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About GSO

The Geological Society of Oman (GSO) was established in April 2001 as a vocational non-profit organization which aims to advance the geological sciences in Oman, the development of its members and to promote Oman's unique geological heritage.

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Dear Readers,

It is our great pleasure to welcome you to this edition of AL Hajar, the premier publication of the Geological Society of Oman (GSO). As always, our aim is to bring you insightful articles, groundbreaking research, and fascinating stories that highlight the rich geological heritage of Oman and beyond.

In this issue, we take you on a journey through Oman's unique geology, beginning with a fascinating exploration of the Folded Cleavage Planes in Wadi Al-Arbeieen near Firq (sheet Quryat).

Our international focus includes a comprehensive look at the Mesoarchean tidal deposits from the Western Iron Ore Group of rocks, Singhbhum Craton, India, as well as a detailed note on the preservation and conservation of Lower Gondwana Beds of Mandakpal, Pulwama Kashmir by the Department of Geology and Mining, JK (UT) India.

Additionally, we are thrilled to bring you an exclusive interview with a leading expert in the field, Professor Victoria Pease.

We extend our gratitude to our contributors and readers for their unwavering support. Your enthusiasm and engagement are what drive us to continually strive for excellence. Thank you for being a part of this journey. We hope you enjoy reading this edition as much as we enjoyed creating it.

Warm regards,

Laila AL Zeidi
GSO Content Editor

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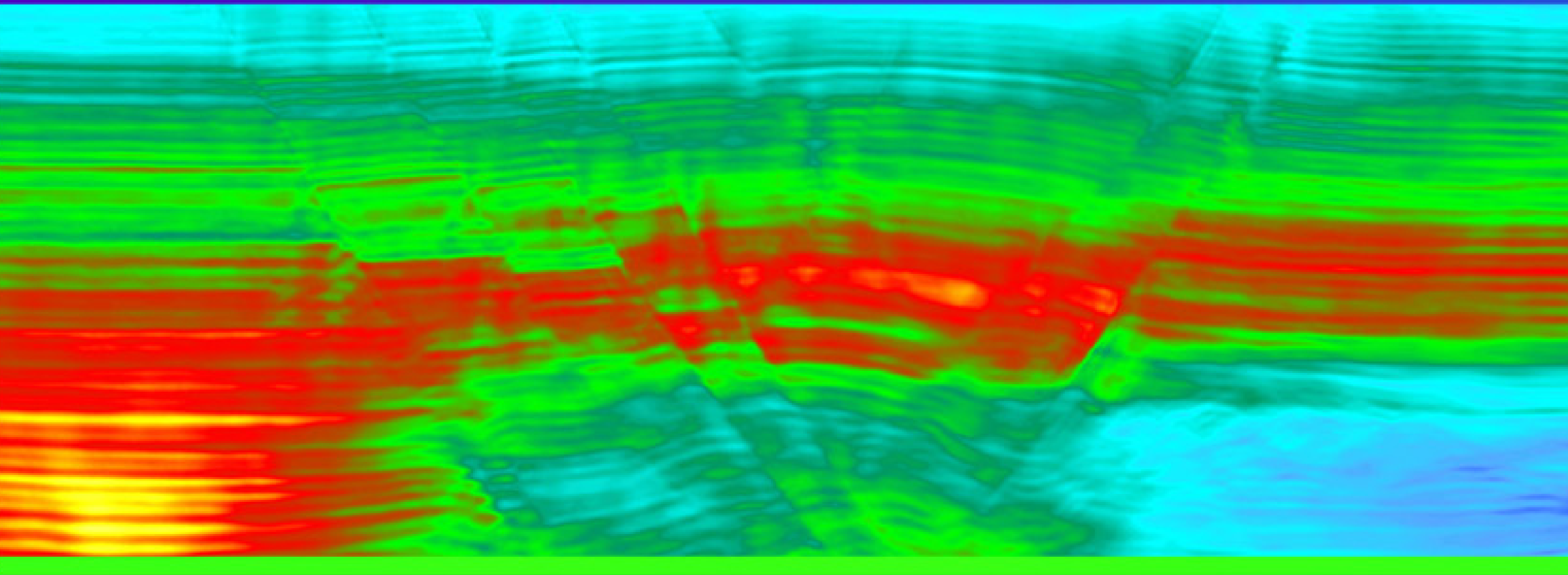

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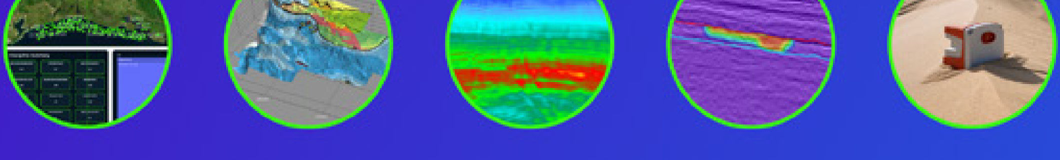

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SEE THINGS DIFFERENTLY

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Folded Cleavage Planes in Wadi Al-Arbeieen near Firq (sheet Quryat)

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Introduction

Folded cleavage planes are relatively common in fold-and-thrust belts. As deformation increases, the axial-parallel cleavage in fine-grained rocks will begin to fold once the cleavage planes reach a low angle relative to the principal stress axis. This often results in the formation of cleavage crenulations, which are commonly observed in greenschist-facies rocks with a high content of phyllosilicates. However, tightly folded cleavage planes are less common in low-grade metamorphic rocks. The folding and cleavage formation often occur contemporaneously with the peak stress, while subsequent phases of deformation may lead to brittle or brittle-ductile structures, such as faults or kink bands. A review of the literature on Google Scholar identified only 16 papers describing folded cleavage planes at the macroscopic scale, from locations including the Pyrenees, Zambia, Alexander Island (Antarctica), and various sites in the USA.

In the winter of 2019/20, the late Prof. Janos Urai informed us of an outcrop in Wadi Al-Arbeieen, south of Quryat, exhibiting folded cleavage. A detailed structural analysis of the outcrop and its surroundings in January/February 2021 provided the material for this article.

Field observations

The outcrop is located in Wadi Al-Arbeieen, about 19 km SSW of Quryat at N 23°03’28.7”, E 58°58’58.1” (Fig. 1). It is a natural outcrop with a length of c. 70 m immediately east of the road through Wadi Al-Arbeieen.

Figure 1. Outcrop with folded cleavage planes (Wadi Al-Arbeieen), view to the NNE.

Stratigraphically, the exposed rocks consist of thinly bedded limestones, ranging from 2 to 5 cm in thickness, alternating with beige calcareous siltstones (Fig. 2).

Figure 2. Detail of the outcrop. Traces of bedding planes are visible as fine lines to the right of the GPS.

This sequence is about 30-40 m thick and was mapped as uppermost Permian Saiq 3 (Le Métour et al. 1986). It is squeezed between the underlying 250 m nodular limestones and dolomites of the lower Saiq Formation and 700-800 m massive dolomites of the Mahil Formation (Fig. 3).

Figure 3. Well bedded dolomites of the Triassic Mahil Formation, Wadi Al-Arbeieen, view to the north.

The finely layered, relatively thin Saiq 2 and 3 beds are the weakest components within more than 1000 m thick beds of Permo-Triassic dolomites and limestones, and they are strongly deformed.

Analysis of tectonic elements

The cleavage planes exhibit a regular spacing of approximately 3-4 cm (Fig. 1). These planes are folded with interlimb angles between 90 and 70° (open folds), wavelengths around 25 cm and amplitudes of 10-15 cm. The fold axes are subhorizontal and the hinge zones are narrow, classifying the folds as upright chevron folds.

The poles of the cleavage planes plot on a great circle with a pole at 255/04 (Fig. 4).

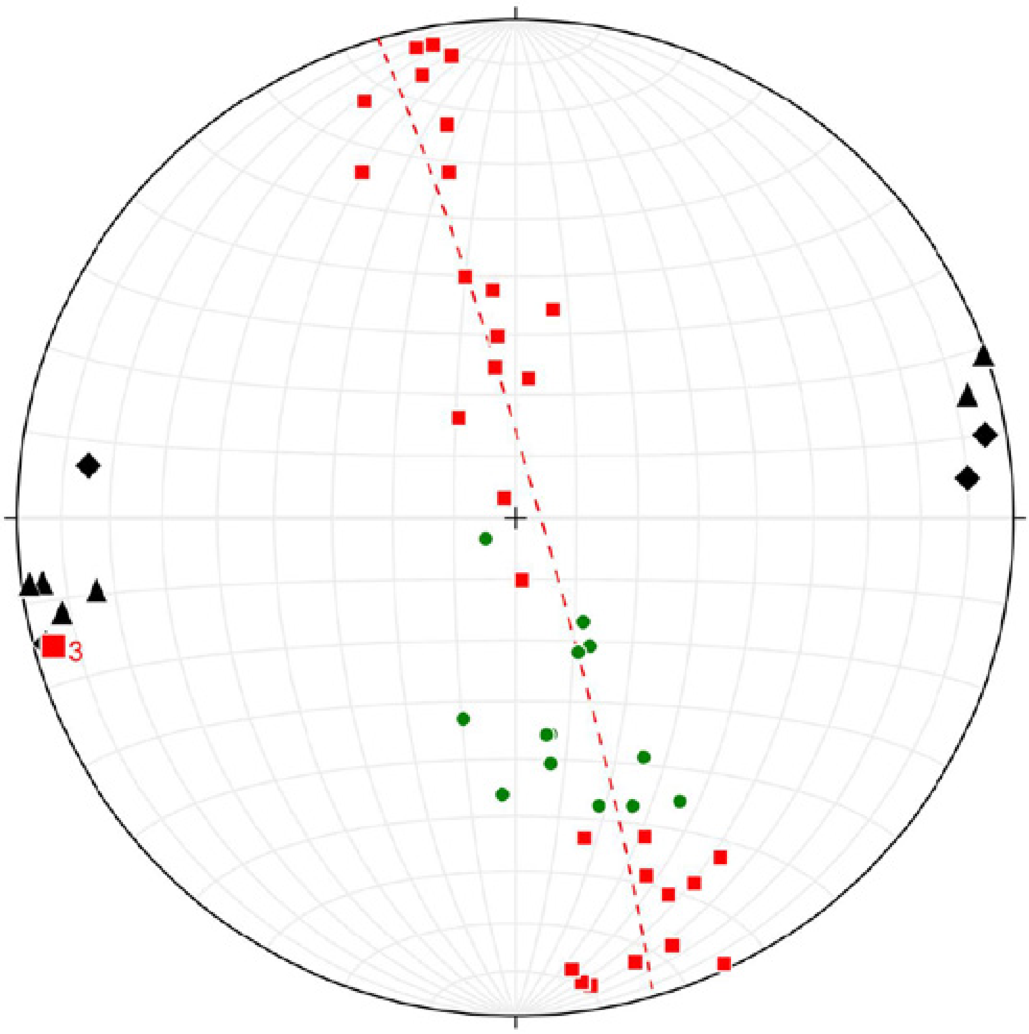

Figure 4. Structural elements plotted in a Stereonet, lower hemisphere. Red squares: poles to the cleavage; green circles: poles to the bedding; red dashed great circle: cylindrical best fit to the poles of cleavage; black triangles: fold axes; black diamonds: intersection lineations between bedding and cleavage; 3: 3rd Eigenvector=pole to great circle.

This pole is close to the fold axes and intersection lineations which both are oriented WSW-ENE. The bedding dips gently to steeply in northern to northwestern directions.

The folding of the cleavage is attributed to a ≈N-S compression, which may correspond to the 'Tectonic Stage 3' described by Fournier et al. (2006). This compression phase began at the Oligocene/Miocene boundary with an E- to NE-directed compression that later rotated during the Pliocene to a N-S and NNE-SSW orientation. This compression is also observed in the Eocene Rusayl Formation near Al-Khoud village, as documented by Scharf et al. (2016). Given the competence contrast between the massive Saiq 1 and Mahil dolomites and the thinly bedded Saiq 2 and 3, the folded cleavage likely represents a strain partitioning, located in the least competent parts of the Permo-Triassic, during the Arabia-Eurasia convergence in the Pliocene. A systematic analysis of similar late Cenozoic deformation features like kink bands in the uppermost Amdeh Formation and the Hatat schists is still outstanding.

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Mesoarchean tidal deposits from the Western Iron Ore Group of rocks, Singhbhum Craton, India

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INTRODUCTION

Laterally and/or vertically accreted, laminated to thinly bedded medium- to fine-grained sandstone, siltstone and mudstone that are produced by tidal activity are known as tidal rhythmites (Williams, 1991, Kvale et al., 1999; Kvale, 2003; Mazumder and Arima, 2005). Such rocks bear a record of astronomically induced tides. In the absence of fossils, such rocks are unambiguous evidence of marine sedimentation (Mazumder and Arima, 2005 and references therein). Therefore, recognition of tidally influenced sedimentary deposits in Precambrian successions is extremely important for interpreting depositional sedimentary environments (Eriksson and Simpson, 2000, 2004; Williams, 2000; Mazumder and Chaudhuri, 2021; Heubeck et al., 2022). The Applied Geosciences Department of the German University of Technology in Oman has an ongoing research project (BF 2023) on Mesoarchean sedimentary deposits of the western Singhbhum Craton, funded by The Research Council (TRC) of Oman. Faculty members and students are working to infer depositional environments through research collaboration with the Birbal Sahni Institute of Paleosciences. This research communication reports on a recently identified well-preserved Mesoarchean tidal deposit from the western part of the Singhbhum Craton, near the city of Rourkela, India (Fig. 1A-B).

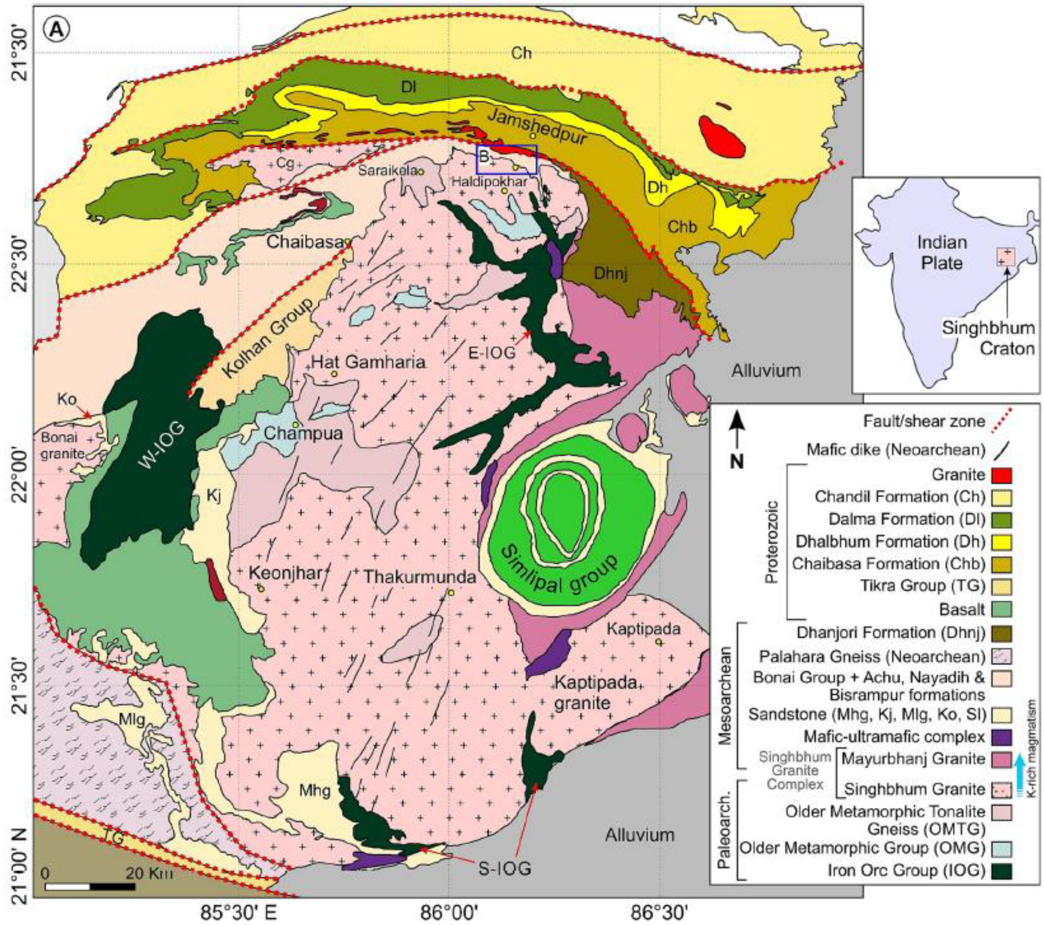

Figure 1: Maps: (A) Simplified geological map of Singhbhum Craton (modified after Saha, 1994, Olierook et al., 2019, and Yoleikhai et al., 2023). (B) Google Earth image showing the location of Rourkela.

GEOLOGICAL BACKGROUND

The Singhbhum Cratonic block is among one of the five Indian Cratonic blocks that bear a geological record from 3500 to 900 million years ago (Paleoarchean to Neoproterozoic; Fig. 1A; Mazumder et al., 2012; Chaudhuri, 2020; Mukhopadhyay and Matin, 2020 and references therein). The Tonalite-Trondhjemite-Granodiorite (TTG) (known as Older Metamorphic Tonalitic Gneiss (OMTG) dating to 3400 Ma on average, Chaudhuri et al., 2018) form the basement of deposition of the Iron Ore Group (IOG) and the Older Metamorphic Group (OMG) of rocks. The IOGs are exposed along three different belts—eastern, western, and southern—referred to as EIOG, WIOG, and SIOG respectively (Fig. 1A). The banded iron formation (BIF) is one of the most important lithologies of the three IOG successions (Saha, 1994; Mukhopadhyay, 2001; Mukhopadhyay et al., 2008; Mazumder et al., 2012). In addition, the IOG successions consist of quartzites, schists, phyllites, ultramafic (komatiitic), mafic (basalts) and rhyolitic volcanics and volcaniclastics.

While the IOG rocks indicate low-grade (upper greenschist facies) metamorphism, the OMG successions indicate relatively higher-grade (amphibolite facies) metamorphism (quartzites, schists, metamorphosed BIF; see Saha, 1994; Mukhopadhyay, 2001; Hofmann and Mazumder, 2015). During the Paleoarchean (3300 Ma), the Singhbhum granitoid batholith intruded the metasedimentary successions (Nelson et al., 2014; Upadhyay et al. 2014; Olierook et al., 2019; Chaudhuri, 2020; Chaudhuri et al., 2022). The IOG rock successions suffered multiple phases of deformation; the intensity of deformation is more in the EIOG compared to the WIOG belt (Saha, 1994). Interested readers may consult Mukhopadhyay et al. (2008), (2012), Mazumder et al. (2012), (2022), Mukhopadhyay and Matin (2020), Mazumder and Bauer (2020), Mazumder and Choudhuri (2021) for a review of IOG successions.

The WIOG sedimentary succession is bound by two thick mafic lava sequences (known as lower and upper lava respectively, Beukes et al., 2008; Wright and Basu, 2024). Wright and Basu, (2024) reported a Sm-Nd isochron age of around 3400 million years from the lower lava sequence and an age of about 3300 million years from a dacitic tuff horizon below the BIF. The tidal deposits we examined during a recent field trip forms part of the upper WIOG clastic sequence. As per the available geochronological data, the depositional age of these upper WIOG sandstone is around 3000 million years (Hofmann et al., 2022; Gond et al., 2023). Thus, the lower part of the WIOG succession is of Paleoarchean age whereas the upper WIOG sandstones are of Mesoarchean age.

WESTERN IRON ORE GROUP (WIOG)

The WIOG succession has been investigated by a number of authors (Majumdar and Chakraborty, 1977, 1979; Rai et al., 1980; Rao and Dasgupta, 1995; Beukes et al., 2008; Mazumder and Chaudhuri, 2021). Detailed sedimentological facies analysis has been undertaken by Mazumder and Chaudhuri (2021). These authors have subdivided the bottommost part of the WIOG succession (occurring below the banded iron formation) into three distinct facies associations: a lower alluvial fan-fluvial, a middle shallow-marine coastal, and an upper fluvial facies association. The uppermost facies association is overlain by the lower shale facies. Mazumder and Chaudhuri (2021) inferred a terrestrial-shallow-marine depositional environment during the lower IOG sedimentation. The lower shale and the BIF (Fig. 2) were deposited in a relatively deeper shelf setting (Beukes et al., 2008; Mazumder and Chaudhuri, 2021).

Figure 2: Banded Iron Formation of the Western Iron Ore Group succession (pen 11 cm).

Tidal deposits of the upper WIOG succession

The sedimentary succession examined in this study is part of the upper WIOG succession. The greenish mica-rich sandstones (fuchsite quartzite; Fig. 3A-B) are characterized by small-scale asymmetric ripples (Fig. 4A), parallel lamination (Fig. 3A), and herringbone cross-stratification (Fig. 4B). The cross-stratified sandstone foresets are bound by thin mudstone drapes. The parallel laminated sandstones also exhibit thin mudstone drapes (Fig. 4B). The oppositely oriented cross-stratification and sandstone-mudstone alternation clearly indicate tidal influence (Eriksson and Simpson, 2000, 2004; Kvale, 2003; Mazumder and Arima, 2005) and these sandstones are tidal rhythmites (Mazumder and Arima, 2005). The precursor sandstone is moderate to poorly sorted with quartz, rock fragments, and mica (Fig. 3B). Detailed sedimentary facies analysis and petrographic investigation of the upper WIOG succession are under process.

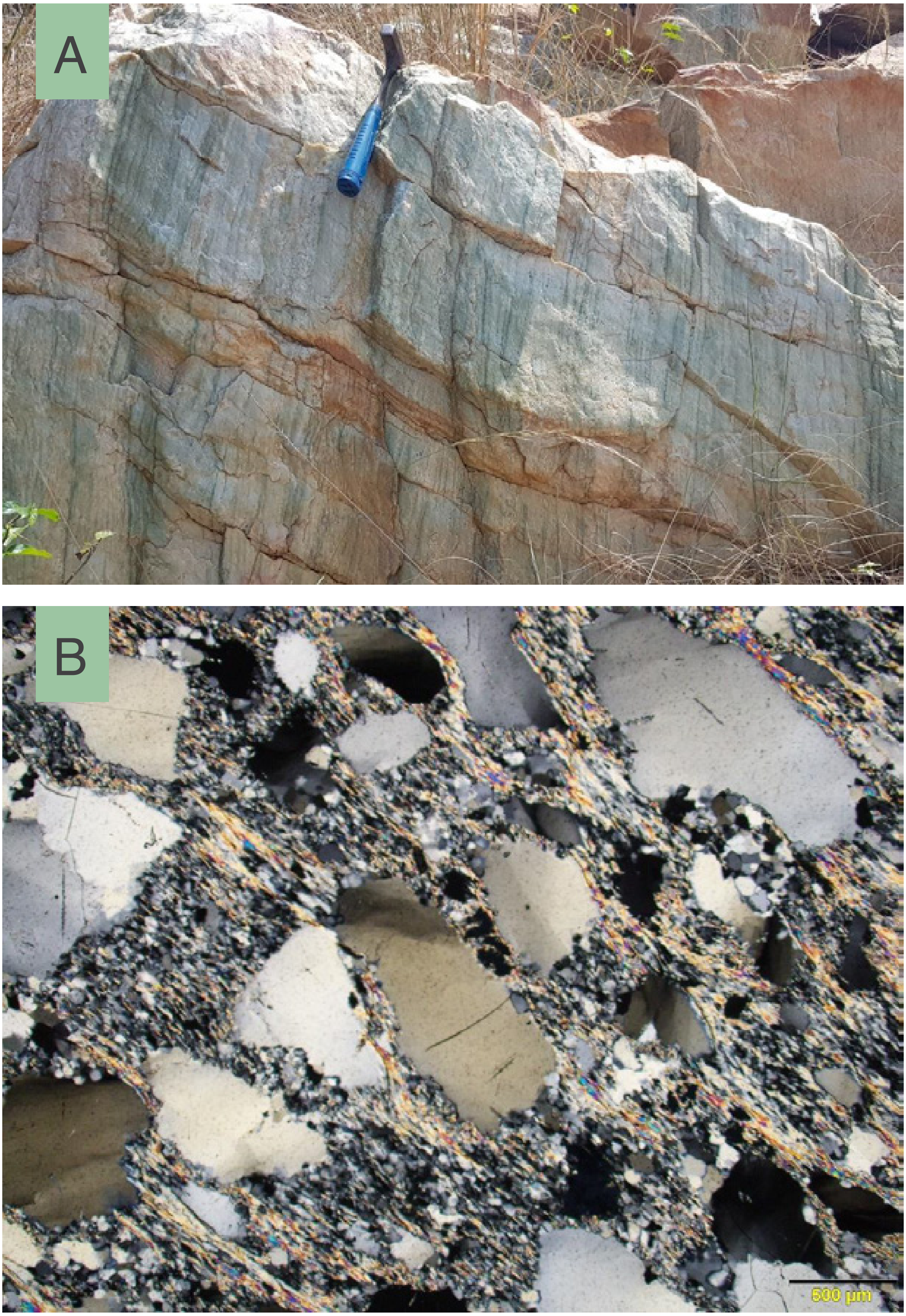

Figure 3: Fuchsite quartzite of the upper Western Iron Ore Group: (A) field photograph showing alternate cross-laminated and plane laminated facies (hammer length 42cm). (B) Photomicrograph of fuchsite quartzite; the precursor sandstone is moderate to poorly sorted with quartz, rock fragments, and mica (scale bar 500   m).

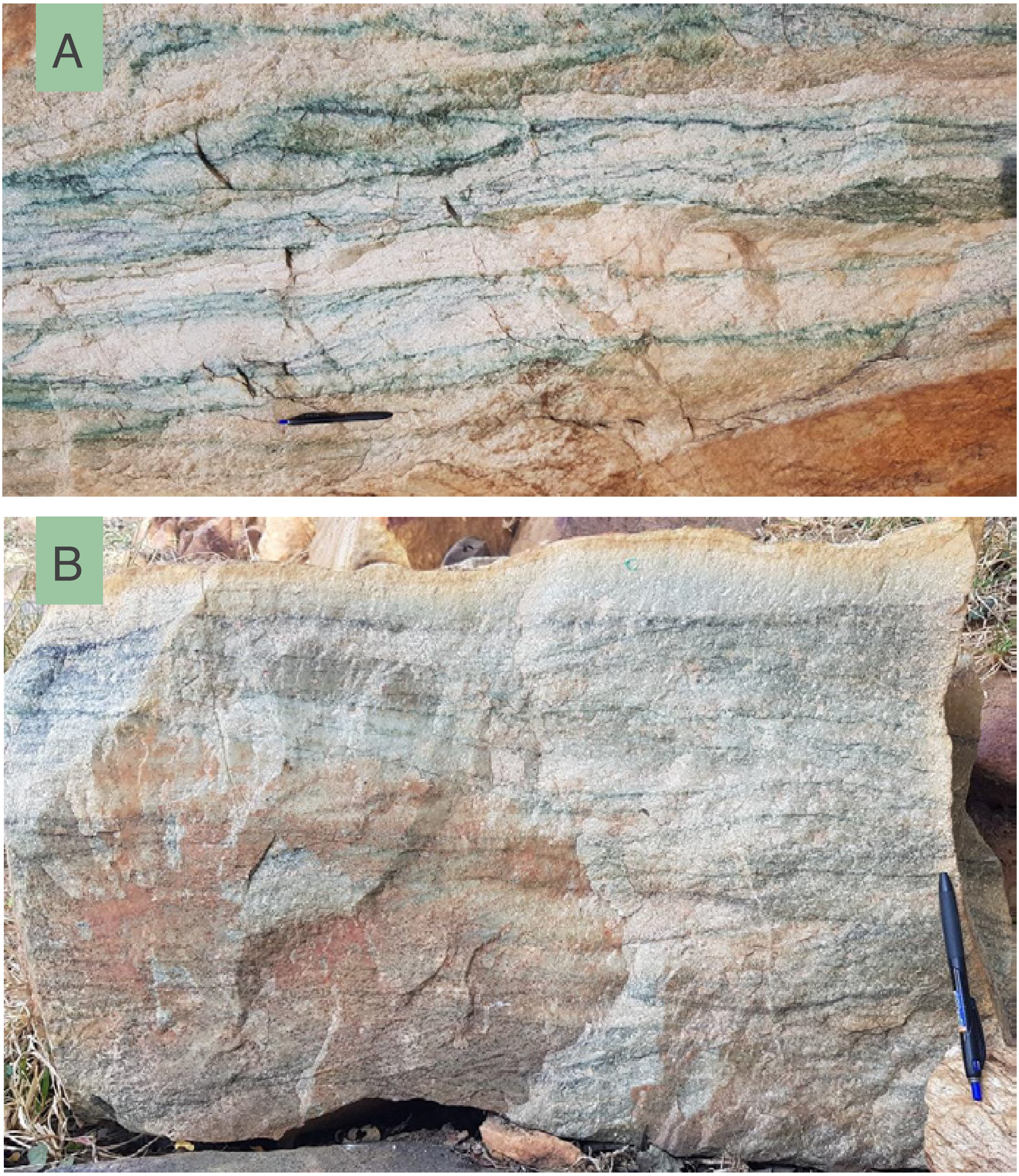

Figure 4: Mesoarchean tidal rhythmite (fuchsite quartzite) from upper Western Iron Ore Group succession: (A) Cross-laminated sandstone (precursor lithology). (B) Oppositely oriented cross-stratification (herringbone); foresets are separated by thin mud drapes (Pen lenth 10 cm).

DISCUSSIONS

Although tide-influenced shallow-marine deposits are known from several cratons (Mazumder and Arima, 2005), the oldest unambiguous tidal rhythmite was reported from the Moodies Group of South Africa (Eriksson and Simpson, 2000; Heubeck et al., 2022). Paleoarchean tidal deposits were previously reported by Mazumder and Chaudhuri (2021) from the lower WIOG succession in the western part of the Singhbhum Craton. Bhattacharjee et al. (2021) reported Mesoarchean tidal deposits from the Simlipal Group occurring in the eastern part of the Singhbhum Craton (Fig. 1A). We have recognized the tidally influenced shallow-marine deposit from the northwestern part of the Singhbhum Craton. Mesoarchean tidal deposits also occur in the southern part of the Singhbhum Craton (Chakrabarti et al., 2021; De, 2021). However, the Archean sedimentary succession occurring to the northern part of the Singhbhum Craton is entirely terrestrial (De et al., 2023). Although Neoarchean (~2700 Ma) tidal deposits are known from the Bababudan Group of the Dharwar Craton (Chadwick et al., 1985; Srinivasan and Ojakangas, 1986; Bhattacharyya et al., 2015), no Neoarchean tidal deposit is hitherto reported from the Singhbhum Craton. This is probably due to high continental freeboard conditions during the Mesoarchean-Neoarchean time in the northern part of the Singhbhum Craton relative to lower sea level conditions (De et al., 2023).

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A short note on the procedures adopted for the preservation and conservation of Lower Gondwana Beds of Mandakpal, Pulwama Kashmir by the Department of Geology and Mining JK(UT) India.

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Abstract

The Mandakpal geo-heritage site, situated about 25 kilometers northeast of District Pulwama, is approachable from the paved Pampore-Ladhu road and is a known Lower Gondwana fossiliferous site in the Kashmir Region of India. The geo-heritage site falls in the Survey of India (S.O.I) toposheet no. 43 N/4 and 43 O/1 with geographic coordinate (33°59'30.70"N, 75°01'34.70"E) at an average elevation of 1871 meters above mean sea level. The 252.9-million-year-old Mandakpal fossil beds are located amidst picturesque exposures of the Zabarwan Mountain Range to the north-west and the Wastarwan Mountain Range to the south-east side of the Kashmir valley. Due to the location's immense importance in the field of paleontology, sedimentology and environmental geology, the Regional Office of the Department of Geology and Mining (located in the summer capital of Srinagar), geologically mapped the area and demarcated the boundaries of the fossiliferous zone. Accordingly, Government Order No. 159-IND of 2019 declared the Mandakpal fossiliferous Zone as a protected geo-heritage site within an area of 1012695 square meters.

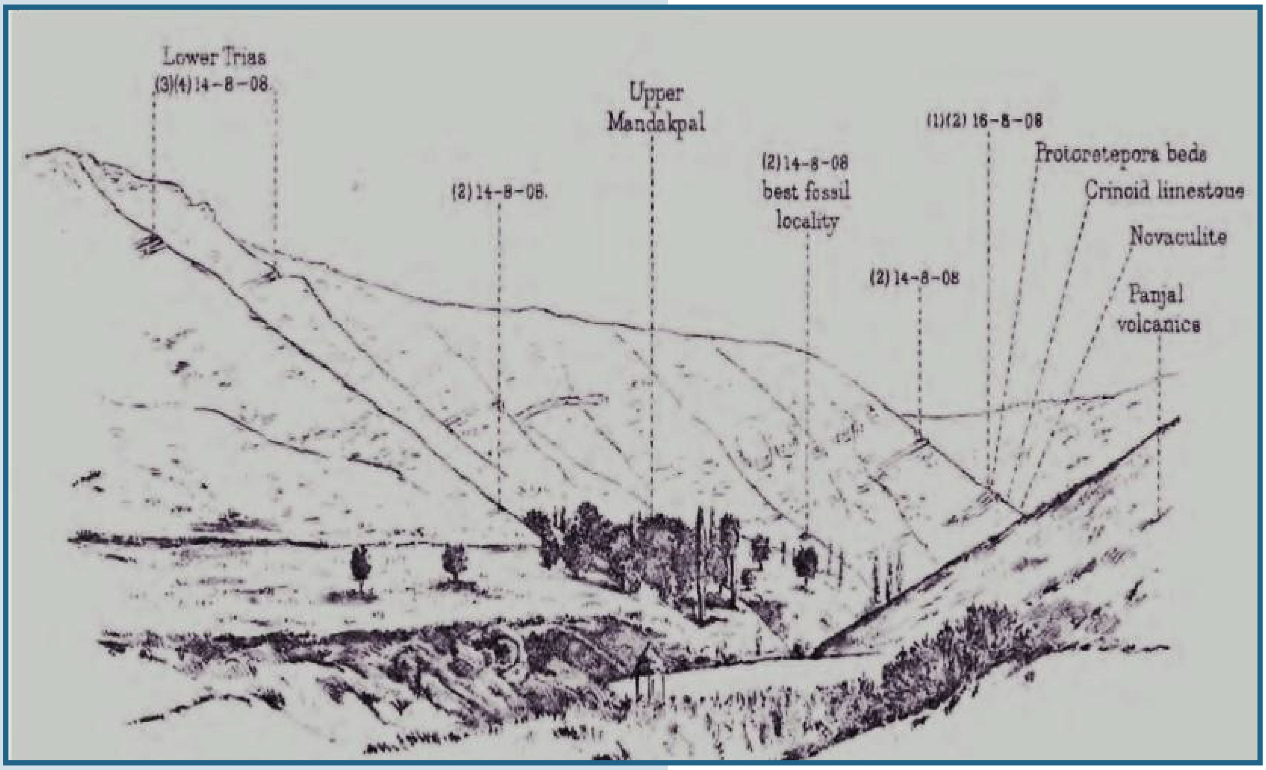
Keywords: *fossiliferous site, Repository fossil beds. Marginifera himalayensis, Spirifer rajah.*

Introduction

The Valley of Kashmir is blessed with a large number of magnificent geological sites spanning an enormous geological timeframe. These sites attract not only earth scientists from all over the world, but have also gained the attention of the general public. The Mandakpal fossiliferous site contains a large and rare collection of invertebrate fossils. Specimens recovered from the Mandakpal geo-heritage sites are being preserved and displayed at the Department's Geoscience Museum, located at Budgam, and were identified and documented by geologists from the Department of Geology and Mining, Srinagar.

Geological Setup

The area under report forms the south-eastern part of the Kashmir Basin (KB) wherein Proterozoic to Quaternary rocks of diverse origin are exposed. The Formations consist of Panjal Volcanics, Gondwana Beds, the late-Permian Zewan formation, and Triassic limestone and Quaternary deposits of Holocene age (Table 1)[1, 2]. The Lower Gondwana Beds of Mandakpal represents a large and well-preserved fossil assemblage[3] . Marine as well as some terrestrial well-preserved fossil remains marks the section's importance in terms of biologic perception of the Permian–Triassic Boundary (PTB) event. The rocks of the Lower Gondwana Beds at Mandakpal consist of an arenaceous sequence grading upwards through argillaceous into a more carbonate sequence[4] . At Mandakpal, a rock sequence exposed on the northwest -southeast trending ridge (Figure 1), forms the base of the Permian, and all the beds are calcareous in comparison[5,6]. In the middle of the lower shale bed, two fossiliferous bands are well exposed bearing *Marginifera himalayensis* and other *brachiopods*[7] . Further upwards in the section, is a well-preserved calcareous bed, measuring less than 0.2 meters in thickness bearing specimens of *Spirifer rajah* and other species of *Spirifer.*



(Figure 1): Middlemiss C.S (1910) drawing of the Mandakpal Valley with the main stratigraphic levels.

Formation	Lithology	Age
Quaternary	*Alluvium and Talus/Scree*	*Holocene*
Triassic Limestone	*Limestone, Shale and Sandstone*	*Triassic*
Zewan	*Limestone, Calcareous Sandstone and Shale*	*Mid-Late Permian*
Gondwana Beds	***Black Shale and Novaculite***	***Early Permian***
Panjal Volcanics	*Dark coloured amygdaloidal basaltic Lava flows*	*Permo-Carboniferous*

Table 1: The litho-stratigraphic sequence of the Mandakpal geo-heritage site

Fossil assemblages

Bryozoans, Brachiopods, Marginifera himalayensis, Spirifer rajah, Bivalves, and Ammonoids are geological age representatives of the Permo-Triassic and were observed in black shale and limestone of Zewan (Figure 1)[5, 6, 7]. The *Novaculite Bed* is representative of Early Permian aged Gondwana Beds and was observed at geo-coordinate 33°59'30.70"N 75°01'34.70"E (Figure 2).

(Figure 2): Novaculite Bed age representative of Early Permian

The general strike of the Zewan beds is N 75° E to S 75° W with inslope dip of 13° due north-west. Taking into consideration the lateral extension of the bedrocks that bear these *important fossil assemblages*, (Figure 3, 4, 5, 6) the Department reserved the area as *a geo-heritage site* from the water tank upwards to the top of the hill near the shrine of Niam Sahib (Figure 7 and 8).

Figure3: Repository fossil beds Spirifer rajah

Figure. 4. Spirifer Rajah, an index fossil.

Figure. 5. Dorsal view of brachiopod shell.

Figure. 6. Permian Fossil assemblage at Mandakpal

Figure7: Picture of Mandakpal Geo heritage site

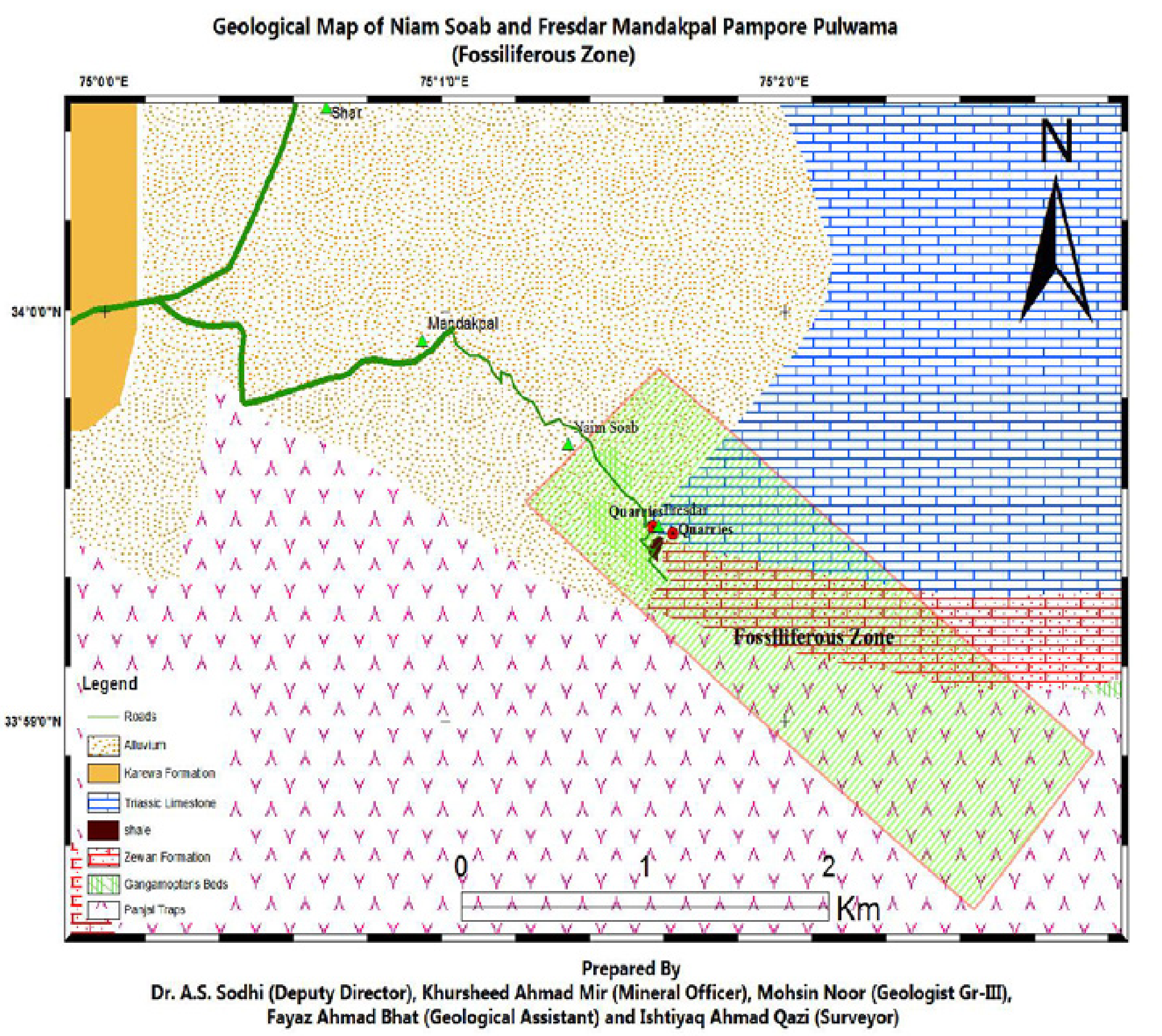


Figure 8: Mandakpal Geo-heritage site base map.

Demarcation, preservation and maintenance of Mandakpal geo-heritage site.

During the summer of 2018, geologists from the Department of Geology and Mining, Srinagar including Mohsin Noor, Khursheed Ahmad Mir and Fayaz Ahmad Bhat, under the supervision of Dr. Amerjeet Singh Sodhi, Deputy Director, geologically mapped the Mandakpal fossiliferous site over an area of 1,012,695 square meters with the help of an Electronic Total Station (E.T.S) and Navstar Global Positioning System **(GPS)**, a satellite-based radio navigation system[8, 9]. After the field work, the base map (Figure 8) was prepared on GIS

Platform by the team which was cross-checked once again in the field before its final submission to the Administrative Department, Civil Secretariat, Srinagar for issuance of notification as a protected zone in the Government Gazette. Accordingly, on 26th of July 2019, through Government Order No. **159-IND of 2019**, the Mandakpal fossiliferous site was declared as a geo-heritage site[10]. Presently, the Mandakpal geo-heritage site is looked after by a team of geologists and is maintained through funds of the District Mineral Foundation Trust (DMFT), Pulwama [11,12,13].

Conclusion

The Mandakpal geo-heritage site hosts a well-preserved mega fossil assemblage in the Lower Gondwana beds with a geological age of 252.9 million years. Marine and some terrestrial fossil remains marks the Sections importance in terms of biologic understanding of the Permian–Triassic Boundary (PTB) event. At present, the geo-heritage site is looked after by a team of geologists and maintained through the funds of District Mineral Foundation Trust (DMFT), Pulwama.

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The first author is thankful to Mr. O. P. Bhagat, Director, Department of Geology and Mining, Jammu and Mr. Nisar Ahmad, Joint Director, Department of Geology and Mining, Kashmir for their active support and guidance. I am also thankful to Seyedeh Saeideh Mortazavi, Research Institute for Earth Sciences, Iran for technical support rendered to me during the submission of this research article. This has only been possible because of her guidance and time management.

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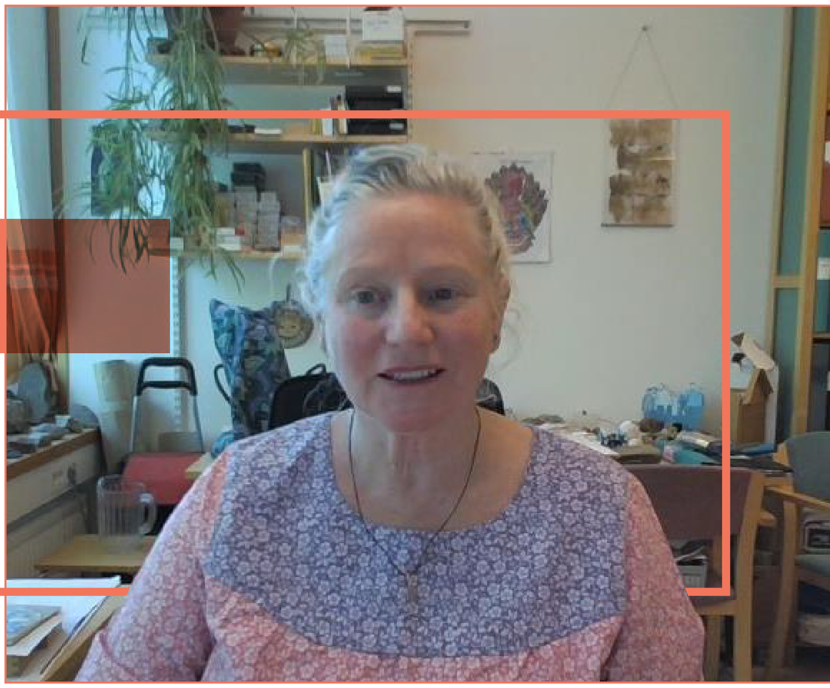


Interview with Professor

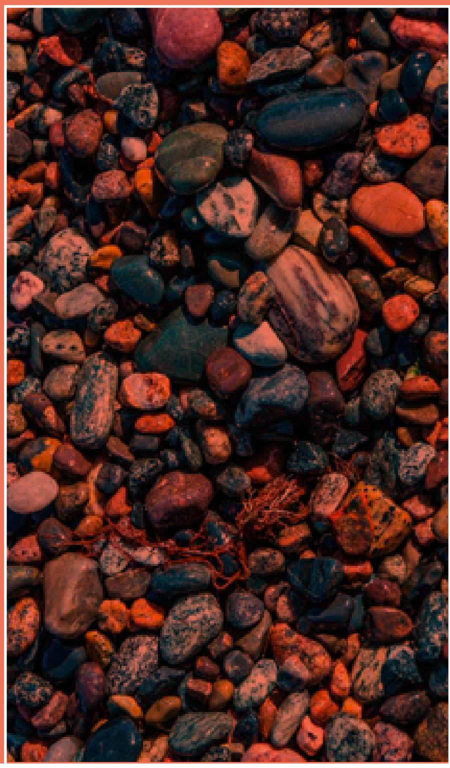
Victoria Pease

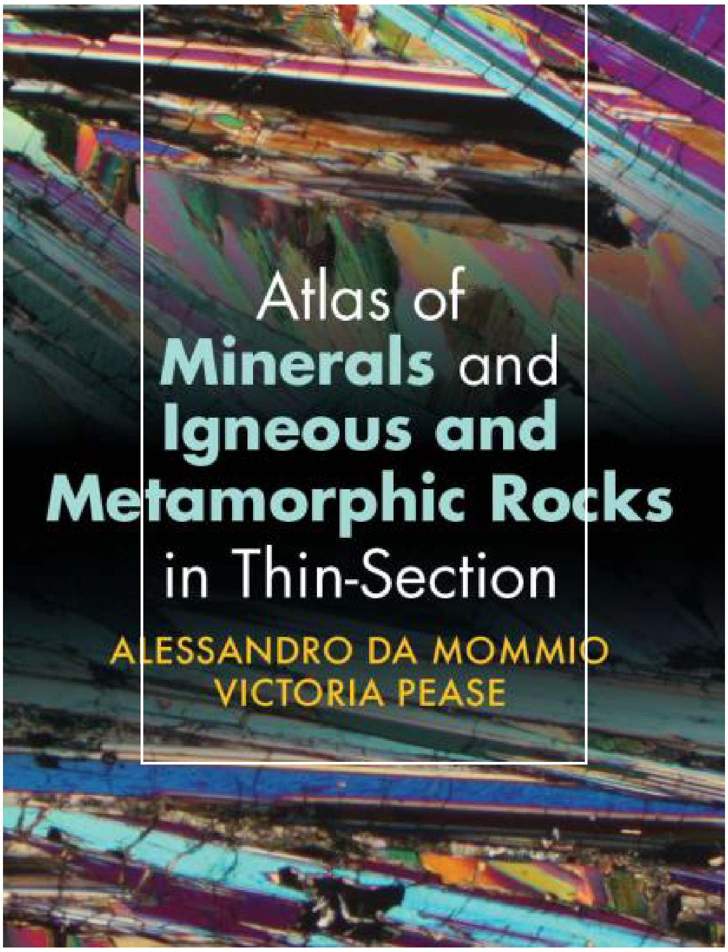
- Please tell us about yourself

I am a geologist, the professor of Tectonics and Magmatism at Stockholm University, Sweden. I moved to Sweden in 1989 and have spent most of my professional life here. I was born in the U.S. and after completing my BSc at the University of California (Santa Cruz), I worked at the U.S. Geological Survey for about ten years. This was an inspirational time for me because I got to explore different subdisciplines in the subject (field mapping, laser terametry, isotope dating, paleomagnetism, geochemistry, etc.), travelled across the vast western U.S. (and got paid for it!), and I met so many fantastic people… It was a great time for me, both personally and educationally. During this period, I met and married my husband, Martin Whitehouse, who was a visiting post-doc from the U.K. After marrying, we moved to England where I completed PhD at University of Oxford under the supervision of Prof. John Dewey, an inspirational field geologist and expert in tectonic processes.

-How did you become a geologist?

As an undergraduate, I took a mineralogy course to satisfy part of the university 'natural science' requirement and I loved it! I immediately changed my degree to Earth Sciences so I could keep learning about minerals and rocks. Studying minerals under the microscope opened my eyes to a whole new world! Some people find rocks to be quite boring, but I can tell you that a single thin-section of a rock and the minerals in it reveals so much about how and where the rock formed, the pressures, temperatures and processes that affected it, whether or not it can be dated to determine the age of these processes - there is so much information stored in a simple thin-section. This is why I and my colleague Alessandro Da Mommio wrote our text book on minerals and rocks in thin-section. Petrographic thin-sections are a simple yet incredibly powerful method for understanding minerals and rocks, and it is necesasry to convey to our students something of the importance of what they are doing and why they are doing it.





To be published by Cambridge University Press in 2025

Geology on Ellesmere Island, Canada.

- What scientific projects/locations have you worked in?

Being a geologist is fantastic because most of my work involves getting to secluded and pristine sites of natural beauty. I have floated down the wild rivers of Alaska, hiked across the remote tundra of Arctic Russia, helicoptered into Arctic Canada, taken ships to isolated Arctic islands, and driven across vast regions of Egypt, Jordan, Yemen, and Oman. I have led two larger international research teams, one project focussed on Arctic tectonics and another on the tectonic evolution of Saudi Arabia. All of my work relates to understanding the tectonic evolution of an area - this is the driving motivation of most of my research because I want to understand how the land we live on came to be the way it is. My kind of work is not for everyone, but if you like being physical and going places where not many others have been, its great!

- Do you have a favorite?

This is a difficult question because I love all of nature, from the stark beauty of the desert, to the remote, dense forests of Alaska. However, there is one super, special place that I have worked and would love visit again - that is the island of Socotra in the Arabian Sea! This unique and beautiful island has excellent geology in a very special setting - Socotra is a geologically isolated fragment of southern Gondwana. Consequently, it has a rich and unique biodiversity - an absolutely special location on our planet.

SOCOTRA

This unique and beautiful island has excellent geology in a very special setting.

Dragon blood trees of Socotra.

- What methods do you employ?

During fieldwork we are hiking or boating and sleeping in tents. We cook on small stoves and have to bring all our food for the expedition with us. We also have to bring weapons to defend ourselves against grizzly or polar bears. Otherwise we are moving by helicopter from a base-camp or ship. Once back at the lab with samples, I employ petrographical, geochemical, and geochronological analytical methods. I mostly use x-ray fluorescence (XRF) and laser ablation inductively coupled mass-spectrometry (LA-ICPMS). For XRF, I crush the rock into powder and convert it to a homogeneous glass at 1000°C. The glass is then analyzed for major and trace element compositions, which are used to determine the tectonic setting of the rocks. I also do a lot of U-Pb isotopic dating (mostly zircon) for both igneous and sedimentary rocks - this provides me with ages of the samples.

Autofusion turns rock powder into glass.

- What are the challenges for students and professionals in the geological sciences today?

A big challenge for the geosciences today is the ability to adapt to rapidly changing needs. The profession is always changing, whether due to societal needs or technological advances, however, the speed of change just now is very fast and this is a real challenge for us. This is especially true with regards to the green energy transition and the shift away from the oil and gas sector - this change is happening rapidly and sometimes exceeds the ability of universities and industry to adapt. For example, in hiring new staff with appropriate skills, as well as being able to educate students appropriately by rapidly adjusting and delivering a revised curriculum for geoscience students. In addition, with the declining birth demographics of many countries, the education and employment of women is more and more important; female education and expanding career choices need to be better integrated with the changing needs of the field.

- Do you have any advice for young academics trying to navigate this profession?

I am very grateful for the work I am able to do, the places I get to visit, and the people I have met throughout my career. However, it has not always been easy and without my passion for the subject, I might have given up before I was able to make the achievements I have. If I can offer anyone advice, first and foremost I would say find your passion and follow your heart. Without passion for your work, you will never have a career, but just have a job. If you want a long, satisfying career, pursue something you love!

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