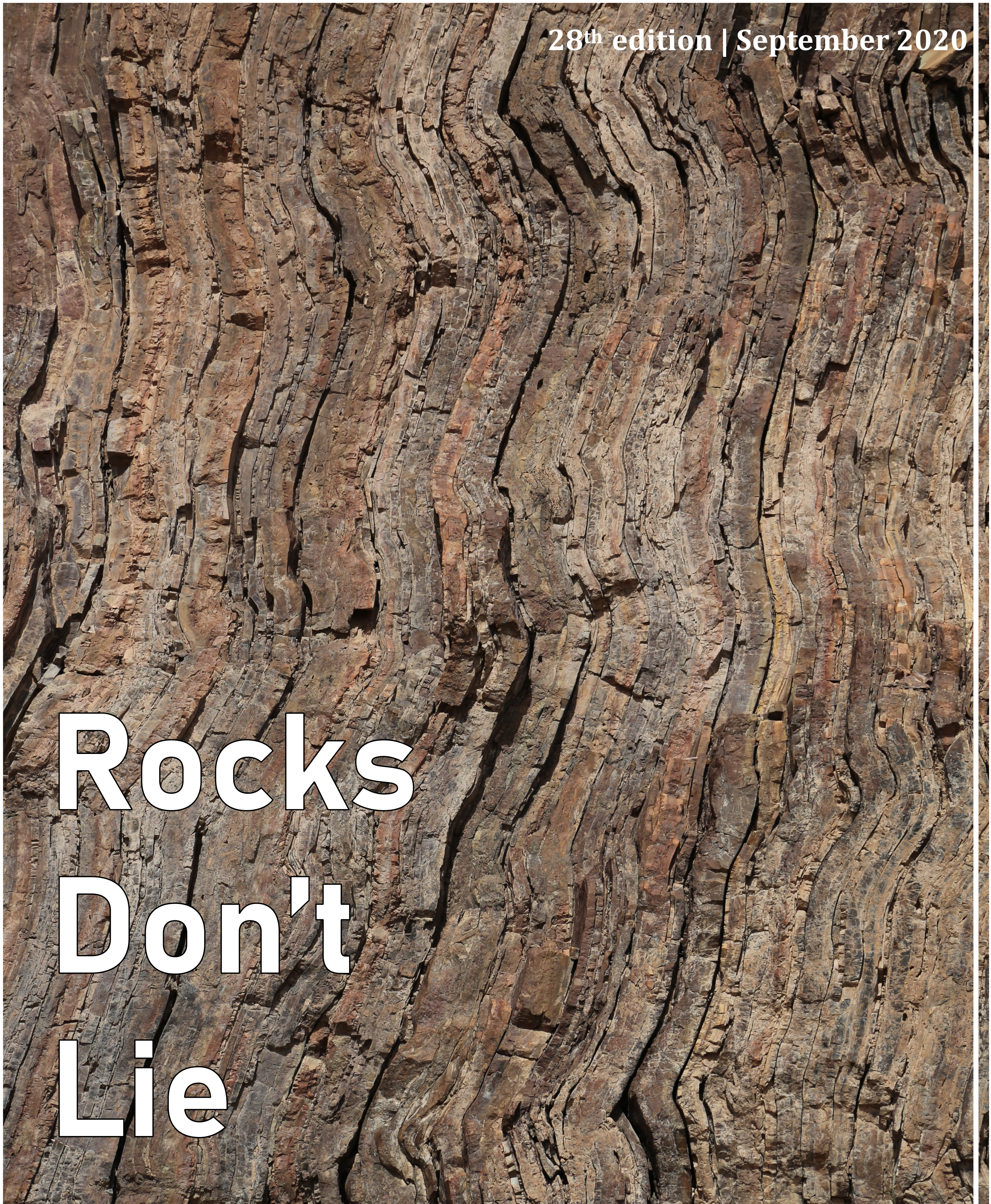
Al HAJAR

28th edition | September 2020



Rocks Don't Lie

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ON THE COVER

Deformed rocks of cherts and mudrocks of the Hawasina Group. The photo was taken from Wadi Sabt in Al Sharqiyah Governorate.

ABOUT GSO

The Geological Society of Oman GSO was established in April 2001 as a vocational non profitable organizations which aims to advance the geological science in Oman, the development of its members and to promote Oman's unique geological heritage.

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BY THE EDITOR

Dear GSO member,

“Rocks don’t lie”, a statement that I heard once and immediately made me thinking about the philosophy behind it. It is true! The rocks are our evidence of the past of our planet and it can reveal a lot of information that is waiting for us to observe, analyze and discover . In this issue, we published two articles from geologists who shared their observations and interpretation with the rest of us to reveal a piece of the puzzle of the history of the Earth. We hope that you will enjoy reading this issue and to be encouraged to share your studies with us as well so we can share it with the rest of the GSO community and for those who are excited to understand Earth.

Stay Safe.

Husam Al Rawahi

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Petroleum Development of Oman

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President Address

Dear Colleagues,

I trust by now going into the 3rd quarter of the year; the society managed to progress most of its technical program during this difficult time. With the restriction of socializing, the committee members managed to build 2020’s agenda and communicate with individuals both from Oman and externally to host talks, workshops and technical sessions using available online platforms. The feedback received was excellent and our broadcast reached all members of the society and the public. We have also incorporated some of our talks related to Geo-Tourism, mining, and Earthquakes in Oman via Oman Cultural Club platform. This bonding relationship with the cultural club is the start of a future engagement to widen our communication to the public and to show the importance of brightening the geology of Oman in different scales, tourism, mining, virtual geological excursion, and many related to heritage places associated with geological history.

With this I wish that we have delivered a solid & diversified technical program, rich of knowledge and to your expectation. If you have any suggestion or recommendation, please do not hesitate to communicate it to us and surely your voice is heard as we all are opted to provide the best.

Elias Al Kharusi

President of the GSO

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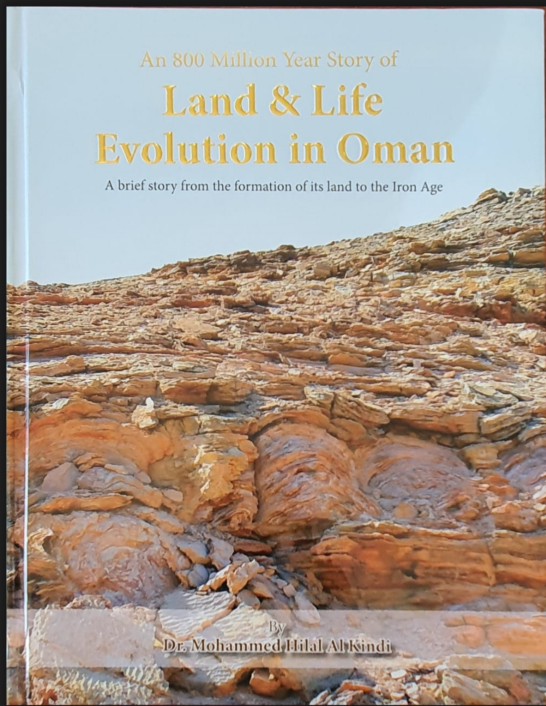

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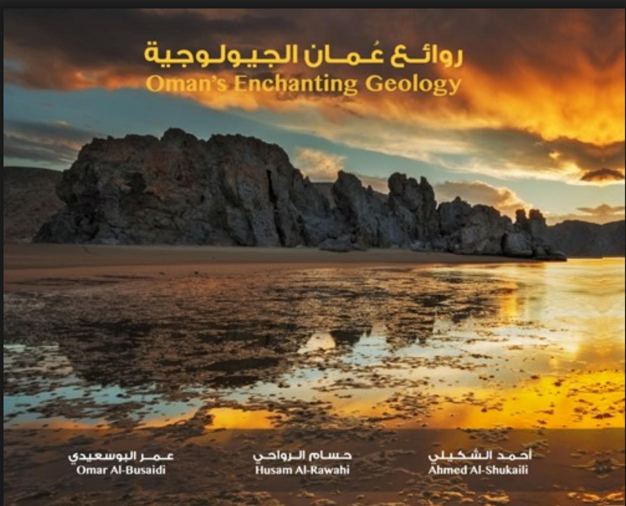

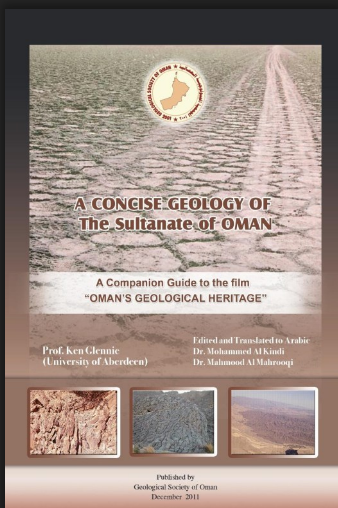

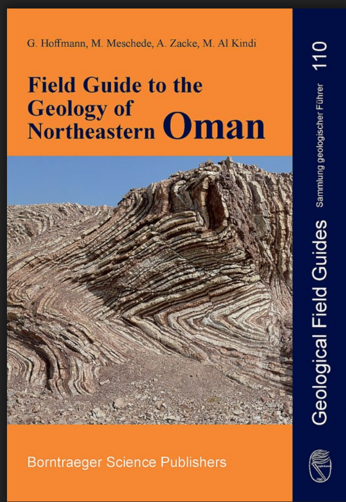

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GEOLOGY OF THE PALEOARCHEAN EASTERN IRON ORE GROUP OF ROCKS, INDIA

By: Rajat Mazumder and Wilfried Bauer

Introduction:

The Department of Applied Geoscience is currently undertaking research of Precambrian terrains, formerly adjacent to the Arabian Plate in a Gondwana configuration. We are currently examining an interesting Paleoarchean succession in eastern India (the eastern Iron Group of rocks, EIOG) as part of our The Research Council (TRC) of Oman sponsored research project. In this article we are summarizing some interesting field observations from the eastern Iron Ore Group of rocks which is part of a Paleoarchean granite-greenstone succession.

Paleoarchean (3.6-3.2 billion years) rocks are rare on earth and are largely preserved in South Africa, North America, Western Australia, Brazil, Greenland and India. These rocks provide us valuable information on early earth surface processes and crust-mantle interactions (Eriksson et al., 2004; Rollinson, 2007; Van Kranendonk et al., 2019). According to Miller et al. (2018), India has perhaps "*the richest Paleoarchean to Paleoproterozoic crustal components on Earth*". However, in significant contrast to other cratonic blocks of the world (Eriksson et al., 1994; Van Kranendonk et al., 2019), the Paleoarchean successions of India are largely unexplored (Mazumder et al., 2019a).

Geological setting:

The Singhbhum cratonic block in eastern India is one of the five cratonic blocks of India that preserve an almost continuous geological record from Paleoarchean to Neoproterozoic (Mazumder et al., 2019a). The oval shaped Singhbhum ganitoid (SG) batholith along with the mafic-ultramafic (minor felsic) volcanic and volcano-sedimentary succession and banded iron formation (BIF) Iron Ore Group (IOG) constitute the Singhbhum nucleus and represents a typical Archean granite-greenstone terrain (Mukhopadhyay, 2001; Fig. 1). The IOG volcano-sedimentary succession is exposed along three distinct belts to the east, west and south of the SG and are known as the eastern, western and the southern IOG belt (Fig. 1) respectively. The Singhbhum supracrustals are polydeformed and metamorphosed (up to upper amphibolite facies; Saha, 1994). The IOGs are metamorphosed up to the upper greenschist facies.

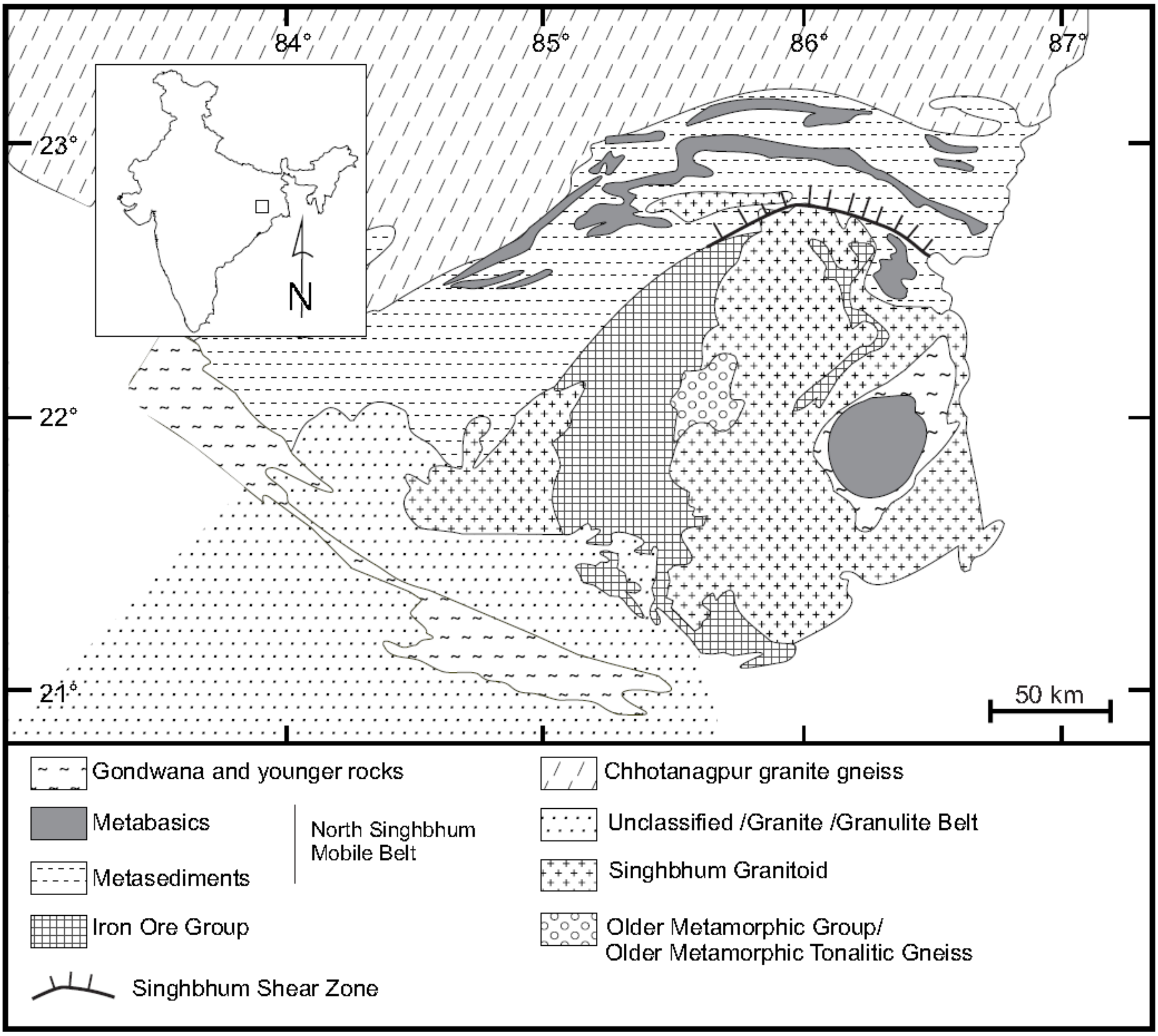

Fig. 1: Geological map of Singhbhum craton (modified after Mukhopadhyay, 2001).

Zircon grains from dacitic lava occurring below the BIF from the basal part of the southern IOG belt indicates concordia age around 3.5 Ga (Mukhopadhyay et al., 2008) and this age is considered as the older age limit of the IOG succession. Nelson et al. (2014) have reported ~3.38 Ga age of granitoid intruding the IOG rocks at the Deo river section which indicate that the BIF of the western IOG belt cannot be younger than 3.38 Ga. The 3.32 Ga U-Pb zircon age from the monzogranite with BIF enclave near Rairangpur (Nelson et al., 2014; Fig. 2) indicate that the eastern IOG succession is □ 3.3 Ga. Thus, the BIF bearing IOG successions of the Singhbhum craton are of Paleoarchean (~3.5-3.3 Ga) age. The Paleoarchean successions unconformably overlies a ~3.5-3.4 billion years Tonalite-Trondhjemite-Granodiorite (TTG) complex in the eastern IOG belt (Acharyya et al., 2010). Researchers have reported 4.24-4.03 billion years old xenocrystic zircons from the OMTG (Chaudhuri et al., 2018). The Paleoarchean Older Metamorphic Group (OMG) of rocks are characterized by intercalations of clastic sedimentary rocks and mafic igneous rocks deformed and metamorphosed to amphibolite facies (Saha, 1994; Mukhopadhyay, 2001; Hofmann and Mazumder, 2015; Chaudhuri, 2020). Olierook et al. (2019a) and Chaudhuri (2020) have presented an updated critical synthesis of geochronological data generated from the Singhbhum craton.

EIOG volcano-sedimentary succession:

The EIOG succession is exposed in the eastern part of the craton in form of a narrow and arcuate belt (Fig. 2) with steep dip (around 60-65° but sub vertical at places). The succession overlies the 3.45 billion years TTG (Fig. 3A). The EIOG sedimentation initiated with the deposition of shale-heterolithic (sandstone-shale)-sandstone association in the Potka-Chirugora-Kudada sector (Fig. 2) whereas in the Ruansi-Baliabadi-Bhatgora sector, the EIOG sedimentation started with deposition of coarser clastics (conglomerate-pebbly sandstone-coarse-grained sandstone). Ultramafic (komatiitic)-mafic-minor felsic volcanics are the magmatic components of the EIOG succession. The komatiites display well preserved spinifex (Fig. 3B) and cumulate zones (Chaudhuri et al., 2015, 2017). In addition to komatiites, pillowed and vesicular basalts are common. Recent field studies also reveal minor felsic volcanics (Sengupta et al., 1997; Ghosh et al., 2019; present study). BIF is an important constituent of the EIOG succession like the WIOG and SIOG (Fig. 1) and is the major resources of iron in India (Mukhopadhyay, 2020).

The two sedimentary facies associations of the EIOG succession do not show lateral transition and hence it is difficult to comment on lateral faci-

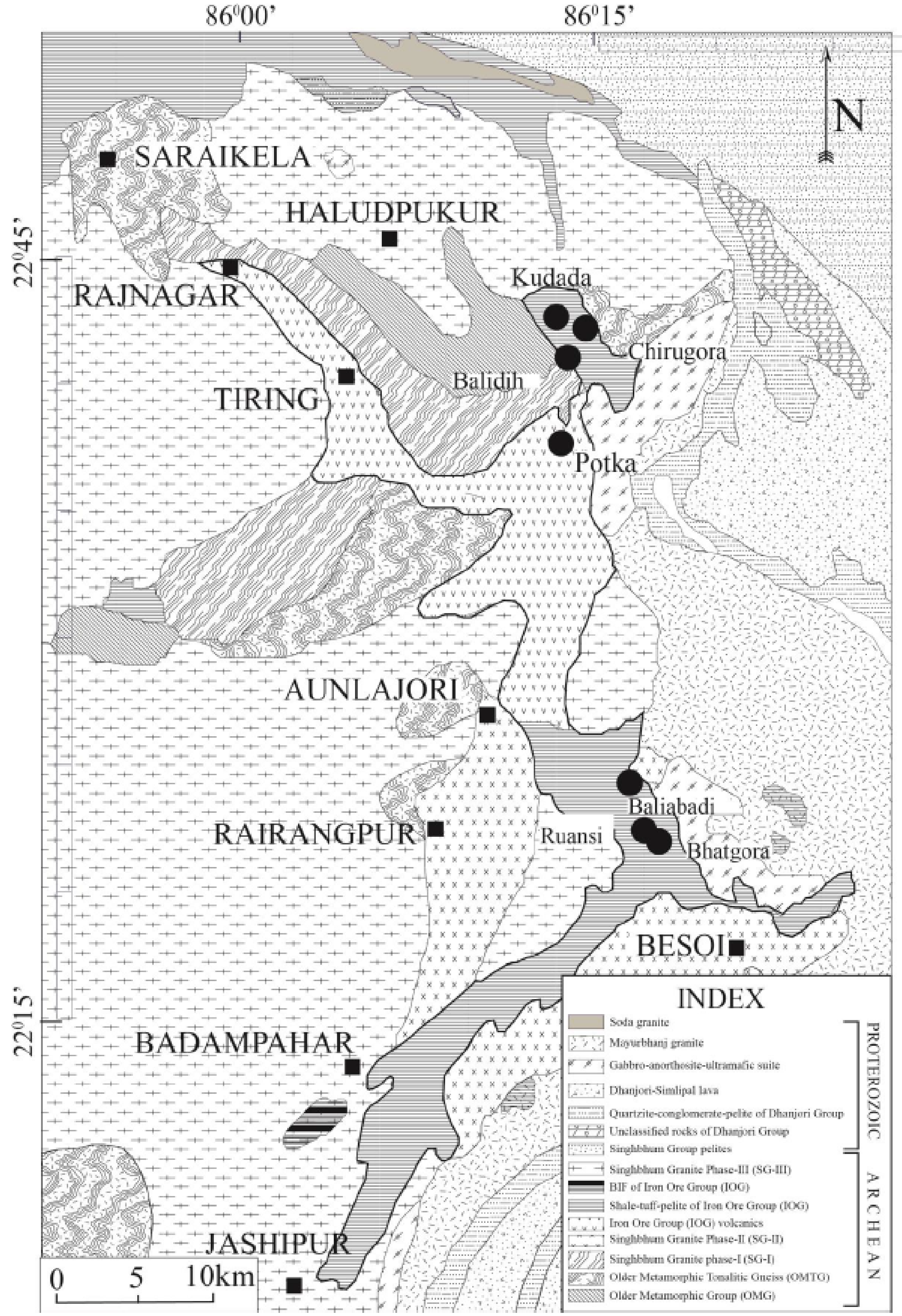

Fig. 2: Geological map showing the disposition of the Eastern Iron Ore group succession and the study locations (modified after Saha, 1994).

Fig. 3: Field photographs from the EIOG belt: (A) Granitoid basement (B) Komatiite with characteristic spinifex texture (C) Clast supported polymictic conglomerate (D) Coarse grained pebbly sandstone (E) Fine-grained sandstone showing normal grading (F) Cross-bedded sandstone with alternate thick-thin foresets and mud drapes.

es change. However, the sedimentary characteristics of the sandstones are different. The conglomerates are polymictic, largely clast supported, poorly sorted and bedded (Fig. 3C). Pebbles of chert, fuchsite quartzite, quartz vein, and jasper are common. Clasts are sub-angular to subrounded (Fig. 3C). The coarse sandy matrix is greenish in color due to the presence of fuchsitic mica. The sandstones are coarse to medium-grained (Fig. 3D) and bear sedimentary structures like planar lamination and cross-bedding. Both tabular and trough-cross beds are observed. Compound cross -stratification is preserved at places. At places, massive sandstone beds are also observed. The sandstones and the coarse sandy matrix of the conglomerates bear a variety of heavy minerals, including zircons (Chakravarthi et al., 2017) and have potentialities for sedimentary provenance analysis. The conglomerate units are generally 2 to 5m thick but at places attain thickness more than 10m. Locally reverse grading is developed in the sandstones (Mazumder et al., 2019b). Sedimentary facies analysis is under process. However, preliminary study suggests a terrestrial (alluvial fan-fluvial) interpretation for the conglomerate-sandstone facies association. Lack of mudstone/shale probably indicate the braided nature of the fluvial system.

In contrast, the sedimentary facies of the Potka-Chirugora-Kudada are fine-grained and is devoid of conglomerate. The succession starts with a thick shale unit which is overlain by a heterolithic (sandstone-shale mixed facies) and then by sandstone facies. The sandstone occurring in the lower stratigraphic level is fine-grained dark colored and show normal grading (Fig. 3E), indicating deposition from turbidity current. Minor ripple lamination and massive to plane lamination has also been observed. The thick shale facies also suggest a relatively deeper water environment, although the depth cannot be estimated as the succession is unfossiliferous. However, lack of hummocky and swale cross stratification and wave generated structures indicate that deposition took place below the storm wave base (150m; Reineck and Singh, 1980). Preliminary study reveals presence of carbonaceous (organic) matter in these sedimentary deposits. The sandstones occurring at higher stratigraphic level, however, bear cross lamination, mud drapes (Fig. 3F) and rhythmic thick and thin lamination, indicating these are tidal deposit (Mazumder and Arima, 2005; Mazumder et al., 2019b). The BIF also bears ripple marks and has been interpreted as shallow marine deposit (Majumdar and Chakraborty, 1977).

Future research:

The EIOG succession represents one of the few Paleoarchean successions of the world and have immense potentialities to unlock the early earth surface processes. For example, detailed sedimentary facies analysis will reveal the nature of Paleoarchean fluvial system. It has been recently proposed that life might have originated in terrestrial near coastal setting (Djokic et al. (2017). If so, the Paleoarchean EIOG terrestrial succession may provide valuable information on early life. The carbonaceous matter preserved in the EIOG sandstones exposed near Potka is promising. Carbon isotopic studies on a few samples is under process at Nagoya University, Japan and IPGP, France. A comparative sedimentological and stratigraphic study with the Paleoarchean successions of Pilbara (Western Australia) and Kaapval (South Africa) cratons will provide valuable information on global sea level change on early earth.

Acknowledgement:

The authors are grateful to the TRC for financial support in form of the Block 2018 research funding and to the AGEO, GUtech for infrastructural support. They are thankful to Dr. Shuvabrata De (Shandong University of Science and Technology, China) and Dr. Trisrota Chaudhuri (University of Calcutta, India) who prepared Figures 1 and 2 respectively.

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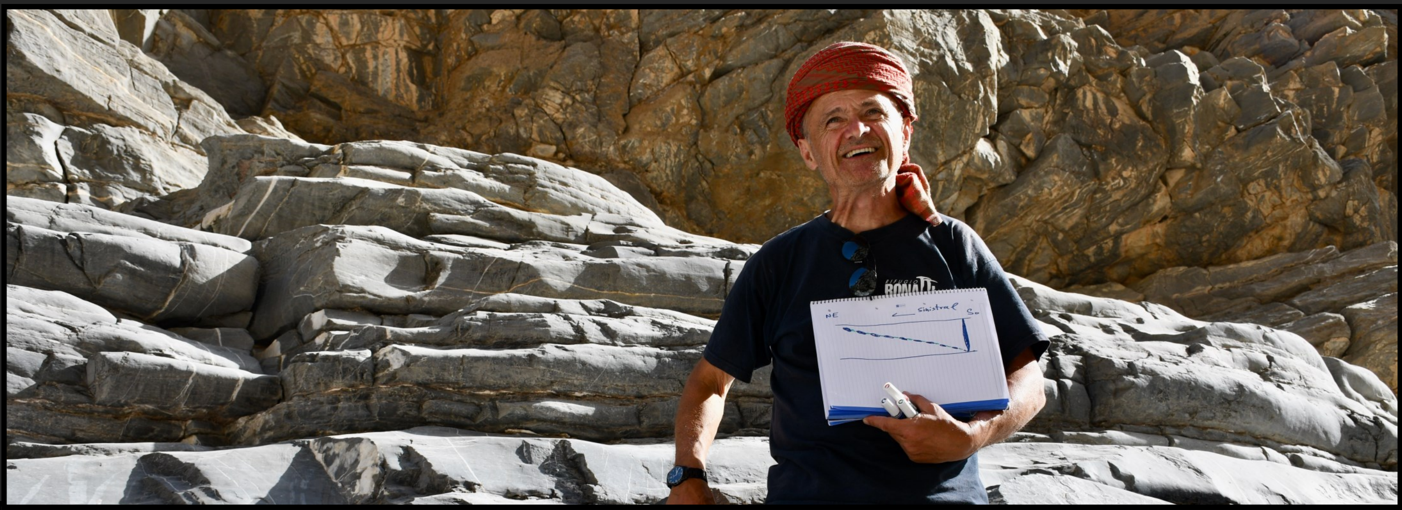

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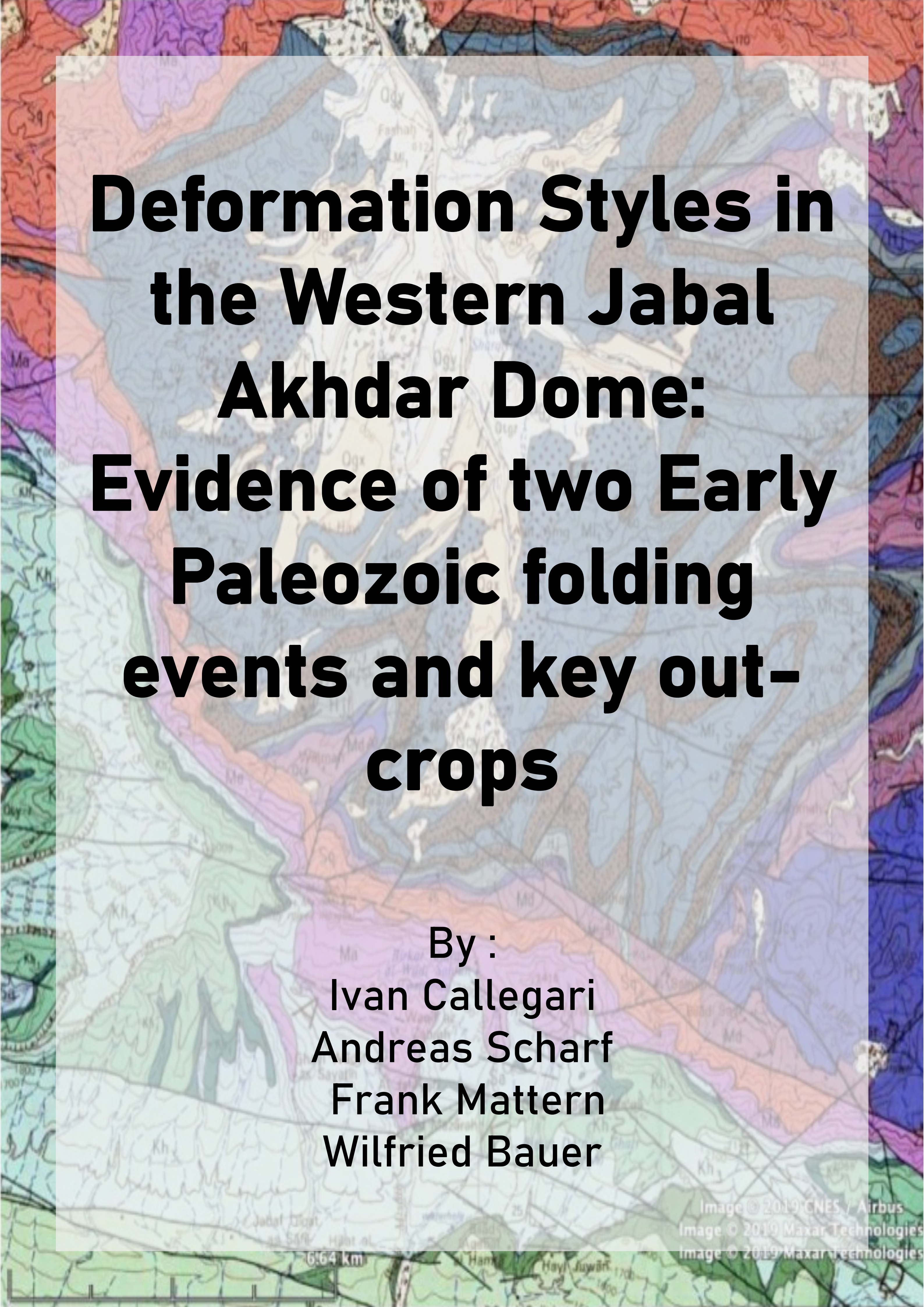


Deformation Styles in the Western Jabal Akhdar Dome: Evidence of two Early Paleozoic folding events and key out-crops

By :
Ivan Callegari
Andreas Scharf
Frank Mattern
Wilfried Bauer

Abstract:

The Cambrian metasediments of the Jabal Akhdar Dome where exposed to two Ealy Paleozoic folding events. The older deformation is characterized by NE/SW-shortening (Cadomian Orogeny) and the younger event was related to NW/SW-shortening (Angudan Orogeny). The Cadomian folds are characterized by metric, tight to isoclinal folds with an amplitude of a few to several tens of meters and low-dipping fold axial planes (recumbent folds). Associated with the Cadomian deformation are low-dipping, SW-directed thrusts. These thrusts were in part reactivated as extensional faults. The Cadomian folds were refolded by the Angudan event. Besides being larger than the Cadomian folds (amplitude of few kilometers), the Angudan folds are open to close with sub-verical to steep fold axial planes dipping towards the NNW and fold axis plunging moderately either towards the ENE or WSW. While the Cadomian cleavage is shallowly dipping and changes its orientation along the Angudan folds, the Angudan cleavage is penetrative, subvertical and strikes ENE.

Introduction:

The Jabal Akhdar Dome (JAD) of the Oman Mountains contains Neoproterozoic to Cretaceous rocks and was created by obduction of the allochthonous sedimentary Hawasina rocks and the igneous Semail Ophiolite during the Late Cretaceous. Both rock units originate from the Tethys Ocean. Eventually, the JAD was exhumed, exposing rocks of the Arabian Plate below the tectonic cover of the allochthonous rocks. Thus, the JAD is one of the few places in the Oman Mountains where pre-obductional rocks and structures can be studied. This and the superb outcrop conditions make the JAD a natural laboratory for structural investigations. The metasediments and sedimenetary rocks of the JAD are divided into the “Autochthonous Unit A” (Neoproterozoic to earliest Cambrian) and “B” (Permo-Mesozoic), which are separated by the “Hercynian Unconformity”. The deformation history of the Permo-Mesozoic rocks is well-known, and they accumulated on the shelf of the of a passive margin. The Paleozoic deformation of the “Autochthonous Unit A” is complex. Recently, Callegari et al. (2020) documented two Paleozoic deformation events within the western JAD. The older one is characterized by NE/SW of convergence while the younger event is defined by NW/SW convergence. Before that, only the latter event was known (e.g., Mann and Hanna, 1990; Breton, 2009). This article summarizes the Paleozoic deformation history and the fold styles in the western JAD with the two distinct deformation events, based on the work of Callegari et al. (2020). Furthermore, we present key outcrops depicting structures of the two Paleozoic deformation events.

Regional Geological Setting:

The Oman Mountains contain an assemblage of Neoproterozoic to Neogene siliciclastic and carbonate rocks. The Neoproterozoic and earliest Cambrian rocks (known as the "Autochthonous Unit A“; e.g., Béchennec et al., 1992) are locally exposed at the cores of two large domes: the JAD and Saih Hatat Dome (SHD; Figs. 1 and 2).

From base to top, the Neoproterozoic and earliest Cambrian rocks of the JAD are divided into five formations, (1) Neoproterozoic Mistal Formation (an alternation of siltstone and sandstone with a diamictite in the lower part, total thickness >1250 m), (2) Hajir Formation (□100 m-thick black fetid limestone), (3) Mu'aydin Formation (800 m of mainly siltstone with thin carbonate beds), (4) Kharus Formation (□245 m of limestone and dolostone), and (5) Fara Formation (380 m chert, volcanoclastics, siltstone, sandstone and conglomerate). The Fara Formation is Neoproterozoic-earliest Cambrian in age (e.g., Beurrier et al., 1986; Bowring et al., 2007; Fig. 3). The folded formations of the "Autochthonous Unit A" terminate at the top at the "Hercynian Unconformity".

The "Autochthonous Unit B" above this unconformity represents the Permo-Mesozoic Arabian shelf rocks with a total thickness of ~1.75 km. These shelf deposits are mostly carbonates. They are collectively known as the "Hajar Supergroup" (Figs. 2, 3). From base to top, the Hajar Supergroup consists of (1) the Permian Saiq Formation (mostly dolomite and limestone with a conglomerate bed at its base, total thickness of ~450 m), (2) the Triassic Mahil Formation (dolomite with a thickness of ~600 m), (3) the Jurassic Mafraq and Dhruma formations (sandstone, clayey limestone at the base to massive oolithic limestone at the top with a varying thickness of 40 to 80 m), (4) the Lower Cretaceous Rayda, Salil and Shams formations (partly silicified limestone at the base, followed by clayey-cherty limestone and marls and dark limestones at the top; total thickness is ~850 m), (5) the Lower Cretaceous Nahr Umr Formation (alternation of marl and limestone with a thickness of 140-200 m) and (6) the Lower/Upper Cretaceous Natih Formation (limestone/marly limestone alternations with a total thickness of ~200 m (Beurrier et al., 1986; Rabu et al., 1986; Fig. 3).

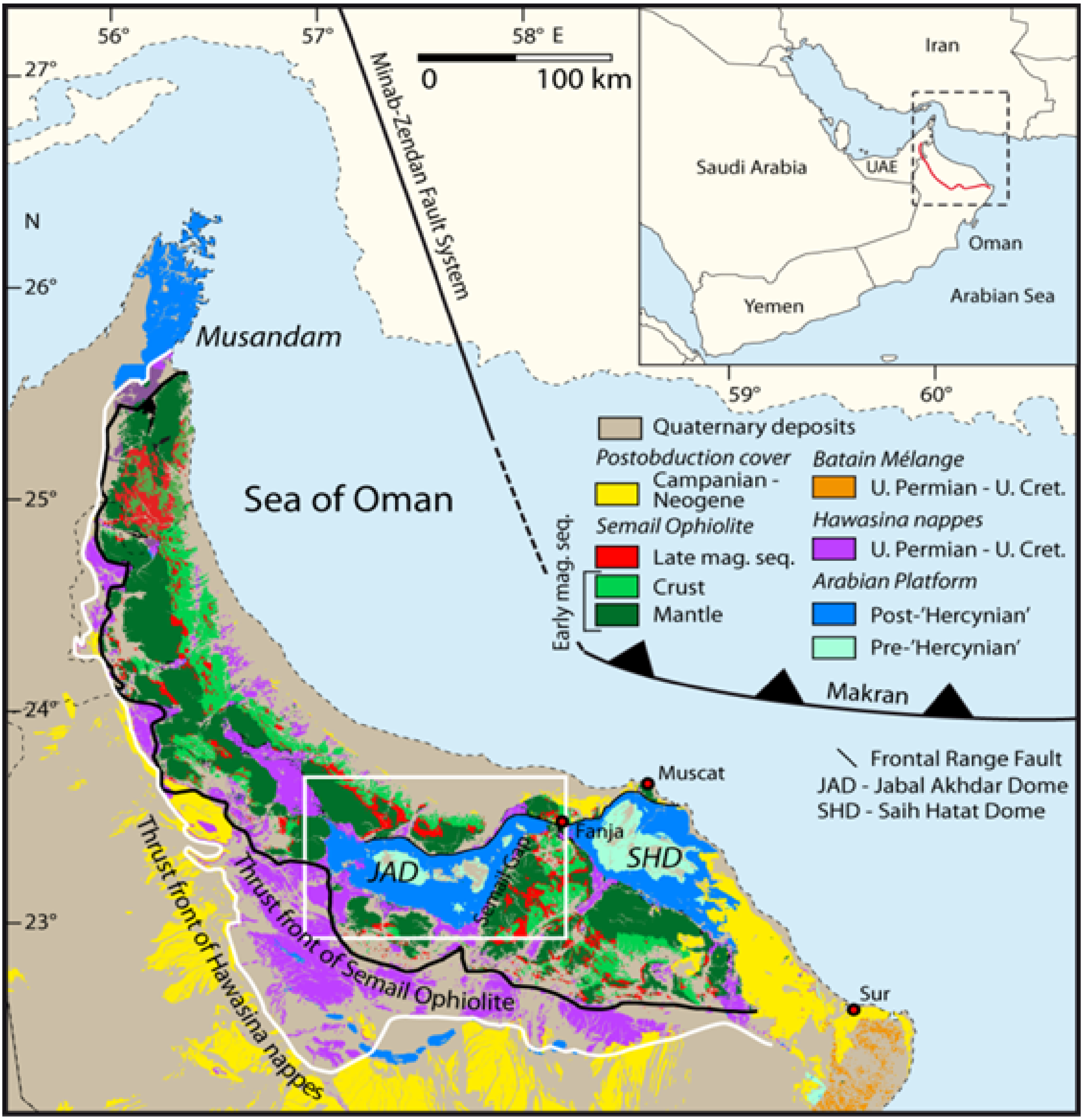


Fig. 1: Tectonic overview map of the northeastern Arabia. Base map modified after Béchennec et al. (1993) and Scharf et al. (2019). White box outlines the position of Figure 2. Frontal Range Fault after Mattern and Scharf (2018). Inset shows the greater study realm with thrust front of the allochthonous nappes in red.

These rocks have been deposited on the southern passive margin of the Tethys Ocean and have been overridden by the allochthonous Tethys-derived the Semail Ophiolite during the late Cretaceous. At the base of the ophiolite, Permo-Mesozoic ocean-floor sediments of the Hawasina Supergroup have been thrust along and partly metamorphosed by the hot ophiolite ("metamorphic sole" of the ophiolite; e.g., Cowan et al., 2014; Rioux et al., 2016). Furthermore, the Semail Ophiolite and the Hawasina units overrode the sediments of the Aruma Foreland Basin from the NE which had formed in response of loading by the

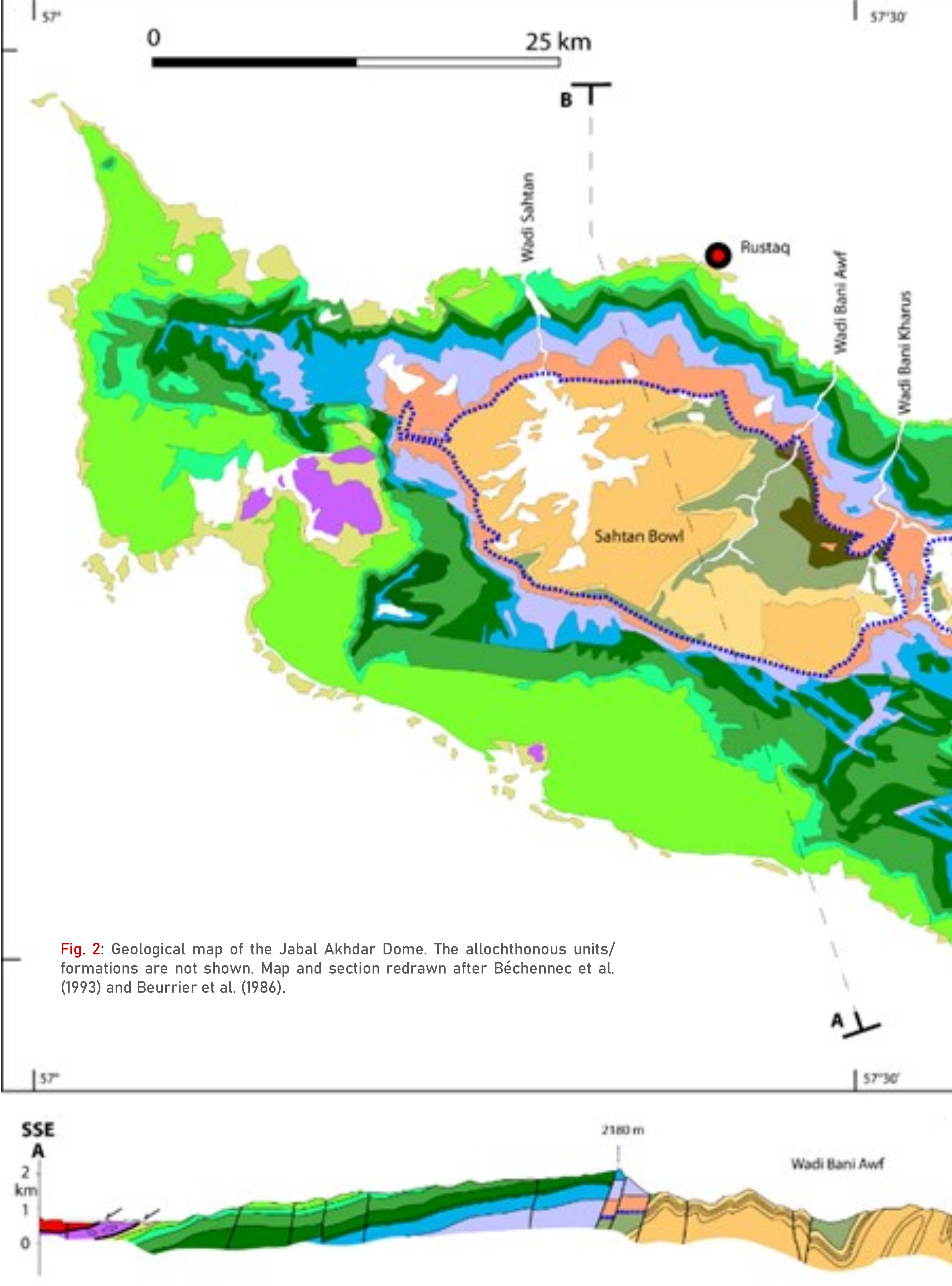
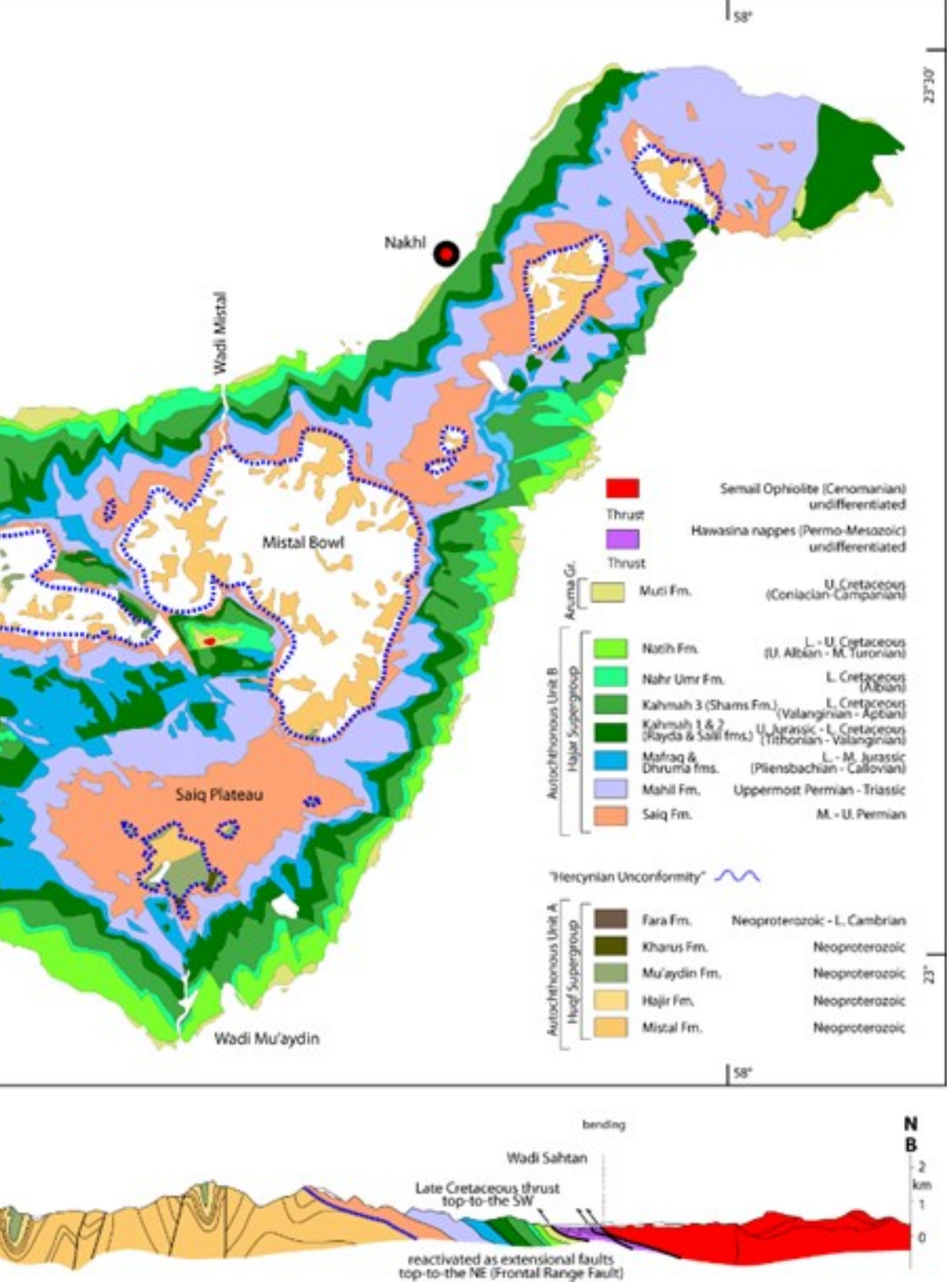


Fig. 2: Geological map of the Jabal Akhdar Dome. The allochthonous units/formations are not shown. Map and section redrawn after Béchennec et al. (1993) and Beurrier et al. (1986).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Muti Fm.
U. Cretaceous (Coniacian-Campanian)
Autochthonous Unit B
Hajar Supergroup
Natih Fm.
L. - U. Cretaceous (U. Albian - M. Turonian)
Nahr Umr Fm.
L. Cretaceous (Albian)
Kahmah 3 (Shams Fm.)
L. Cretaceous (Valanginian - Aptian)
Kahmah 1 & 2 (Rayda & Salil fms.)
U. Jurassic - L. Cretaceous (Tithonian - Valanginian)
Mafraq & Dhruma fms.
L. - M. Jurassic (Pliensbachian - Callovian)
Mahil Fm.
Uppermost Permian - Triassic
Saiq Fm.
M. - U. Permian
"Hercynian Unconformity"
Autochthonous Unit A
Huqf Supergroup
Fara Fm.
Neoproterozoic - L. Cambrian
Kharus Fm.
Neoproterozoic
Mu'aydin Fm.
Neoproterozoic
Hajir Fm.
Neoproterozoic
Mistal Fm.
Neoproterozoic
bending
Wadi Sahtan
Late Cretaceous thrust top-to-the SW
reactivated as extensional faults top-to-the NE (Frontal Range Fault)
N
B
2
km
1
0

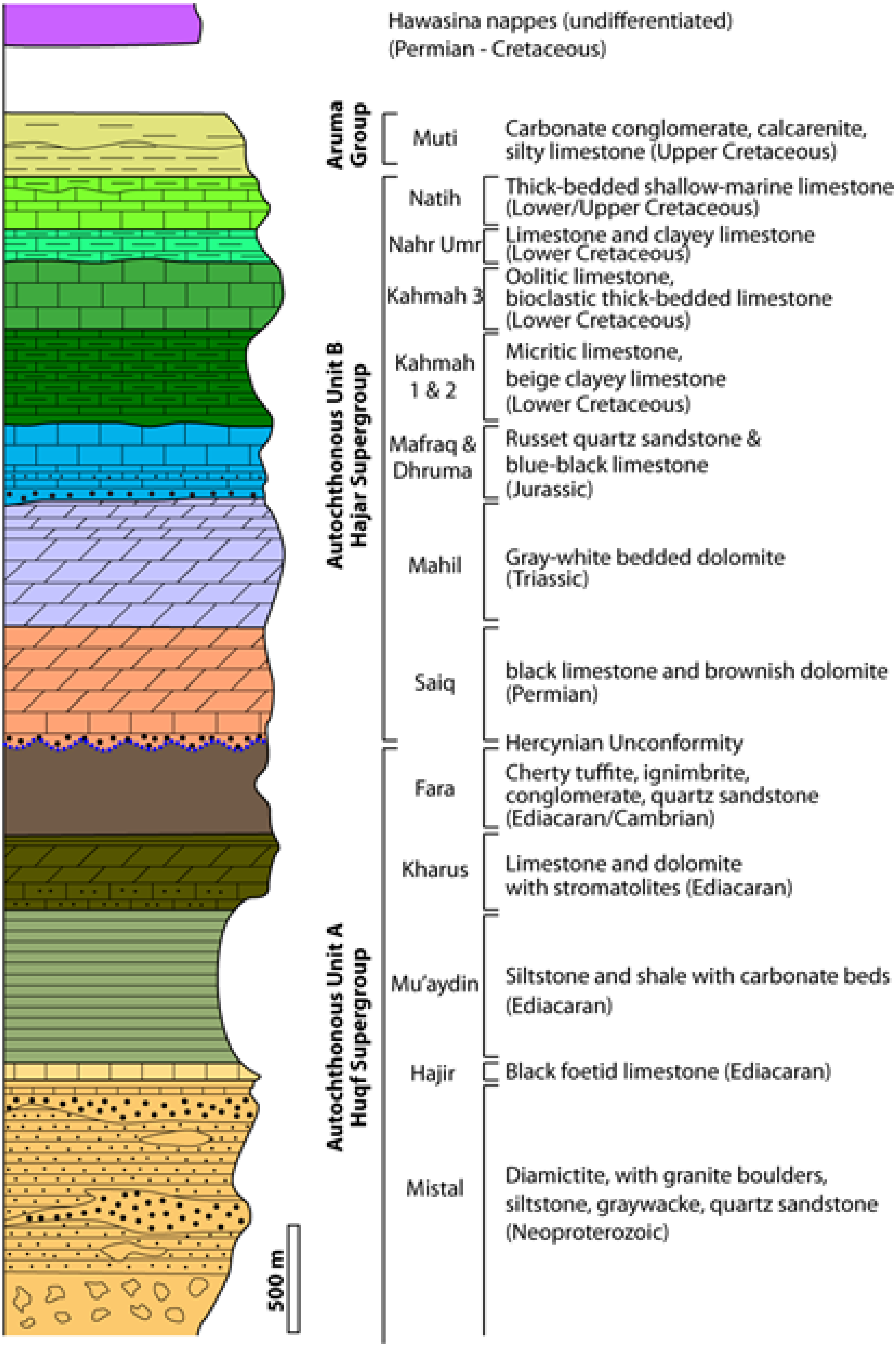


Fig. 3: Lithostratigaphic column of the Jabal Akhdar Dome, slightly modified after Beurrier et al. (1986).

allochthonous rock masses (Aruma Group; e.g., Glennie et al., 1973, 1974; Searle and Malpas, 1980; Lippard et al., 1986; Searle and Cox, 1999; Hacker et al., 1996; Goffé et al., 1988; Glennie, 2005).

Deposition in the Aruma Foreland Basin coincided with uplift and erosion of the forebulge (e.g., Searle, 2007). This uplift is proven by exhumation of the upper parts of the Hajar Supergroup of the northern Jabal Akhdar and Saih Hatat flanks (e.g., Béchennec et al., 1992). Hence, at the northern JAD, the Cretaceous Nahr Umr and Natih formations are missing (Fig. 2). The related stratigraphic gap between the Hajar Supergroup and the Aruma sedimentary rocks is known as the "Wasia-Aruma Break" (e.g., Robertson, 1987; Searle, 2007). Postobductional sedimentation resumed since the late Cretaceous, continued to the Miocene north of the JAD and is characterized by mostly limestone.

The exhumation history of the JAD is divided into two stages. The first stage occurred during the latest Cretaceous to the Paleocene/Eocene boundary and is associated with top-to-the-NE extensional shearing (e.g., Breton et al., 2004; Mattern and Scharf, 2018; Grobe et al., 2019). The second stage (final doming) occurred during the Late Eocene to Oligocene and is responsible for 4-6 km of exhumation (Hansman et al., 2017; Corradetti et al., 2019; Grobe et al., 2019). Further details on the geology and tectonics of the Oman Mountains are provided in Scharf et al. (2020).

Two Paleozoic deformation events (after Callegari et al. 2020):

The Neoproterozoic to earliest Cambrian formations in the western JAD have been deformed during two folding events and their resulting distinctive styles. The age of these two folding events must be Paleozoic because the earliest Cambrian Fara Formation had been affected by both events. However, the Permian Saiq Formation, above the Hercynian Unconformity lacks these two folding events and their respective fold styles.

The older deformation event (D1) is characterized by F1 metric tight to isoclinal ductile folds with an amplitude of few to several tens of meters within the Hajir Formation. The fold axial planes are low-dipping (Fig. 4). Associated with the D1 event are low-dipping thrust towards the SW within the Hajir Formation. These thrust were in part reactivated as extensional faults.

The F1 folds were refolded by the D2 event. The respective F2 folds are open to close with subverical to steep fold axial planes dipping towards the NNW and fold axis plunging moderate either towards the ENE or WSW (Fig. 4). The F1 folds reveal a consistent NE vergence after restoration the F2 folds (Fig. 4). The F2 folds were previously described as "possible Hercynian" in age (Mann and Hanna, 1990).

The D1 and D2 events are related to NE/SW- and NW/SE-directed convergence, respectively. The D1 event correlates with the Cadomian Orogeny, while the D2 folds formed during the the Angudan event. The age of the latter is determined to occur at 525 ±5 Ma (Al-Husseini, 2014). Thus, the D1 event must post-date the deposition of the Fara Formation at 542 Ma but pre-date 525 ±5 Ma of the Angudan event (Fig. 5).

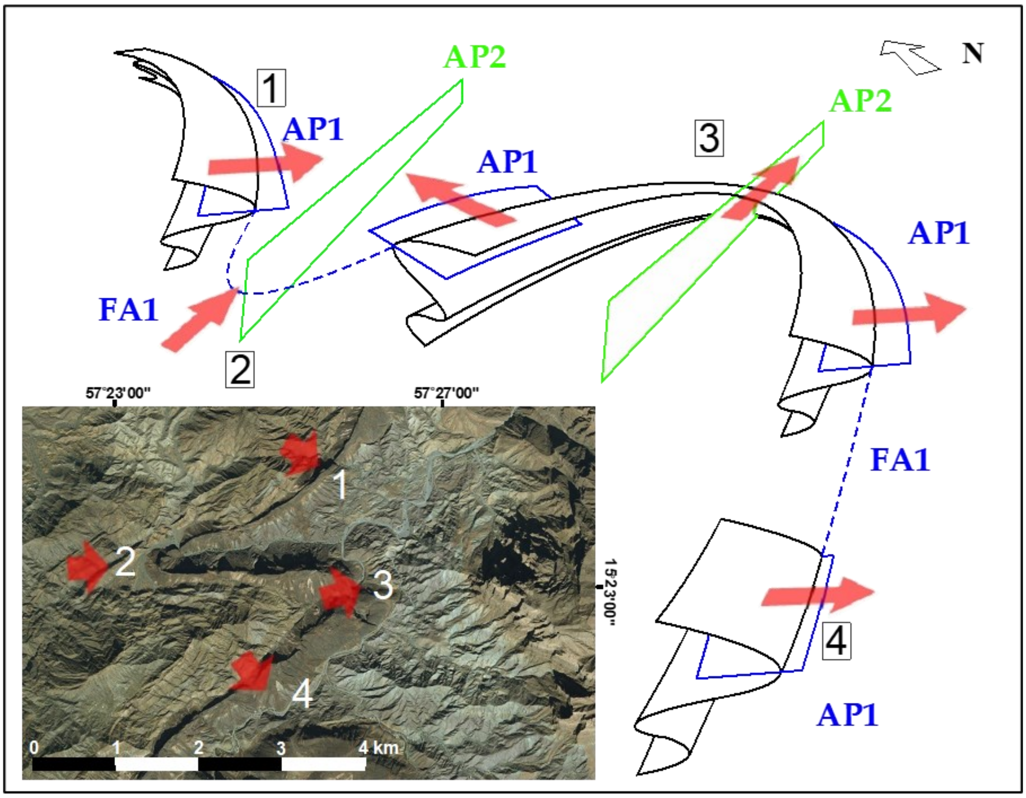


Fig. 4: Schematic illustration of the two fold generations in the western Jabal Akhdar Dome (Callegari et al., 2020). Numbers from the satellite image correlate with numbers in the sketch. FA – fold axis; AP –axial plane. FA1 and AP1 (in blue) correlate to the first folding event (F1), while FA2 and AP2 (in green) reflect the second folding event (F2).

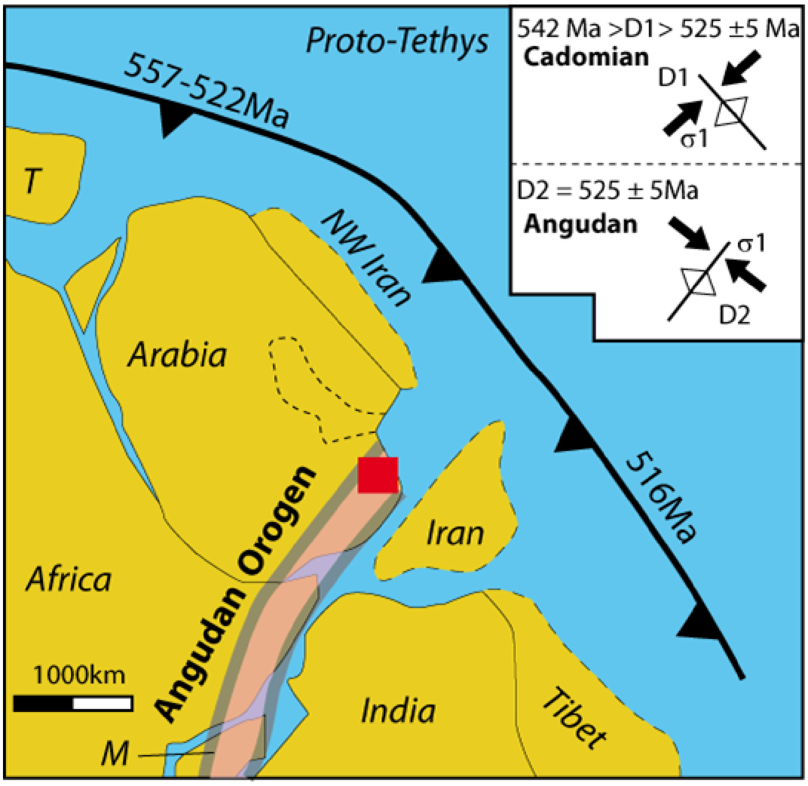


Fig. 5: Plate configuration of the greater study area at the Neoproterozoic/Cambrian transition (Callegari et al., 2020). M – Madagascar; T – Turkey. Ages of the Cadomian subduction zone are from Hu et al (2017). The pink semi-transparent belt indicates the Angudan Orogen after Droste (2014). The red rectangle represents the position of the Jabal Akhdar Dome. Inset provides the timing and kinematics of the Cadomian and Angudan events.

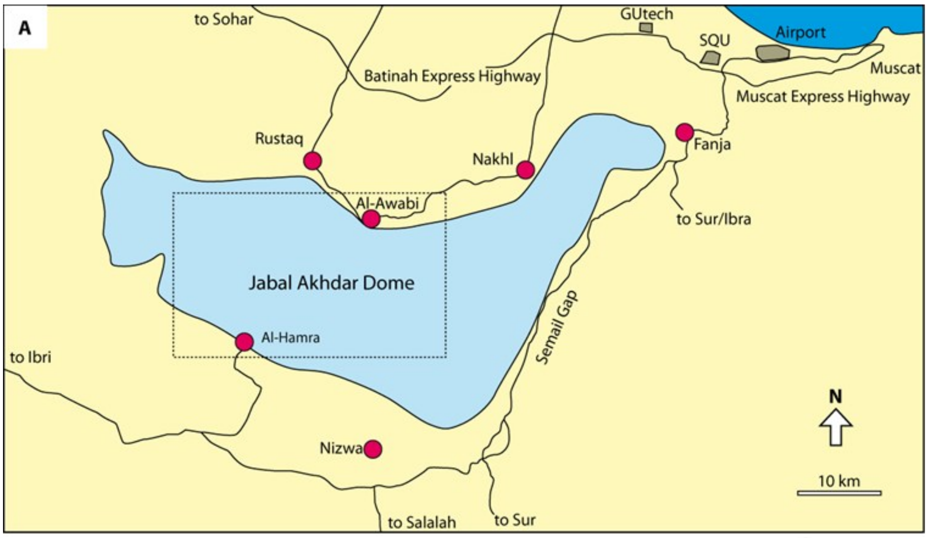
Outcrops:

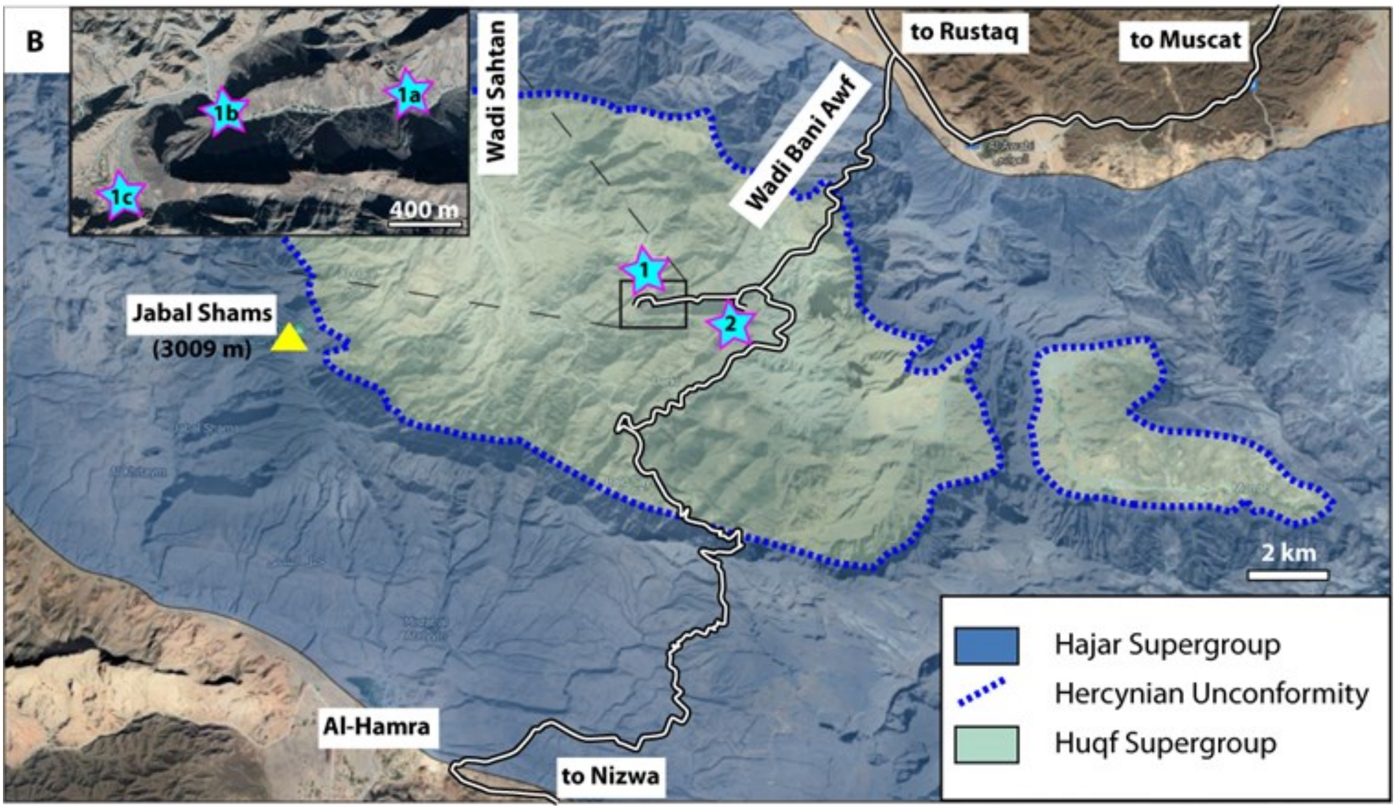
Figure 6 depicts the road map from Muscat to the Jabal Akhdar and the location of three outcrops. The drive from the Campus of Sultan Qaboos University in Al-Khod to the entrance/exit of Wadi Bani Awf via Rustaq at the northern flank of the JAD is approximately ~115 km long and takes about 1:15 hours. The margin of the JAD (mostly carbonates) is framed by a small corridor of Hawasina units (chert and carbonates), some Muti shales of the Aruma Group and topped by the Semail Ophiolite (dark brown rolling hills). The contact of the autochthonous and the allochthonous units is a major thrust which has been reactivated as a major extensional fault with a throw of a few to several kilometers in some places (Frontal Range Fault; Mattern and Scharf, 2018).

Fig. 6: Location/road maps.

A) Overview location/road map. The blue area represents the Jabal Akhdar Dome. The main roads are shown in black. Rectangle indicates the location of map B.

B) Simplified geological map superimposed on a satellite image (Google Maps) showing the road and outcrops as well as the main wadis. Inset at the top left highlights outcrop 1, which is subdivided into three stops.





Outcrop 1. Two generations of folds and foliations in Wadi Bani Awf (23°15'13"N / 57°24'17"E):
Stop 1 highlights two fold generations in Wadi Bani Awf (F_1 - Cadomian, F_2 – Angudan; see Fig. 7).
The entire stop is divided into three related outcrops.
A) "Angudan" fold and two sets of cleavage (S_1 - "Cadomian"; S_2 - "Angudan") in the Mu'aydin Formation,
B) isoclinal "Cadomian" folds in the Hajir Formation,
C) large Angudan folds in the Mistal and Hajir formations.

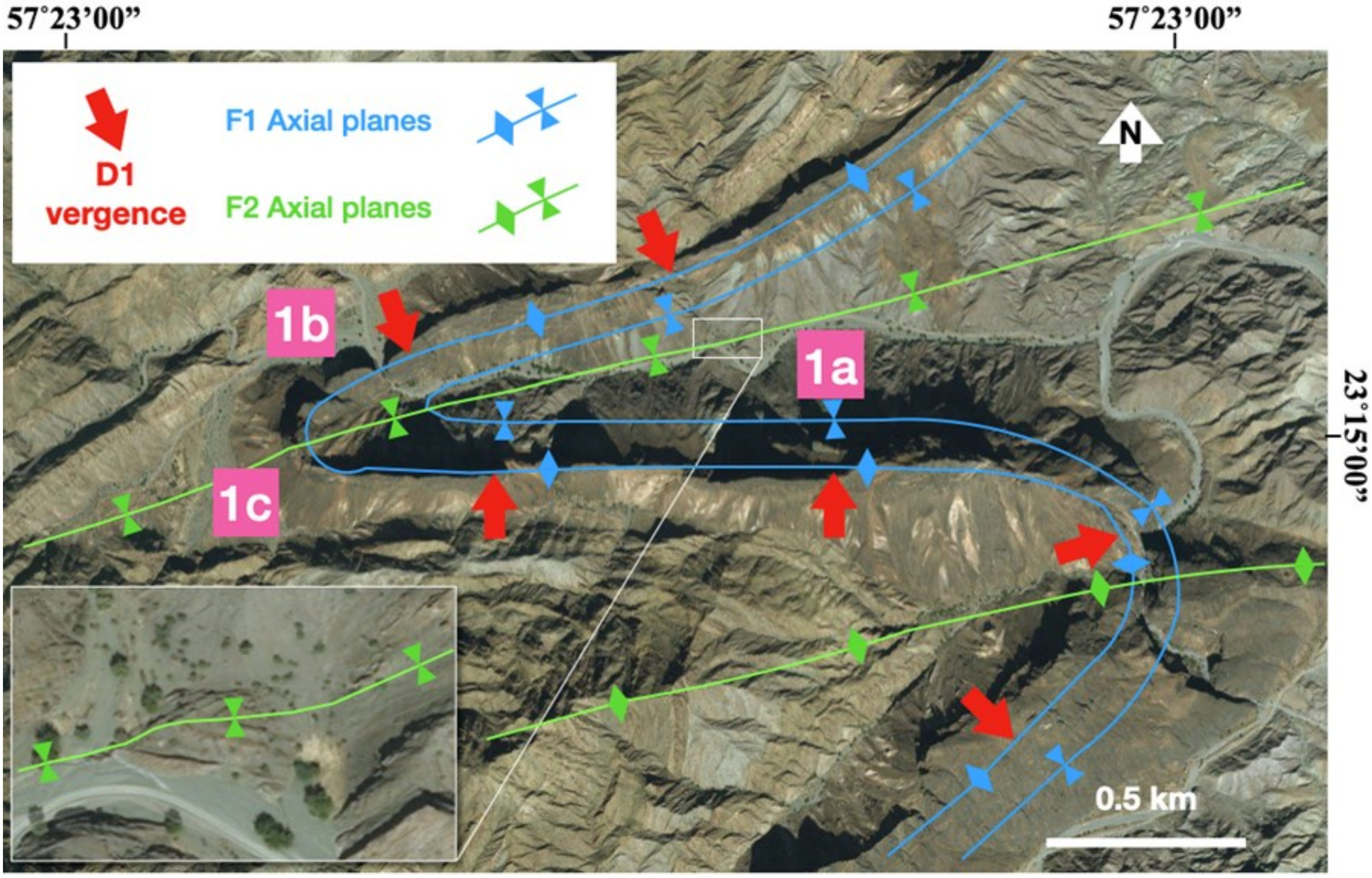


Fig. 7. Satellite image of Stop 1 modified from Callegari et al. (2020).

Outcrop 1A - (23°15'22.32"N / 57°24'41.31"E):
This stop is located at the fold axis of a large F_2 syncline, cored by the Mu'aydin Formation The steep cliffs on either side of the valley are made up of the older Hajir Formation After reaching the overview point ~20 m above the wadi ground, the F_2 syncline is clearly visible (Fig. 8). A closer inspection of this outcrop reveals two cleavages. S_1 is shallowly dipping and changes its orientation along the F_2 syncline. S_2 is penetrative and subvertical. S_2 strikes ENE.

Fig. 8 Photograph of Outcrop 1A. View is toward SE showing the tight F2 fold with sub-vertical axial plane (in green) in the Mu'yadin Formation.

Outcrop 1B – (23°15'16"N / 57°23'48"E):

This outcrop is within a steep N/S-oriented gorge in the Hajir Formation. At the northern side is the contact to the older Mistal Formation, while at the opposite side the younger Mu'aydin Formation is exposed. Within the dark limestone of the Hajir Formation are numerous tight to recumbent F_1 folds with subhorizontal fold axes trending WSW (Fig. 9). The fold axial planes are shallowly dipping towards the NNW. These folds formed during the Cadomian Orogeny between ~540 Ma and 525 ±5 Ma (Callegari et al., 2020).

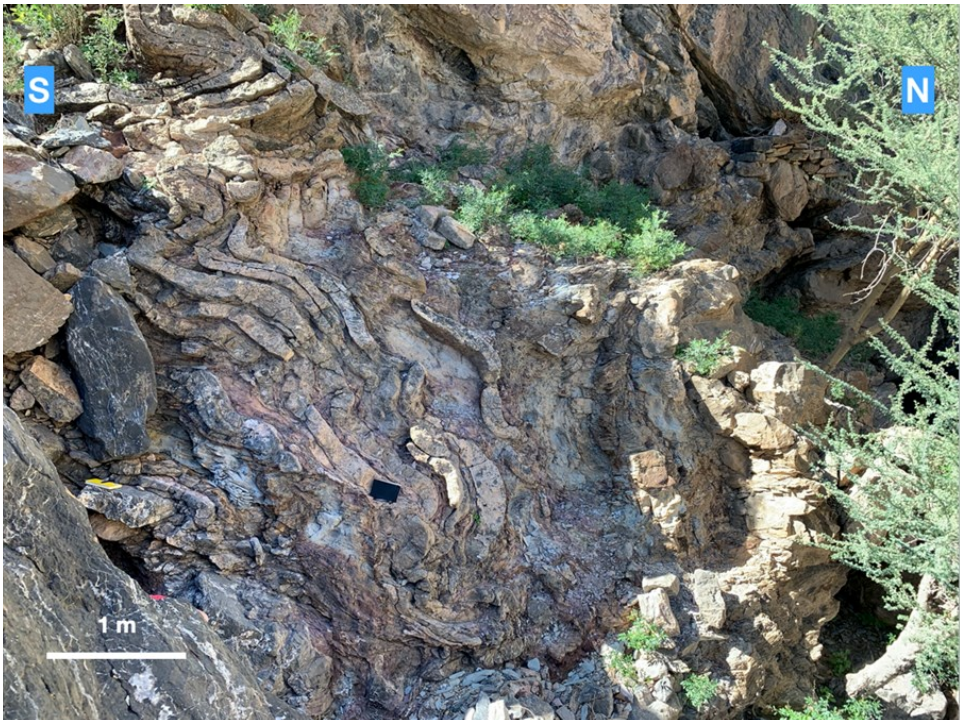


Figure 9. Recumbent folds in the Hajir Formation. Fold vergence is towards the south. Yellow and black field books for scale.

Outcrop 1C – (23°14□53 N / 57°23□18 E):

This is a vista outcrop, located at the hinge of a large and tight F_2 syncline which formed during the Angudan Orogeny at 525 ±5 Ma (Callegari et al., 2020). The position is within the Mistal Formation. The view is to the ENE onto the black carbonates of the Hajir Formation (Fig. 10).

Fig. 10. Panoramic view of the hinge of the F2 fold. The two arrows show opposite directions of vergence of F1 folds. The black line highlights the geological contact between Hajir Fm. and Mistal Fm. and the dashed line show the structural line of the bedding on Hajir Fm.

Outcrop 2. Thrusts within the Hajir Formation (23°14’47”N / 57°25’53”E)
Several spectacularly exposed thrusts within the Hajir Formation with top-to-the-ENE kinematics characterize this stop (Fig. 11). Several shear-sense indicators such as folded shear veins reveal the shear sense for transitional conditions from ductile to brittle. Furthermore, brittle structures along the fault plane indicate an extensional overprinting of the thrusts. Besides the thrusts, also several F_1 folds can be inspected. One fold is very closely associated with a thrust. The entire outcrop is located within the hinge of a large F_2 anticline.

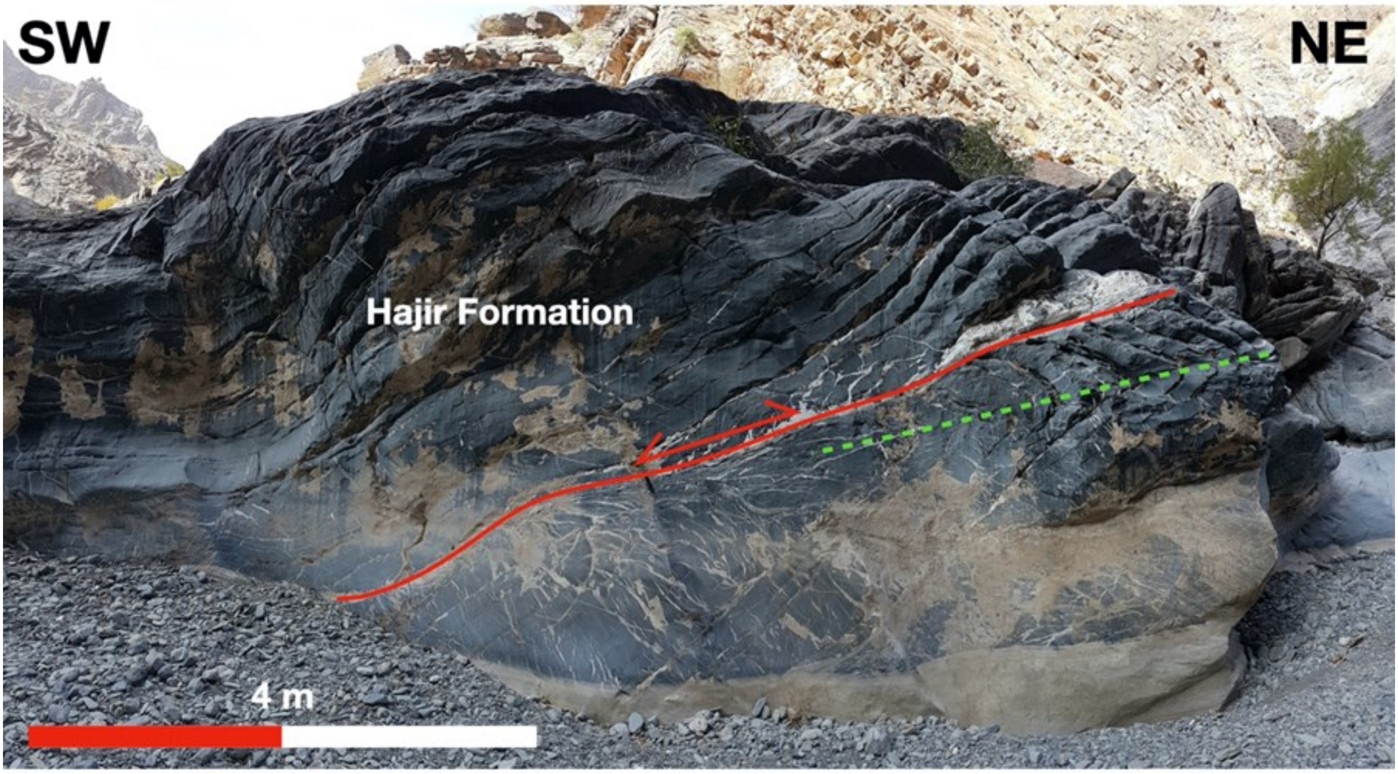


Fig 11. Thrust, reactivated as an extensional fault dipping towards the SW (red line). Beneath this fault is a recumbent fold. The axial plane is indicated by the dashed green line.

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PHOTOS FROM GSO MEMBERS

WHO:
Amjad Al Shukri a geologist from Oman

WHERE:
Ras Al Ruwais, Al Sharqiya

WHAT:
IPhone 8 Plus camera

Geologists are always charmed by the magnificent art that nature can create. Here is a large cross bedding features at Ras Al Ruways beach, eastern Sultanate of Oman located about 60 kilometers northeast Mahoot. These lithified sandstone dunes represent the southern part of the Ramlat A Sharqiyah which is a very spectacular place to visit for learning about the aeolian systems near the coast and of course a very nice spot for relaxation

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