellaro,** ***Stacheoceras karpinskyi*** **Gemmellaro,** ***Agathiceras suessi*** **Gemmellaro,** ***Waagenoceras*** **cf.** ***mojsisovicsi*** **Gemmellaro,** ***Adrianites elegans*** **Gemmellaro,** ***Parapronorites konincki*** **Gemmellaro,** ***Propinacoceras beyrichi*** **Gemmellaro,** ***Altudoceras*** **cf.** ***sosiense*** **Gemmellaro,** ***Altudoceras*** **cf.** ***zitteli*** **Gemmellaro,** ***Palermites distefanoi*** **Gemmellaro,** ***Orthoceras*** **cf.** ***oehlerti*** **Gemmellaro.**

A nautilid assemblage with ***Endolobus brouweri Haniel, Nautilus molengraffi*** **Haniel** ***and Aganides bitauensis*** **Haniel.**

3 -2 The Permian Qarari Formation: Bu Fashiqah area

The Bu Fashiqah outcrop with marly light part and centimetric pyritic Wordian ammonoids

3 -3 The Permian Qarari Formation: the Wadi Khawr al Jaramah area, Kungurian-Roadian



The five examined Qarari sections:
3 - Wadi Khawr al Jaramah.

A NE highly fossiliferous outcrops of Qarari Formation have been discovered by Allen P. Heward in the Wadi Khawr al Jaramah (S of Ras al Haad) and it contain brachiopods, crinoids, blastoids, corals, trilobites, bryozoans, ammonoids, nautiloids and fusulinids. With the aid of paleontologists, the rich foraminifera fauna have been studied by Leven and Heward (2013) showing older fusulinid assemblage than those found in N Oman. The extremely well-preserved trilobite fauna was described by Fortey and Hewards (2014) with five new species including one new genus. The brachiopods rich fauna have just been published by Viaretti et al. (2022).

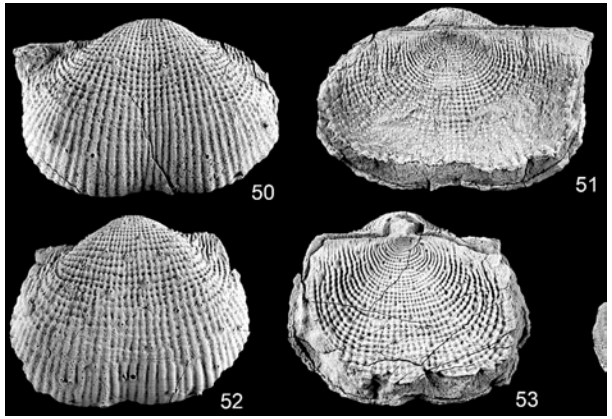
***Parafusulina arabica* n. sp. illustrated by Leven in plate 3 of Leven and Hewward (2013)**

3 -3 The Permian Qarari Formation: the Wadi Khawr al Jaramah area, Kungurian-Roadian

According to Viaretti et al. (2022), 339 very well preserved brachiopod specimens belonging to 68 species (8 orders), among which five species are new.

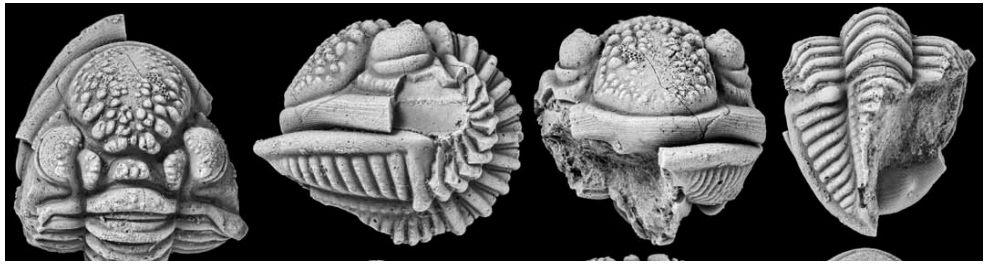
Brachiopod rich outcrop in Viaretti et al. (2022, fig. 2A & B).

The Brachiopod:



***Callytharrella websteri* n. sp. illustrated by Viaretti et al. (2022, plate 1)**

The Trilobite:



Upper part of Fortey and Hewards (2014) fig. 2 with exeptionnaly preserved *Hentigia tornata* trilobite.

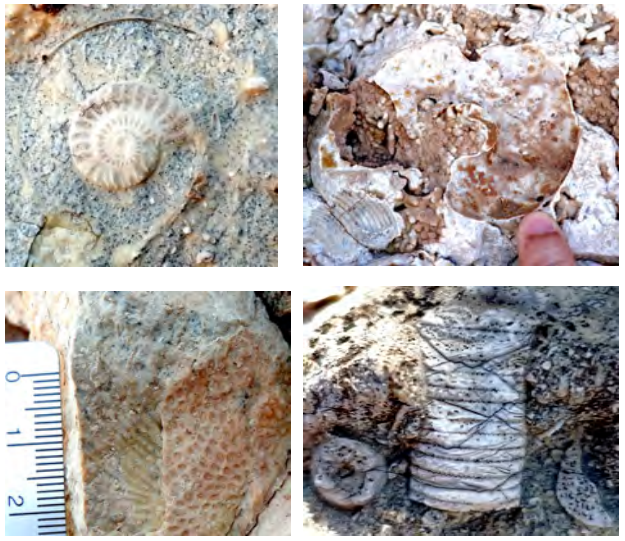
3 -4 The Permian Qarari Formation: the Arch, Wuchiapingian?

A 10m thick fossiliferous late Permian bedded limestone crop out forming an arche in the NE Batain plain at N 22 26'35" E 59 46'01". According to L. Krystyn (oral communication) conodont identification has indicated a Wuchiapingian age for this outcrop.

The main facies consist of light calcarenites locally crinoids rich, with ammonoids, coral,, bivalves and bryozoans. From this and surrounding outcrops, 48 bryozoan species were described by Ernst et al., 2008.

Even, fishes (chondrichthyan) teeth have been discovered by M. Koot (2013). Ammonoids, crinoids, foraminifera and conodonts are present and need to be studied without destroying this protected outcrop.

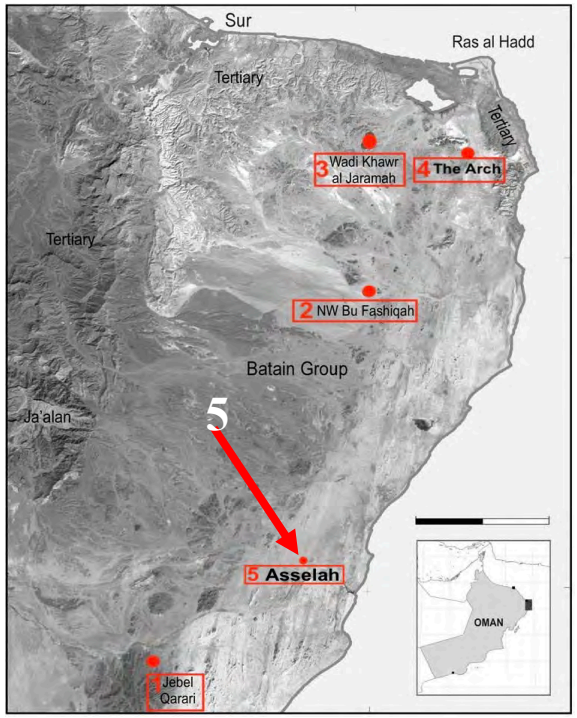
View on the the Arch, part of Oman Geoheritage



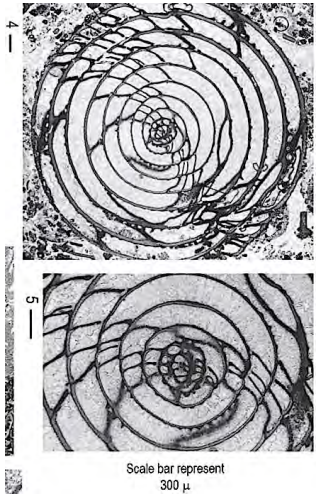
Ammonoid, coral, bivalve and crinoids.

3 -5 The Permian Qarari Formation: the pebbles of the Asselah conglomerates , Kungurian-Wuchiapingian

Studied by Vachard et al., (2002), the Asselah conglomerate contains Qarari reworked limestone pebbles, yielding an exceptionally rich Permian fusulinid assemblages, Kungurian to Wuchiapingian in age.

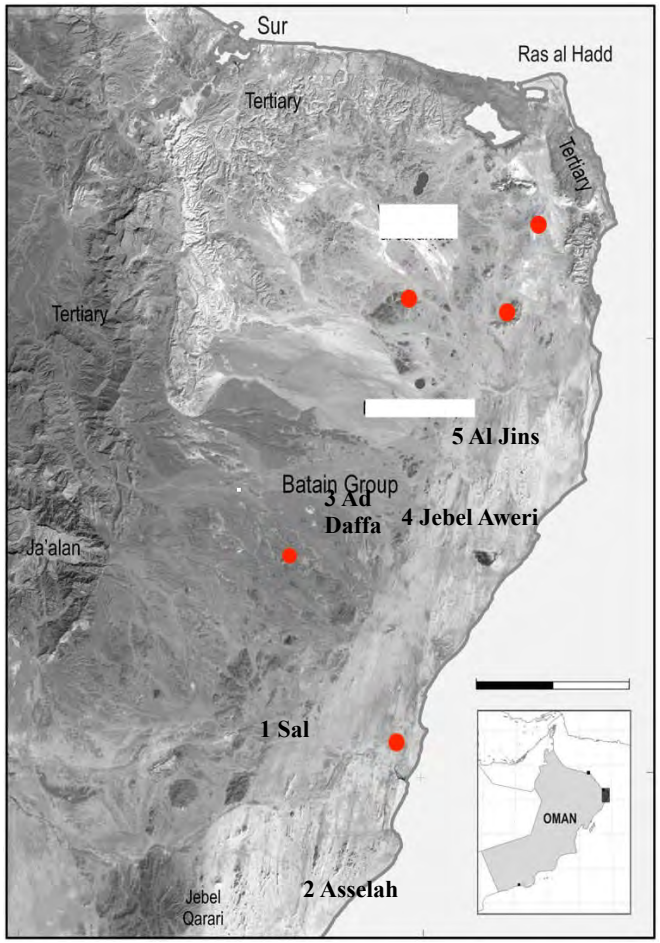


The five examined Qarari sections: 5 - Asselah.



***Verbeekina douvillei* (Deprat, 1912). in Vachard et al., (2002), plate 4**

4 -The fossiliferous Early Triassic



The five examined Lower Triassic sections

Until now, in the sedimentary succession of the Batain area, the Induan time was considered as a sedimentary gap (Hauser et al., 2001). Our finding of more than 40 reworked boulders of lower Triassic, from Griesbachian to basal Anisian coquina and buildup limestone brings new views on the Paleozoic to Mesozoic evolution of this peculiar area and on Early Triassic recovery.

Fossil richness of these Early Triassic boulders with accumulation of ammonoids, bivalves, brachiopods and aboundant well-preserved conodonts is unexpected, and all of these new occurrences record well-oxygenated depositional environments.

The five localities within the Batain hills presented here are:

1 –Sal
2 –Asselah
3 –Wadi ad Daffa
4 –Jebel Aweri
5 – Ras al Jin

4-1 The fossiliferous lower Triassic: Sal Formation

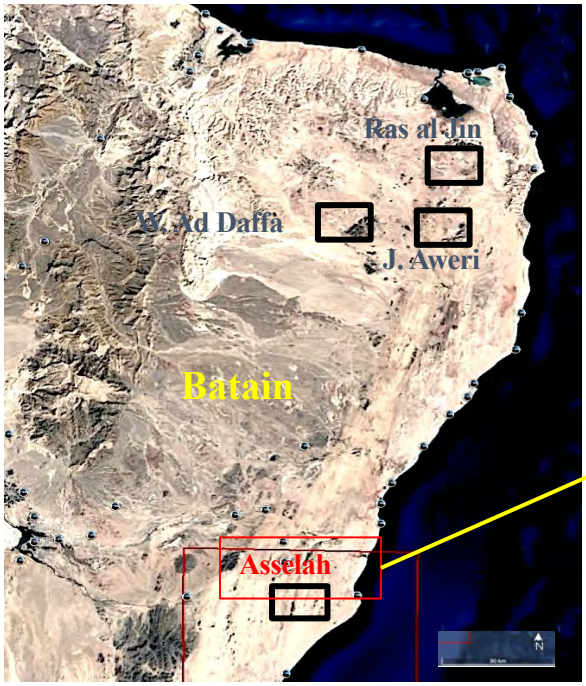
There are no continuous sections from the Permian Qarari limestone to the Triassic Sal Formation. The Sal Formartion start with middle Smithian platy limestone, followed by mudstone, Anisian radiolarian cherts, and Ladinian to Rhetian calcarenite, mustones and radiolarites. In the Batain sedimentary succession, the Early Triassic Induan time was considered until recently, as a sedimentary gap.

Spathian thin-bedded limestone of the Zal Formation, N of Zal village.

Spathian silicified ammonoids on a bed surface

4-2 The fossiliferous lower Triassic: the Asselah basal Triassic boulder

A new basal Triassic marine fauna has been described from a boulder of the middle Jurassic Ad Daffah olistostrome, which provides new insights into the ecology and diversity during Griesbachian time, which shortly followed the Permian-Triassic boundary mass extinction (PTBME). It was derived from an offshore seamount or seaway plateau, and yielded both nektonic and benthic faunas, including conodonts, ammonoids, gastropods and crinoid ossicles in mass abundance. Crinoidea produced enough biomass to form crinoidal limestone during Griesbachian time. A new genus, *Baudicrinus* is confirmed (Brosse et al., 2019).



The five examined Lower Triassic sections

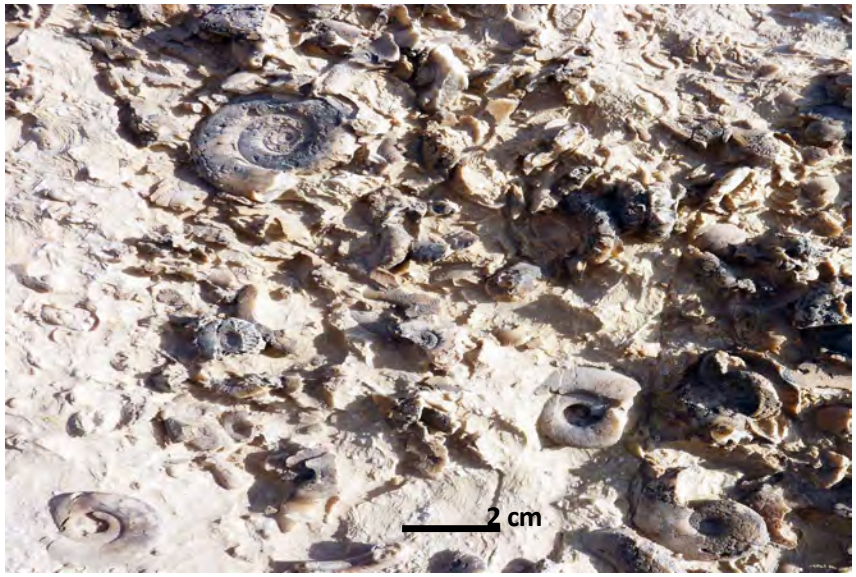
2 -The Asselah area

View of the Asselah hills in SW Batain Area

4-2 The fossiliferous lower Triassic: the Asselah basal Triassic boulder

There is no evidence of anoxia on this well oxygenated shallow neritic plateau, nor any sign of "intense post-extinction acidification". This may explain why the Batain neritic seamount or plateau records a very early (i.e. Griesbachian) episode of marine ecosystem recovery.
The seaway mounds or plateaus apparently escaped the environmental deterioration that prevailed on the continental platform, on the slope and in the basin, and may have functioned as refuge or oases.

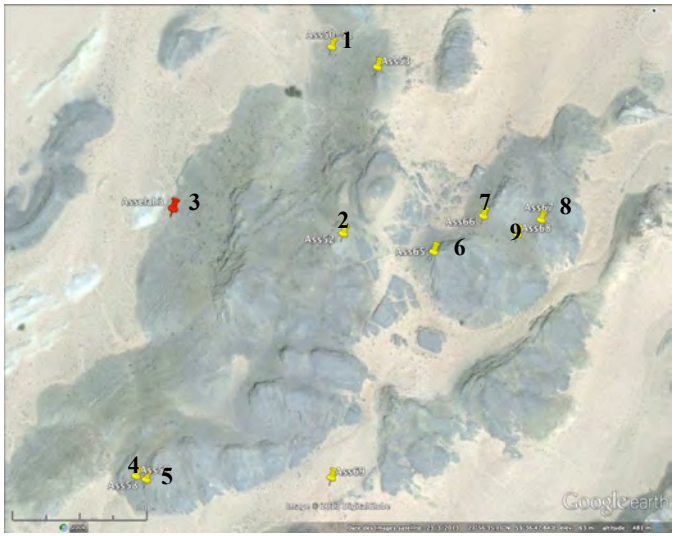
View on the crinoidal boulder



Close view of the boulder surface with an accumulation of skeletal shells and crinoid stems. Five ammonoid taxa have been identified, two of which were only known in East Siberia and NE Greenland (Brosse et al . 2019)

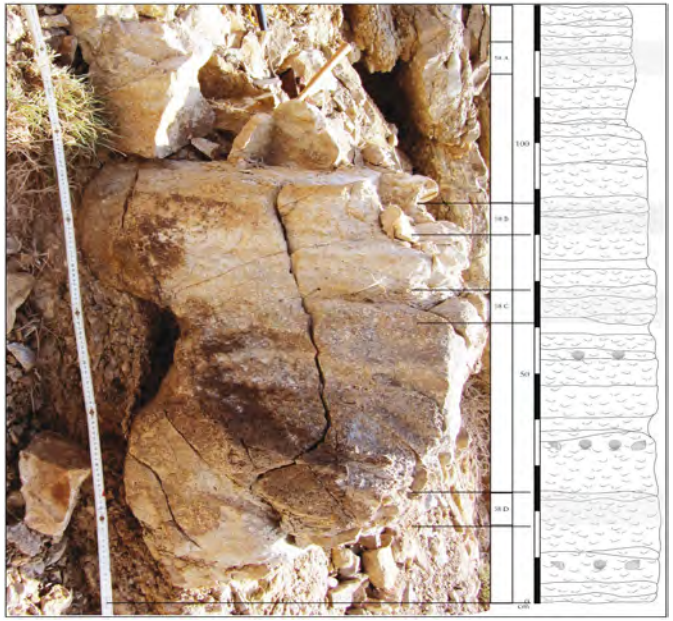
4-2 The fossiliferous lower Triassic: the Asselah Lower Triassic boulders

We found 8 lower Triassic boulders within the middle Jurassic olistostrome in the Asselah area.



Points (yellow and red) of Lower Triassic boulder in the Asselah hills area

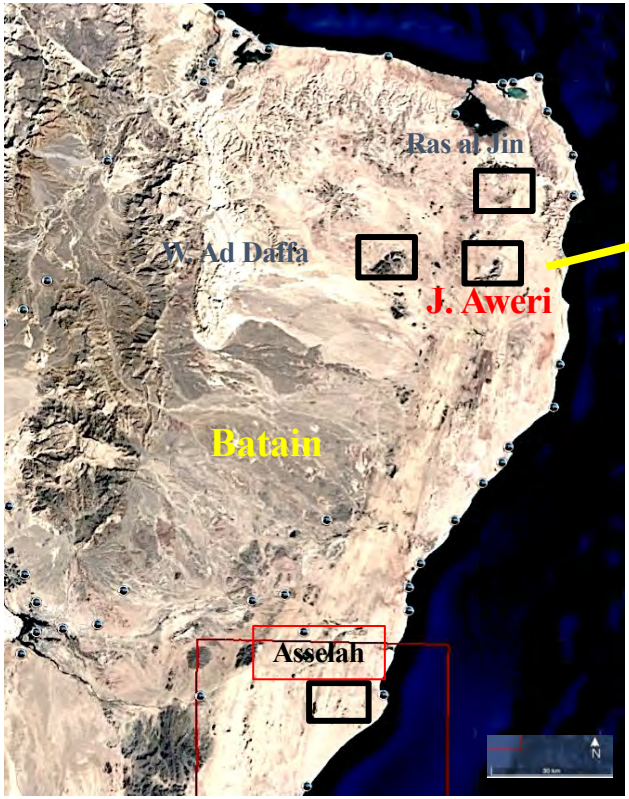
Block No		Ech	rock type	fossils	Age
ASS 1	51	3	Limestone	amm.	Smithien
ASS 2	52	5	"	amm.	Smithien
ASS 3	3	10	"	Am crin. Biv.	Griesbachian
ASS 4	58	4	"	bivalve	Griesbachian
ASS 5	59	1	"	Amm	Smithien
ASS 6	65	8	"	Amm	Smithien
ASS 7	66	9	"	Amm	Smithien?
ASS 8	67	5	"	Amm	Dienerien?
ASS 9	68	3	"	crin. biv.	Griesbachian?



The Griesbachian bivalves boulder ASS 4, 70 cm high
(not yet published)

4-3 The fossiliferous lower Triassic: the Jebel Aweri locality

More than 20 fossiliferous lower Triassic boulders in Jebel Aweri



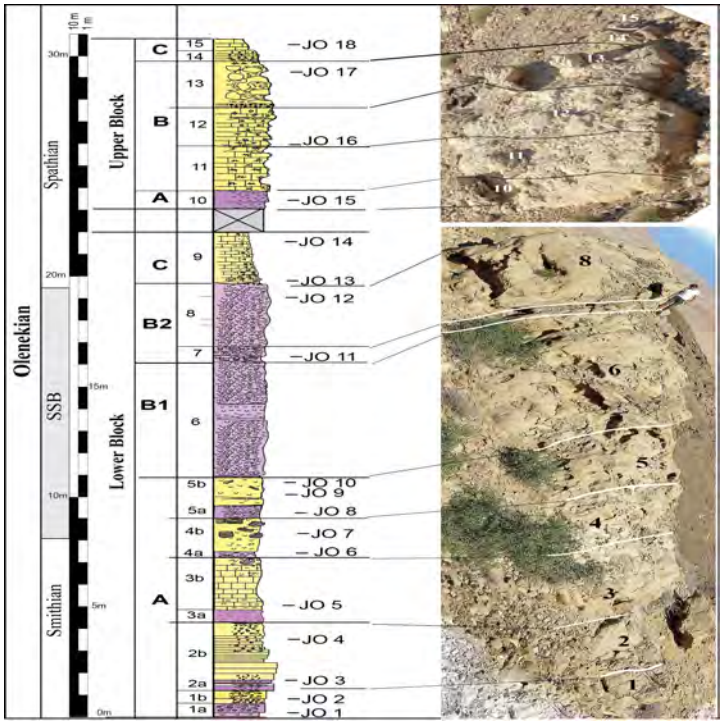
The five examined Lower Triassic sections:
3 - Jebel Aweri

Close view of Jebel Aweri from the North

4-3 The fossiliferous lower Triassic: the Jebel Aweri buildup

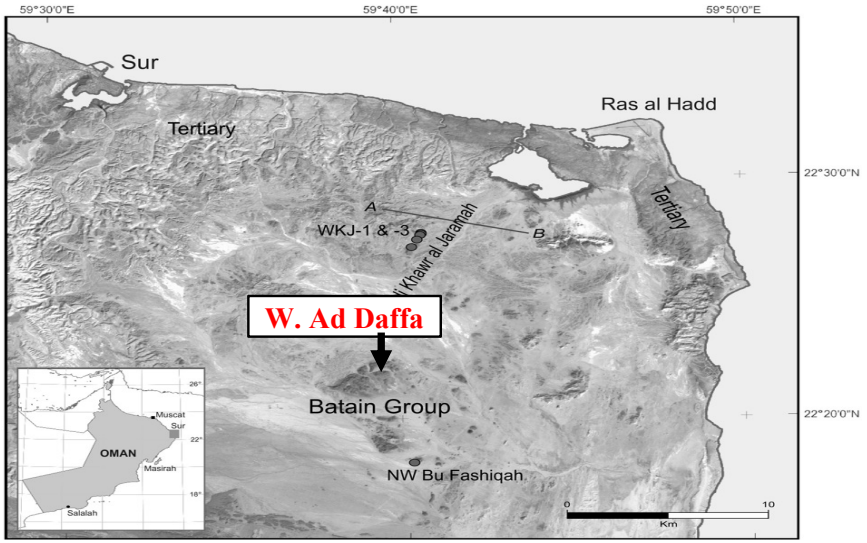
The discovered Jebel Aweri Olenekian buildup block, about 30 m. thick, is one of the largest boulders from the middle Jurassic Ad Daffah olistostrome. The block is derived from an EarlyTriassic seamount. The lower part, 11m thick, is subdivided in 5 cycles biostrome-bioherm. The middle part is a shell supported biostrome, 9m thick of continuous bivalve-brachiopod accumulations. The upper part, with microbial lime clasts and thrombolites is 2m thick. The top part, early Spathian in age, is more diversified and subdivided in 6 levels, with a brachipod supported biostrome base overlain by lime clast supported levels.

Outcrop general view (from W) of the Jebel Aweri giant buildup.

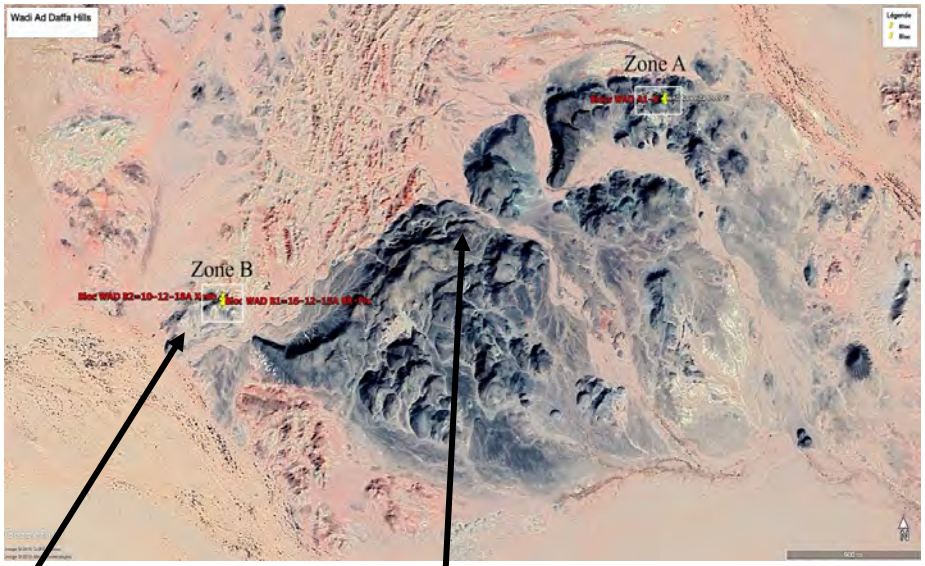


Stratigraphy and outcrop view (from W) of the Jebel Aweri 30 m. high buildup section.

4-4 The fossiliferous Early Triassic: the Wadi ad Daffa locality

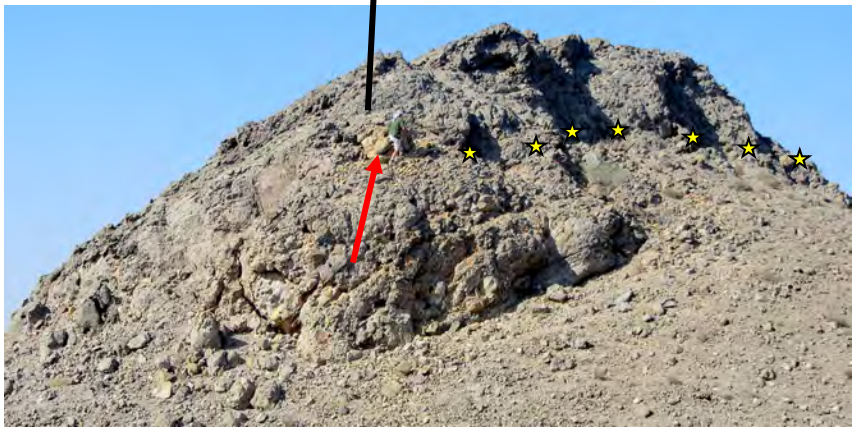


Geographical position of the the Wadi ad Daffa area



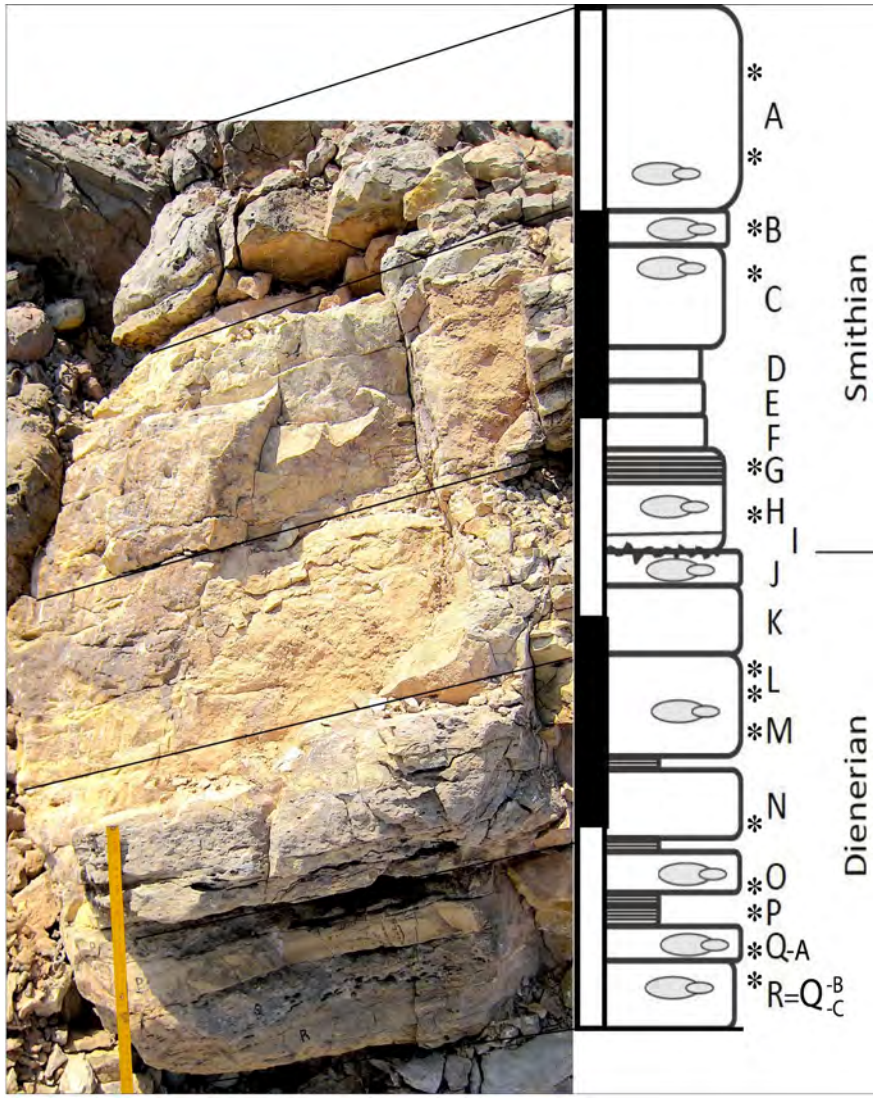
Wadi ad Daffa area with zones A and B

General view (from S) of the Wadi ad Daffa zone B with the position of the Early Triassic boulders .



General view (from S) of the Wadi ad Daffa zone A, with the position of the lower Triassic boulder WAD 2 (red arrow) and the other (yellow stars).

4.4 The fossiliferous lower Triassic: the Wadi ad Daffa boulder 2 (WAD 2)



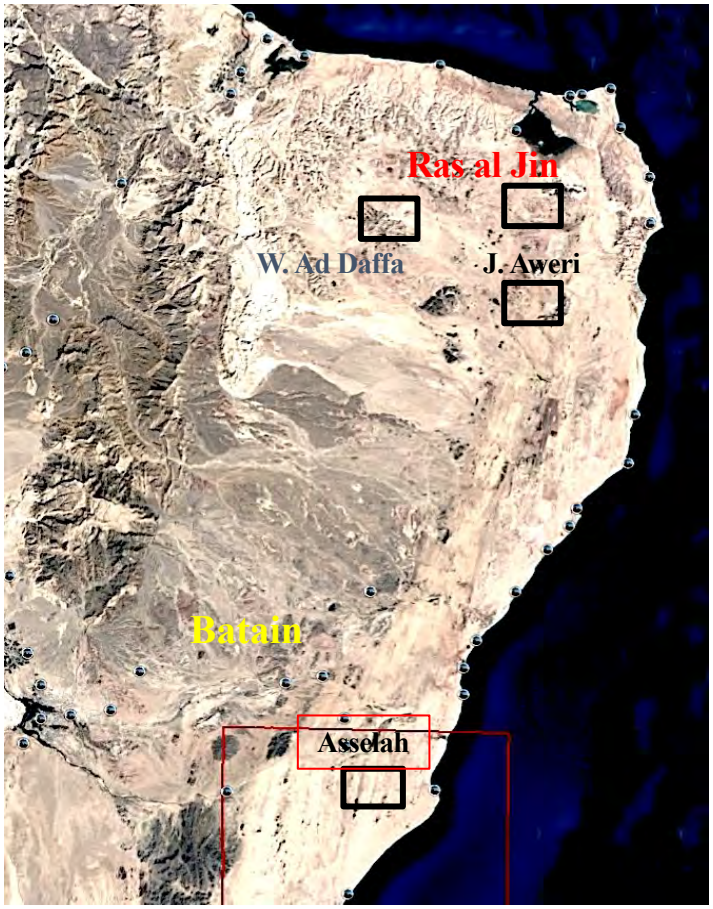
The WAD 2 outcrop view and sketch from Souquet & Goudemand, (2019)

The 1.4 m condensed carbonate sediment accumulation of the Ad Daffah2 ammonoid rich boulder consists of centimetric to pluri-centimetric micro-cycles of macrofossil rich and macrofossil depleted succession. Souquet & Goudemand, (2019) published and illustrate the exceptiomal preserved basal bodies of lower Smithian neospathodid conodont elements.

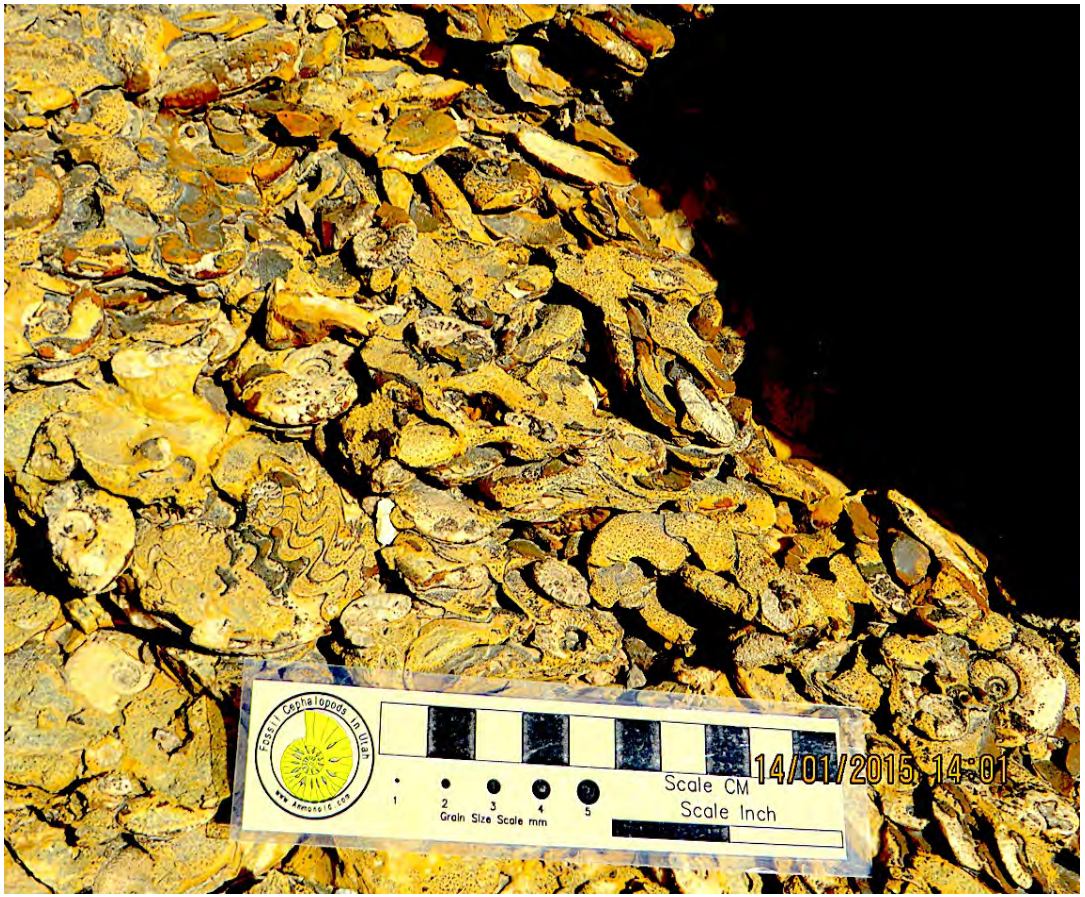
According to Brühwiler et al., (ongoing work in progress) , 10 superposed ammonoid assemblages have been determined in the Dienerian lower part; and 8 ammonoid assemblages in the Lower –Middle Smithian upper part.

Polished surface of the ammonoid rich level Q

4-5 The fossiliferous lower Triassic: the Ras al Jin area, Dienerian



The five examined Lower Triassic sections:
5 – Ras al Jin



Dienerian ammonoid accumulation of the RAJ 1 block

Preliminary conclusions

1- Among the five main Permian Qarari limestone fossil rich localities, two, have been studied in detail: the pebbles of the Asselah conglomerate and the Wadi Khawr al Jaramah. The first one give a list of foraminifera and algae from Kungurian to Lopingian by Hauser et al., (2000), and by Vachard et al., (2001, 2002).
And the second shows fusulinid determined by Leven and Hewward (2013) and well-preserved trilobites illustrated by Fortey and Hewards (2014). Brachiopods have just been published by Viaretti et al., (2022) confirming Late Kungurian to Early Roadian age.

2-Only a list of the Wordian pyritized 15 ammonoids species of the Bu Fashiqah area have been published but are under study by Leopold Krystyn (oral communication).

3- Conodont of the Qarari limestone are under study by Henderson et al. and some results synthetized in his abstract (Henderson etal., 2022, 6e IPC Abstract Volume)

4- Among the more than 40 Early Triassic fossil rich boulders/blocks discovered in the Batain, most have been sampled and stored in Zurich. A first one has been published (Brosse et al., 2019), a second one is in press (Jebel Aweri giant block) and 2 others are currently in press (ammonoids, conodonts, geochemistry).

5- Dienerian and Smithian ammonoid successions are perfectly correlated and identical to these of the Tethys Himalaya and South China.

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Thanks for your attention

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