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GSO Participates in the Exhibition at the Land of the Frankincense

Wendell Phillips in Oman, 1952–1971

Stratigraphic status of the Dhanjori Formation, Singhbhum Craton, Eastern India and its Implications

Passive Seismic Monitoring

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ABOUT GSO

The Geological Society of Oman GSO was established in April 2001 as a vocational non profitable organizations which aims to ad- vance the geologi- cal science in Oman, the de- velopment of its members and to promote Oman's unique ge- ological heritage.

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By The Editor

Dear readers,

It is my pleasure to wish you a happy new year, and I wish you success and more achievements during 2022!

Al Hajar Magazine, as it brings you the significant coverage of the Geological Society of Oman, it seeks forward to shocase various geological news and reports. During this year the GSO has delivered many different activities from field trips, educational lectures, and enriching meetings with various guests.

In this issue, you will find historical talk about Wendell Phillips and his role in oil exploration operations in Oman from 1952-1971. You will also find an interesting topic about the Stratigraphic status of the Dhanjori Formation, Singhbhum craton, eastern India, and its implications. Finally, one of the important topics that will be discussed in the geophysical field is passive seismic monitoring and its applications. Through these topics, we seek to find a diversification of knowledge with various people interested in the geological aspects, whether skilled in the field or young professionals. I hope you have a good knowledge journey throughout this issue.

My Regards,
Yousuf Al Darai
Al Hajar Magazine Editor

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Description: Aqabat Al Amerat Road, Muscat: Mahil Formation, Triassic age, grey-white and beige bedded Dolomite.
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GSO Participates at the *"Oman Geological Heritage: Sustainability and Working Opportunities"* Exhibition at the Land of the Frankincense Museum- Salalah

Written by: Husam Al Rawahi

One of the main objectives of establishing the Geological Society of Oman GSO is to educate the community about the rich geological heritage of Oman and explain to them in a simple language the necessity of conserving and protecting these sites. Therefore, in cooperation with the Ministry of Heritage and Tourism (MHT), in collaboration with Petroleum Development Oman, GSO supported and provided geological contents the Oman Geological Heritage Exhibition at the Frankincense Land Museum in the wilayat of Salalah, Dhofar Governorate, on the 15th of November 2021.

The exhibition includes displays related to different geological topics that introduce a background of the Sultanate of Oman's formation and the various geological sites that represent this record. The displays also explain the importance of conservation of the geological sites and the opportunities to develop these sites for future projects. Since the exhibition was organized in Dhofar, one of the displays reveals the geological treasurers of the area and connects the locals with their heritages.

The exhibition includes some of the unique fossils from different geological periods found in several other areas in Oman. One of these fossils was of the bones of extinct animals discovered in Dhofar governance and was presented beside an interpreted model of these animals, which was made based on scientific descriptions and data.

The geological content was written to be suitable for a wider audience: academics, teachers, university and school students, job seekers, and those interested in geology. The desired outcome is to raise awareness on the significance of preserving the sultanate's geological heritage aligned with Oman Vision 2040 and its strategic objectives and programs to enhance national identity.In addition, to attract potential economic activities to utilize and sustainably develop some geological sites for future geotourism programs.

It is worth mentioning that the exhibition content were prepared by GSO members and geosciences job seekers supervised by senior and expert GSO members. These opportunities were given to the job seekers to develop their communitaction, enhance their geological understanding, and train them on geological content creation. Furthermore, two job seekers (and GSO members) were allocated to guide the exhibition's visitors through the different displays and fossils to enhance visitors' experiences and learnings.

WENDELL PHILLIPS IN OMAN, 1952–1971

By M. Quentin Morton

Wendell Phillips on a visit to London in 1966. (Illustrated London News)

The beach at Mirbat with oil drums lining the shore, March 1948 (Mike Morton)

THE SEARCH FOR OIL IN DHOFAR

In early 1926 the geologist George Martin Lees of the Anglo-Persian Oil Company briefly surveyed parts of the Dhofari coast and concluded that there was insufficient thickness of succession for there to be much chance of finding oil. There matters rested until Anglo-Persian's interest was rekindled by the discovery of oil on Bahrain Island in 1932, which opened up the possibility of finding oilfields on the Arabian mainland. By then Anglo-Persian was tied by the Red Line Agreement (1928) to act through the Iraq Petroleum Company (IPC), a British-led consortium of international oil companies.

IPC was spurred on to sign up the rulers of Qatar, the Trucial Coast, Oman and, in June 1937, Dhofar (which was considered separately from Oman at that time) through its subsidiary, Petroleum Concessions Ltd. Another IPC subsidiary, Petroleum Development Oman and Dhofar, was created to develop the concessions, but little happened after that. There was an aerial reconnaissance and a brief survey around Mirbat, which came to nothing, and then World War II intervened. IPC converted the agreement to a full concession in May 1944.

In February 1947 Sultan Said bin Taimur invited Sir Cyril Fox, a former director of the Geological Survey of India, to conduct a mineral survey of Dhofar. After two-weeks of excursion, Fox reported favorably on its prospects. A year later, an IPC party comprising Tony Altounyan and two geologists – René Wetzel and my father Mike Morton - carried out six-weeks survey of the province. The only sign of oil they found was a seepage on the coast at Mirbat which they attributed to leaking barrels of fuel that had been floated ashore and buried in the sand. Otherwise, the geologists concluded, the province was an unpromising oil prospect. IPC decided to abandon the concession in the latter part of 1950, and 'Dhofar' was removed from its subsidiary's title, which became Petroleum Development (Oman) Ltd (PDO).

IPC soon realized that the boundary of Dhofar was not precisely defined, and might include parts of Oman that were within its PDO concession. That situation might have been recoverable but when another outfit headed by Wendell Phillips appeared on the scene all bets were off.

ENTER WENDELL PHILLIPS

The Sultan received IPC's letter of withdrawal on the 2nd of January 1951 and was apparently 'delighted' by the news. The problem was the next step: the Americans had discovered oil in Saudi Arabia and this was a golden opportunity to get the Americans involved, but they were too engrossed with their concession in Al Hasa to be interested in far-off Dhofar. As the Sultan mulled things over, an American archaeologist and explorer Wendell Phillips arrived to Salalah looking to investigate archaeological sites in Oman. He came to the Sultan's palace with thoughts of ancient ruins in mind and left with an oil concession in hand.

Wendell Phillips was a remarkable character. Born in California, his mother was a gold prospector and wall-of-death rider. He graduated from the University of California at Berkeley with a degree in paleontology. He made his name in the world of archaeology by arranging expeditions to Africa and Arabia under the auspices of the American Foundation for the Study of Man, a non-profit-making organization he founded in 1949. He liked to make a bold impression, and was often seen in the desert wearing an Arab headdress and a pearl-handled revolver strapped to his waist.

In February 1952, he had fled from Yemen after a contretemps with the local officials over an archaeological site at Marib, reputedly the palace of the legendary Queen of Sheba, and took refuge in Dhofar. He established a good rapport with Sultan Said. His connections with the oil business were tenuous, but he did have a talent for networking, a skill that he had used to raise funds for his archaeological expeditions.

'We need oil in Dhofar, not annual payments', the Sultan told Phillips, 'and by the Will of God we shall have oil, for I am granting you the oil concession for Dhofar'. Phillips was taken aback:

I was so completely astounded that to gain time I asked him how big an area Dhofar was. When he replied that it was approximately the size of the state of Indiana, I needed to catch another breath.

The Sultan, who was an expert in international law, drew up a concession agreement and typed it out himself. On the 17th of January 1953 the document was finalised, Phillips signing on behalf of Philpryor Corporation, which combined the names of Phillips and one of his main backers, Sam Pryor, vice president of Pan American World Airways.

'Where does one go from here?' Phillips asks in his book, Unknown Oman. Dhofar had been dismissed by IPC as an oil prospect and was remote from American thinking. There were no docks, roads or facilities. At first, no one wanted the concession, and there was a danger it would become an 'interesting historical document' in his 'mother's scrapbook'. However, in April 1953, the president of Cities-Service Alton Jones agreed to take on the concession with the Richfield Oil Corporation (later known as ARCO) as a partner. The reasons for his decision are not exactly clear, but it is likely that the lure of riches from Arabian oil outweighed the risks of such an undertaking.

In September 1953, with the Sultan's agreement, the concession was duly transferred, and a new operating company Dhofar-Cites Service Petroleum was created. Drawing on Calouste Gulbenkian's example – the Armenian businessman was famously known as Mr. Five Percent for the share he retained in IPC – Phillips gained a 2.5 per cent share of the profits. However, unlike Gulbenkian, he did not have to contribute towards the costs.

‘We need oil in Dhofar, not annual payments’, the Sultan told Phillips, ‘and by the Will of God we shall have oil, for I am granting you the oil concession for Dhofar’.

Phillips (left) with Cities Service chief geologist, Hal Knudsen. (Cities-Service)

DRILLING OPERATIONS

In late 1953, a team of five geologists arrived from the United States to take a cursory look at the whole concession and saw what appeared to be a structure in the Dauka area. Since it was in close proximity to the Rub al-Khali, and they wanted to see what happened to the Arab Zone (the producing zone of Saudi Arabia), they decided it was a good location to test the stratigraphy. Hal Knudsen, chief geologist with Cites-Service, explained their reasons:

We wanted to be in the northern part of the concession to hopefully pick up some of the producing formations of Saudi Arabia and then secondly, since there was a little uncertainty about the borders at that time, it seemed worthwhile perhaps to make a sort of statement in that regard that this was going to be in the province of Dhofar belonging to the Sultan of Muscat and Oman.

Dhofar-Cities Service seat up their headquarters in a palm grove near a beach at Raisut to the west of Salalah.

Much of the drilling and ancillary equipments were shipped from Houston and lightered ashore on landing craft, or simply floated on oil-drum rafts; Schlumberger also had the well-logging contract and their equipments were brought in this way. On the 6th of January 1955 the first cargo was landed, and the first wildcat well was spudded in barely three months later, on the 15th of April: a 50-kilometre road was built in the Qara Mountains for Kenilworth trucks to transport collapsible derricks into the desert interior and a camp was sat up at the drilling site.

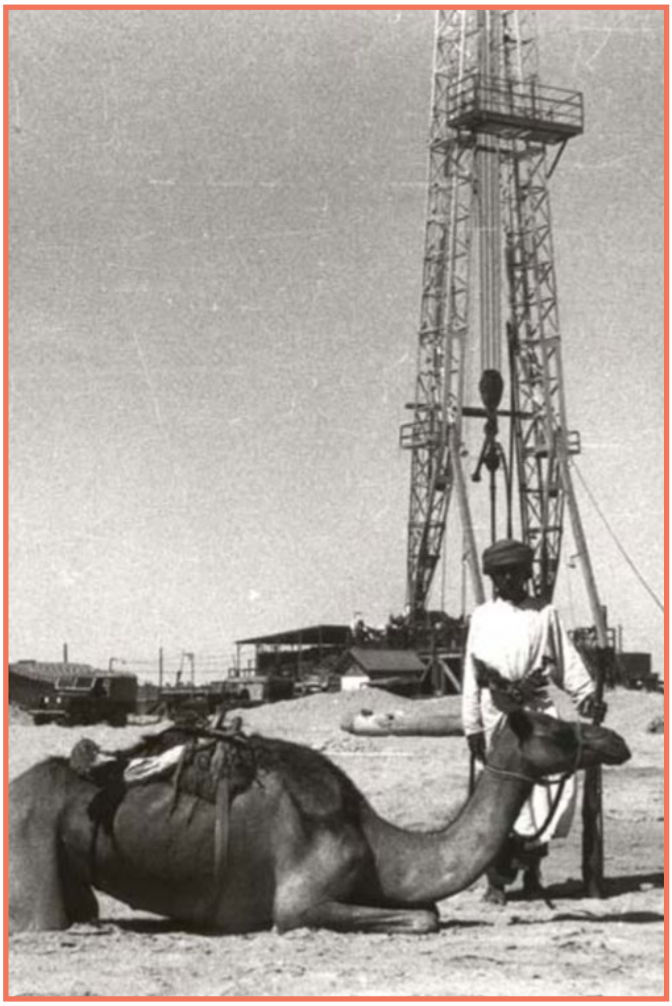
As drilling progressed, the geologists became aware from their studies that the structure was unlikely to be a substantial one, as described by Knudsen:

We We pretty well determined at that time that what we were looking at was a very shallow feature. I’m speaking now of the first couple of hundred feet, where the Rus formation, which is an anhydrite, had become, saturated in some respect, and had expanded, creating this supposed feature at the surface that we were able to see. So it was, as I say, didn’t persist, it didn’t persist at depth. We later confirmed that with a seismic line right across the feature also.

A tank landing craft (TLC) off the shore at Raisut. (Cities-Service)

Schlumberger provided the logs, which were of limited use in the Dauka well because it was a dry hole and therefore the geologists were not determining net pay or anything else. But, when other wells were drilled in the province, they were very useful because they showed how the area and formations correlated elsewhere in the province and might identify formations that were also present in Saudi Arabia. 'It was of much more interest', remarked Knudsen.

The Dauka well was followed by three wells at Marmul – No. 1 spudded in February 1956, No.2 in October 1956 and No.3 in August 1957. Stewart Edgell, Richfield's geologist for the concession, is credited with locating the discovery well in Oman, Marmul No. 1. Unfortunately, the flow declined on testing, and other factors counted against its further development: the oil was heavy (22° API and 40-200 cP viscosity), there was a lack of infrastructure to export the oil, global oil prices were low, and Cities could lift oil from Kuwait more cheaply.



Dauka No.1, the first oil well in Oman (Cities-Service)

Another well at Dahaban looked promising – 'we thought we had hit the mother lode', remarked Knudsen – but it soon petered out in a salt formation. In 1962, the company assigned its interest to John Mecom and Pure Oil. In 1967, after more changes, with $40 to $50 million spent, 29 wells sunk and a deteriorating security situation, the Americans withdrew. They had found oil but at great cost and with no commercial gain.

By then Phillips had moved on to other things, having sold most of his 2.5 per cent share to supporters of his archaeological expeditions. His ventures now spanned the globe, stretching from Venezuela to Africa and south-east Asia. He made a fortune through his dealings in Libya, and tried to become involved in the Trucial States (today's United Arab Emirates): in 1966 he made an offer to the sheikh of Fujairah for an offshore concession, and in 1969 he assembled a group of business interests to apply to the sheikh of Umm al-Quwain for an offshore concession in the Arabian Gulf. And then there was Australia: in 1968, it was reported that he had turned his attention to the Land Down Under. All these activities were coordinated from his home in Honolulu.

A bachelor till the age of 47, he married an eighteen-year-old local girl, but the marriage did not last. 'She just could not adjust to my way of life,' he told the press, alluding to his globe-trotting activities. By then he had eighteen honorary degrees from universities around the world. 'I am first and foremost an explorer and archaeologist. My second objective is to publish my findings. I'm getting close to that goal despite all the money that's come along', he told the New York Times. 'With me, oil is a hobby that happens to pay,' he once said.

L-R, Hamid Mohammed from Salalah, Mohammed Awad from Aden, American geologist Paul J. Gribas, Salim Mohammed and Abdullah Mohammed, both from Salalah, sampling viscous, gloopy oil at Marmul. (Cities-Service

THE END GAME

Phillips's first love remained Oman. He wrote two books about the country and remained on good terms with Sultan Said, describing himself as his 'economic adviser'. In the 1950s, there was talk of an oil concession for the Sultan's territory of Gwadar (now part of Pakistan). In December 1965, it was reported that the Sultan had granted his company, Wendell Phillips Oil, an offshore concession stretching from the Batinah Coast to Ras al-Hadd, which he assigned to a German firm, Wintershall Aktiengesellschaft.

Sultan Qaboos came to power in July 1970, but Phillips was not on such good terms with him as he had been with his father. In March 1971, it was announced that the new Sultan had confirmed the grant of an offshore concession to Phillips's company for the southern coast of Oman, stretching 450 miles from Ras al-Hadd to Ras Minji near the border of Dhofar province. Phillips produced a fine document bound in red leather with gold lettering, but there was confusion about what it actually meant: was it a concession, option, contract, commission to study, or something else?

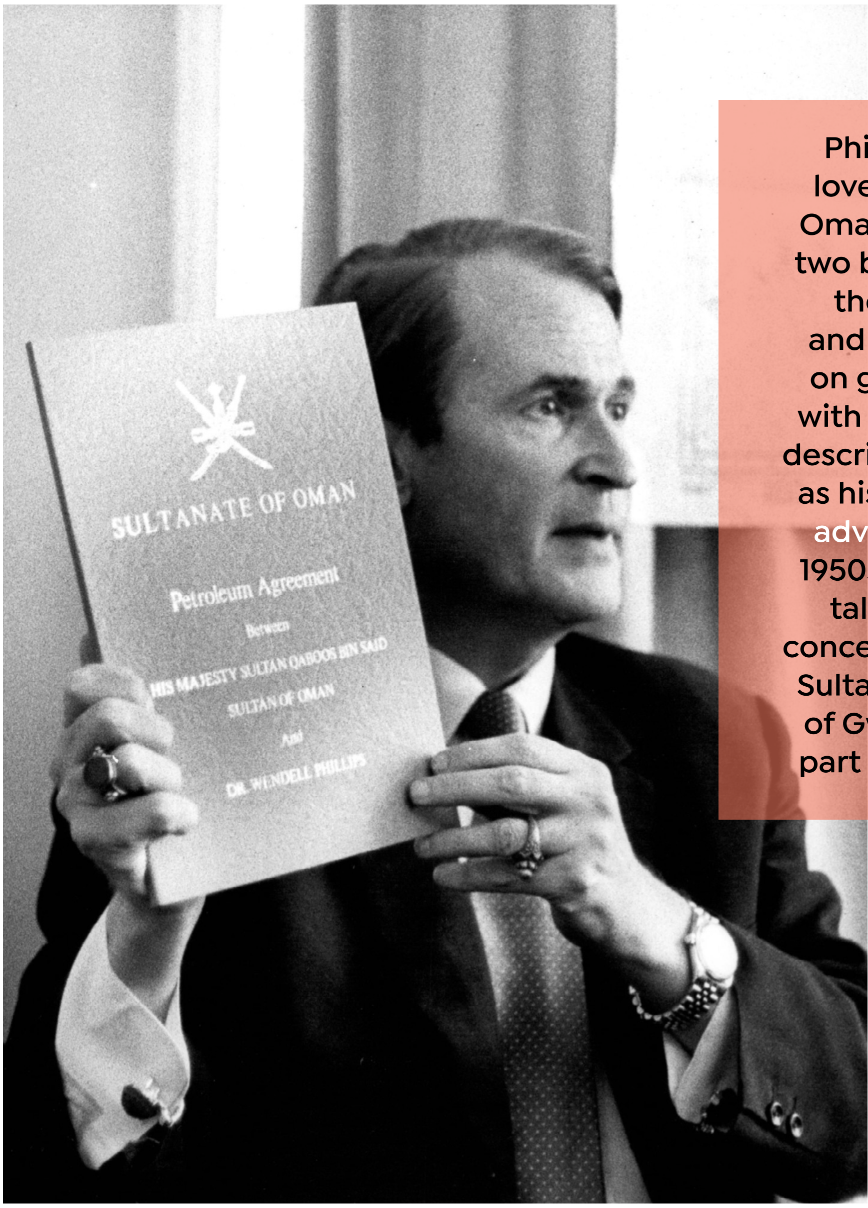
He passed away in 1975 after a heart attack at the relatively young age of fifty-four. He was a very rich man, reputedly with a fortune of over $130 million when he died, and some 40 producing oil wells and oil rights to 100,000 square miles of ocean to his name, although success in Oman eluded him to the last. Nevertheless, his part in securing the concession agreement with Sultan Said which led to the discovery well in Dhofar has ensured his place in the annals of oil exploration in Oman.

In September it was announced that the concession had been cancelled because of a missed down payment and the fact that Phillips had not arrived in Oman to sign the necessary documents.

'No visa was sent to allow me to come to Muscat,' he protested. He jumped on a plane and flew to Dubai, pleading to be allowed into Oman for 'special' medical treatment for a stomach hemorrhage which he claimed was only available at the Mission Hospital in Mutrah. Permission was refused and the days of Wendell Phillips as an influential figure in the affairs of Oman were over.

ACKNOWLEDGEMENTS

To the late Gene Grogan of Oxy, who copied some of the photographs used in this article from Cities' Tulsa archives in 1989, and thanks also to Alan Heward for his kind assistance.



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Phillips defends his offshore 'concession' at a press conference in September 1971. (Keystone Press/Alamy)

STRATIGRAPHIC STATUS OF THE DHANJORI FORMATION, SINGHBHUM CRATON, EASTERN INDIA AND ITS IMPLICATIONS

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INTRODUCTION

In significant contrast to other cratonic blocks of the Indian subcontinent, the Singhbhum craton bears supracrustal records from Paleoarchean to Neoproterozoic (Olierook et al., 2019; Chaudhuri, 2020) and provide a rare opportunity to unlock the mysteries of early Precambrian earth (Mazumder et al., 2012a, 2019a, b; Saha and Mazumder, 2012; Chaudhuri et al., 2018; Miller et al., 2018; Olierook et al., 2019; Mukhopadhyay, 2019; Chaudhuri, 2020). Notwithstanding this, the lack of geochronological data from some critical stratigraphic units of the Singhbhum craton and some dubious doubtful geochronological data make regional as well as global stratigraphic correlation and consequent geodynamic interpretation ambiguous (Mazumder et al., 2012a; Olierook et al., 2019; Mazumder et al., 2019a). For example, the depositional age of the Dhanjori Formation is highly ambiguous (2.8-2.1 Ga.; cf. Sunilkumar et al., 1996; Roy et al., 2002; Misra and Johnson, 2005; Acharyya et al., 2010; see Mazumder et al., 2019a). The Dhanjori Formation that represents a terrestrial (alluvial fan-fluvial) volcano-sedimentary succession formed in an intracontinental rift setting (Mazumder and Sarkar, 2004; Mazumder and Arima, 2009). It has been speculated that the Archean-Proterozoic boundary passes through the Dhanjori Formation (Mazumder et al., 2019a). The stratigraphic status of the Dhanjori Formation is unknown. The students and staff of the Department of Applied Geosciences, German University of Technology are currently undertaking collaborative research project on the Archean stratigraphic successions of the Singhbhum craton through The Research Council (TRC) of Oman sponsored research project. In this research communication, we will critically review the present state of knowledge on the stratigraphic status of the Dhanjori Formation, its tentative correlation with other lithostratigraphic units of the Singhbhum craton and their geological implications.

GEOLOGICAL BACKGROUND

The Singhbhum craton, encompassing the Singhbhum district, Jharkhand, and north Odhisa, exposes a vast tract of Precambrian rocks (Fig. 1). The southern Archaean Singhbhum nucleus consists of various granitoids, the Paleoarchean Iron Ore Group (IOG) of rocks, and Neoarchaean siliciclastics (cf. Mukhopadhyay, 2001; Mazumder et al., 2012a). The ~200 km long North Singhbhum Fold Belt (NSFB), comprising the Dhanjori, Chaibasa, Dhalbhum, Dalma and Chandil Formations, encircle the Archean Nucleus component (cf. Gupta and Basu, 1991, 2000; Acharyya, 2003; Fig. 1). The Chottonagpur Granite Gneissic complex (CGGC), an extensive granite-gneiss and migmatite terrain, occur to the north of the NSFB (Fig 1; see Sanyal and Sengupta, 2012; Chatterjee et al., 2013; Mazumder et al., 2015).

The Dhanjori Formation and the Singhbhum Group have suffered multiple phases of deformation and metamorphism (greenschist to amphibolite facies) (Naha, 1961; Saha, 1994; Ghosh et al., 2006). The Dhanjori and the Chaibasa Formations suffered a late Paleoproterozoic (~1600 Ma) shearing event that give rise to the Singhbhum Shear Zone (SSZ; Fig. 1). Earlier researchers interpreted the SSZ (also known as Copper Belt Thrust in old literature, see Sarkar and Saha, 1962; Saha, 1994) as the plate boundary. Some researchers believe that the SSZ marks the contact between the Dhanjori and Chaibasa formations (Saha, 1994; Bhattacharya et al., 2014). Subsequently, researchers reinterpreted the SSZ as a zone of intense shearing (Sengupta and Mukhopadhyay, 2000; Mazumder et al., 2012b and references therein) that passes through the Dhanjori Formation (De et al., 2015, their fig. 5; see also Olierook et al., 2019). The Dhanjori Formation is overlain by the Chaibasa Formation without any structural discordance (Sarkar and Deb, 1971; Mukhopadhyay, 1976) and the contact appears conformable (Bose et al., 1997; Mazumder, 2005; Olierook et al., 2019).

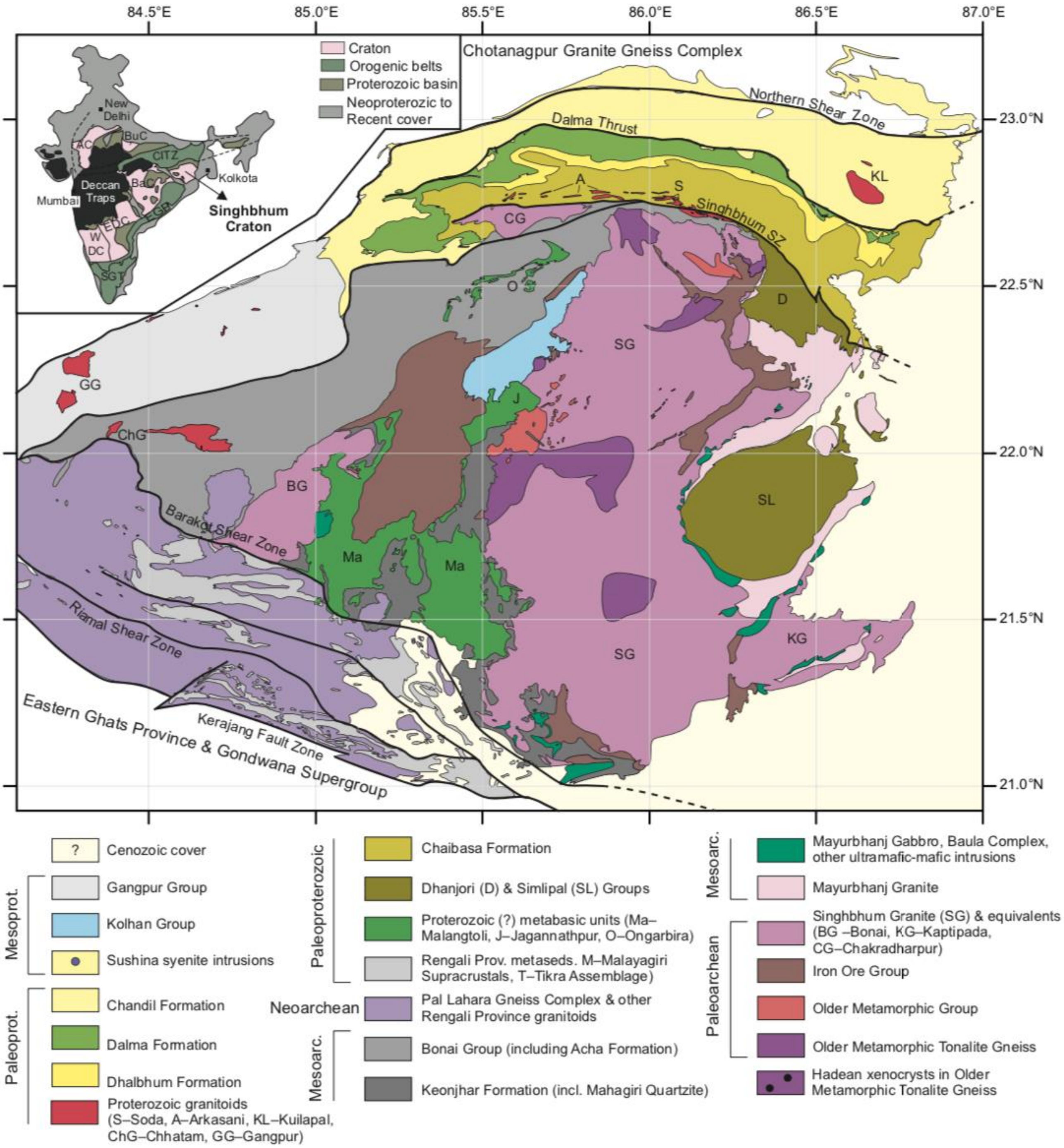

Figure 1: Geological map of the Singhbhum craton, eastern India (after Olierook et al., 2019).

The Dhanjori Formation unconformably overlies the Paleoarchean Singhbhum granitoid (Olierook et al., 2019) and is characterized by a thick terrestrial (alluvial fan-fluvial) volcano-sedimentary successions (Mazumder and Sarkar, 2004; Mazumder, 2005; Bhattacharya and Mahapatra, 2008; Mazumder et al., 2012b, 2015). The Dhanjori Formation is conformably overlain by the Singhbhum Group of rocks (Sarkar and Deb, 1971; Mukhopadhyay, 1976; Mazumder, 2005; Mazumder et al., 2012b).

The boundary between the Dhanjori Formation and the Singhbhum Group was originally interpreted as a tectonic thrust contact (Sarkar and Saha, 1962; Saha, 1994), but subsequent intensive studies by many researchers have disproved this interpretation (Mukhopadhyay, 1976; see Mazumder et al., 2012b and references therein; De et al., 2015).

The two-tiered Singhbhum Group of rocks are made of lower Chaibasa Formation (marine; Bhattacharya, 1991; Bose et al., 1997; Mazumder, 2005) and upper Dhalbhum Formation (terrestrial) (Mazumder, 2005; De et al., 2016 and references therein). Sedimentological and stratigraphic analysis of the Singhbhum Group of rocks reveals an unconformable relationship between the Chaibasa and Dhalbhum formations (Mazumder, 2005; De et al., 2016).

GEOCHRONOLOGY

The depositional ages of the Dhanjori Formation and the overlying Chaibasa Formation are poorly constrained (see Olierook et al., 2019 for a review; Fig. 2). The Dhanjori Formation unconformably overlies the ca. 3.28 Ga Singhbhum granitoid complex (Olierook et al., 2019). Sunilkumar et al. (1996) reported U-Th-Pb chemical ages of zircons separated from the conglomerate occurring at the base of the Dhanjori Formation. According to this preliminary study, the ages ranging from 3.04 to 3.09 represent the minimum age of provenance of Dhanjori sediments and the maximum age of the Dhanjori sedimentation (Sunilkumar et al., 1996). Roy et al. (2002) reported whole-rock Sm-Nd age of ca. 2.07 Ga from the upper Dhanjori basalt samples whereas Misra and Johnson (2005) reported a whole-rock Pb-Pb and Sm-Nd isochron age of ca. 2.85-2.79 Ga. from stratigraphically older basaltic rocks. Acharyya et al. (2010) speculated the depositional age of Dhanjori Formation between 2.6-2.1 Ga. Researchers pointed out the paucity of reliable geochronological data from the Dhanjori Formation and the necessity of reliable age data for the sake of stratigraphic correlation and temporal evaluation (Mazumder et al., 2019a; Olierook et al., 2019). Other volcano-sedimentary successions on the Singhbhum craton may be contemporaneous with the Dhanjori Formation (e.g. the Simlipal complex, Iyengar et al., 1981). The Malangtoli and Jagannathpur volcanic complex occurring to the south-western and western part of the craton may also be contemporaneous with the Dhanjori Formation (Singh et al., 2016, 2017).

Bhattacharya et al. (2014) reported a SHRIMP U–Pb zircon date of 1861±6 Ma from the syn- to post-kinematic Arkasani Granophyre that has intruded the SSZ. This age, according to these authors, represents minimum depositional age of the Chaibasa Formation (Bhattacharya et al., 2014). However, as Olierook et al. (2019) have pointed out, the deposition of the Chaibasa sediments might have ceased well before this time. The age of sedimentation of the deep to shallow marine siliciclastic Chaibasa Formation is lacking (Mazumder, 2005; Mazumder et al., 2015, 2019a).

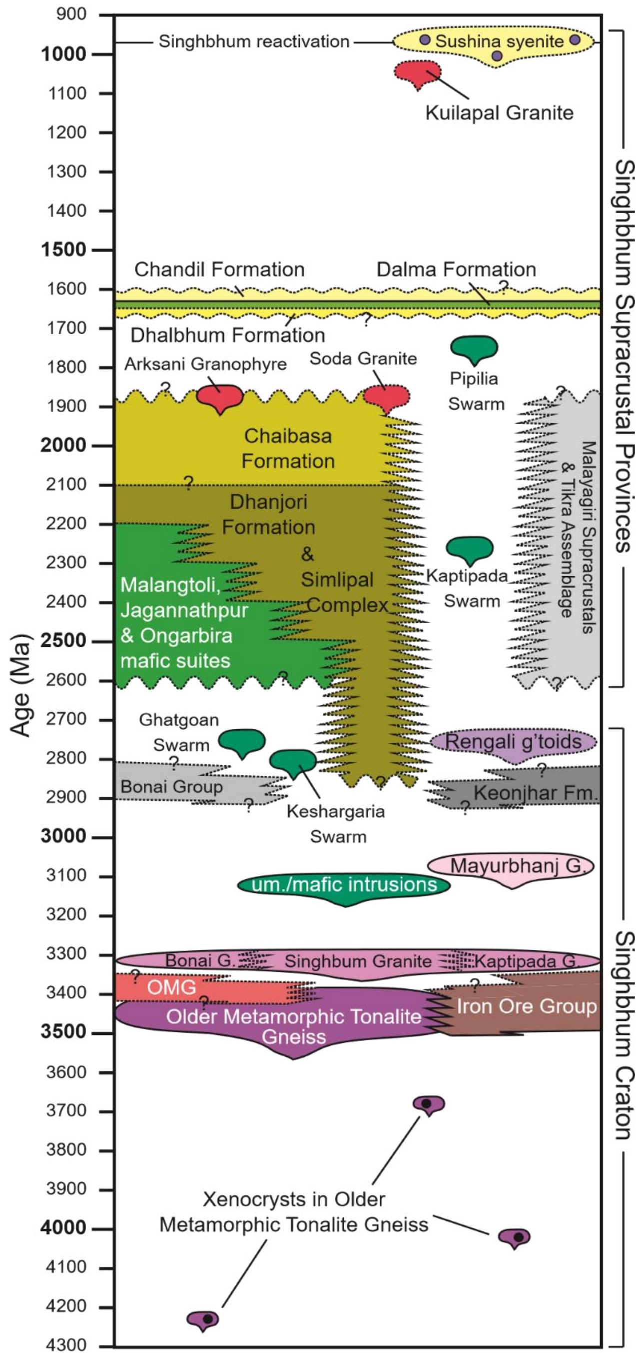

Figure 2: Generalized stratigraphic succession of the Singhbhum craton (after Olierook et al., 2019; see Olierook et al., 2019 for geochronological data).

SEDIMENTARY FACIES

Detailed sedimentary facies characteristics and mode of stratigraphic sequence building of the Dhanjori Formation has been examined by Mazumder and Sarkar (2004), Mazumder (2005) and Mazumder et al. (2015). Here we briefly describe the sedimentary facies characteristics of the Dhanjori Formation for the sake of brevity.

The Dhanjori Formation is made up of two members. The lower Dhanjori Member unconformably overlies the Archaean Singhbhum granitoid (Mazumder and Sarkar, 2004; Mazumder, 2005). It is made up of thin conglomerate, quartzite and phyllites. The conglomerates are clast supported, very poorly sorted and have very coarse-grained sandy matrix (Mazumder and Sarkar, 2004). The conglomerate is overlain by gritty quartzite (Fig. 3A) with trough cross-bedding at places and medium-grained sandstones. The lower Dhanjori Member is made of several fining up cycles (Mazumder and Sarkar, 2004, their fig. 2). The medium-grained sandstones are cross-bedded and is overlain by phyllite. In contrast, mafic volcanic (basalts; Fig. 3B) and volcaniclastic rocks along with some quartzites and phyllites are important components of the upper Dhanjori Member (Mazumder and Sarkar, 2004; Mazumder, 2005; Mazumder and Arima, 2009). The conglomerate–sandstone assemblage at the base of the lower Dhanjori has been interpreted as the distal fringe of an alluvial fan deposit (Mazumder and Sarkar, 2004; Mazumder, 2005). The upper Dhanjori Member represents fluvial channel and mass flow deposits. Geochemical data of the Dhanjori volcanic and volcaniclastic rocks indicates their generation in an extensional setting and the association of inter-banded terrestrial (alluvial fan-fluvial) deposits further constrain its origin in a continental rift setting (Mazumder and Sarkar, 2004; Mazumder, 2005; Mazumder and Arima, 2009).

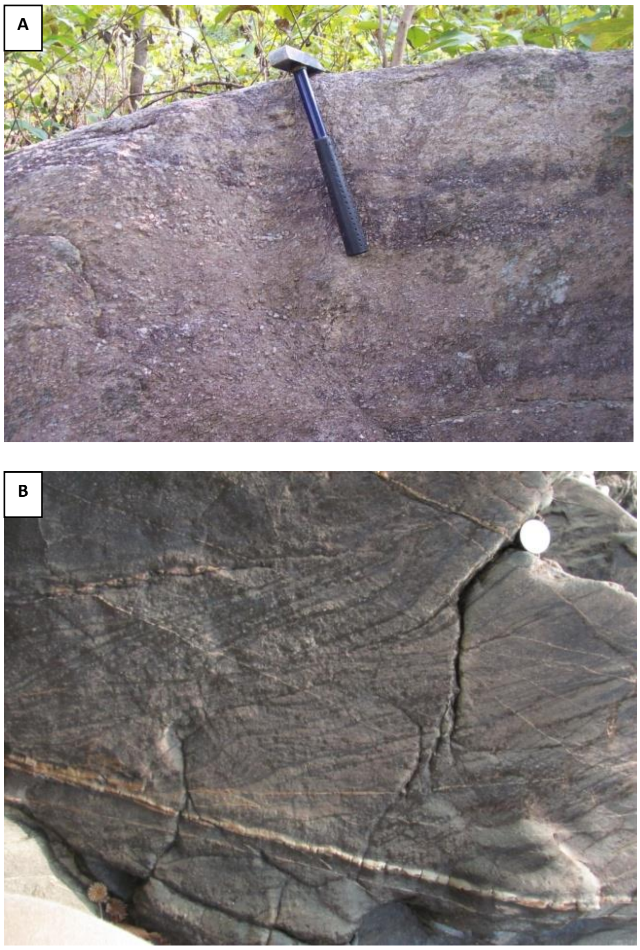

Figure 3: Dhanjori Formation:
(A) Gritty sandstone overlying the Dhanjori conglomerate, Rukmini Temple section, Jaduguda, Jharkhand, India.
(B) Flow banding in Dhanjori basalts, Sargachira village, south of Musabani, Jharkhand, India.

STRATIGRAPHIC STATUS

The stratigraphic relationship between the Dhanjori Formation and the two-tiered Singhbhum Group (the lower Chaibasa and upper Dhalbhum Formations, see Saha and Sarkar, 1962; Saha, 1994) has been a topic of intense debate (see Mazumder et al., 2012b for a synthesis). Late Prof. A.K. Saha and his associates strongly believed that the Chaibasa Formation of the Singhbhum Group of rocks have relatively higher metamorphic grade and are thrusted over the younger Dhanjori Formation (Saha, 1994 and references therein).

Sarkar and Deb (1971) and Mukhopadhyay (1976) suggested that the Dhanjori Formation is older among the two and the Chaibasa Formation of the Singhbhum Group conformably overlies the Dhanjori Formation. Several researchers speculated that the contact between the Dhanjori and Chaibasa formations is of tectonic nature and the Singhbhum Shear Zone separates the two formations (Saha, 1994 and references therein; Bhattacharya et al., 2014). However, Sunilkumar et al. (1996) have observed at the 555m level of crosscut of the Jaduguda uranium mine (N22°39´21″, E86°21´10″) that the Dhanjori metabasalts conformably passes through the uranium-bearing lodes to the schists and quartzites of the Chaibasa Formation of the Singhbhum Group. This observation supports the view of Mukhopadhyay (1976) that the Dhanjori-Chaibasa succession represents a normal stratigraphic order. Therefore, the contact between the Dhanjori and Chaibasa formations is not of tectonic origin as speculated by Saha and Sarkar (1962), Saha (1994) and Bhattacharya et al. (2014).

Bhattacharya et al. (2014) have reported a SHRIMP U–Pb zircon date of 1861±6 Ma for the Arkasani Granophyre. According to these authors, this age provides a minimum age for the shearing/thrusting along the Singhbhum Shear Zone and for the time of closure of the Chaibasa and Dhanjori sub-basins. It is possible that the youngest zircon populations were probably derived either from the Arkasani granophyre or Proterozoic granite plutons that have been subsequently eroded. The minimum age of the Dhanjori sedimentation is unknown. However, if the maximum age of Chaibasa sedimentation is around 1861 Ma, and the Dhanjoris are Neoarchean as suggested by Sunilkumar et al (1996), there is a huge (~800-1000 Ma) time gap between the Dhanjori and Chaibasa sedimentation.

This indicates a prolonged erosion and/or non-deposition between the Dhanjori and the Chaibasa sedimentation. However, detrital zircon data from the uppermost sedimentary successions of the Dhanjori Formation and the lowermost part of the Chaibasa Formation is required to estimate the time gap and thus to verify our hypothesis.

GEOLOGICAL IMPLICATION

U-Pb detrital zircon data from the basal Dhanjori conglomerate reported by Sunilkumar et al. (1996) indicates a Mesoarchean age for the Lower Dhanjori Member (Table 1). On the basis of (1) the occurrence of quartz pebble conglomerate at the basal part of the Dhanjori as well as the Iron Ore Group succession, and (2) the broadly similar heavy mineral characteristics of these two lithostratigraphic units, Sunilkumar et al. (1996) further suggested that the Dhanjori Formation and the Iron Ore Group successions are coeval. However, subsequent geochronological data clearly indicate that the Iron Ore Group successions in the eastern, western and Southern belt are of Paleoarchean age (Mukhopadhyay et al., 2008; Basu et al., 2008; Nelson et al., 2014; Adhikari and Valdamani, 2019; Chaudhuri, 2020; Mukhopadhya and Matin, 2020). It is interesting to note that the basal part of the eastern Iron Ore Group succession as well as the Dhanjori Formation are characterized by terrestrial (alluvial fan-fluvial) deposit (Mazumder et al., 2019b; Mazumder and Sarkar, 2004; Mazumder, 2005). Several conglomerate-sandstone facies associations of tentative Meso-Neoarchean age have been described by Van Loon et al. (2012) and Van Loon and De (2015) from areas to the south of the Singhbhum Shear Zone and further west of the type Dhanjori basin. Sedimentological analysis of these conglomerate-sandstone assemblage indicates that these are also alluvial fan-fluvial deposit like the Dhanjori Formation (Van Loon and De, 2015; see also Bhattacharya and Mahapatra, 2008).

A thorough U-Pb detrital zircon study and heavy mineral studies of these tentative Meso to Neoarchean terrestrial deposits will enable researchers to infer the provenance and their stratigraphic relationship with the Mesooarchean Dhanjori Formation.

Table. 1: Revised stratigraphic successions along the western margin of Singhbhum Craton.

Newer Dolerite dykes and sills		c. 2.80-1.76 Ga[9]
Kolhan Group		c. 1.16-1.00 Ga[8]
----------Unconformity----------		
Pallahara granite		c. 2.8 Ga [7]
Dhanjori/Achu/Bisrampur/Keonjhar Formation, Eastern siliciclastics		c. 3.0-2.8 Ga[5,6]
----------Unconformity----------		
Singhbhum Granite		c. 3.25-3.37 Ga[1, 4]
Upper shale		
BIF-chert-iron ore	Western Iron Ore Group	≥ c. 3.4 Ga[3]
Lower shale	Western Iron Ore Group	≥ c. 3.4 Ga[3]
Chert breccia-dolomite	Western Iron Ore Group	≥ c. 3.4 Ga[3]
Basal lava-tuff-quartzite-shale-QPC	Western Iron Ore Group	≥ c. 3.4 Ga[3]
Older Metamorphic Group		≥ c. 3.35 Ga[2]
Older Metamorphic Tonalitic Gneiss		c. 3.40-3.45 Ga[1]

Numbers refer to cited works for geochronological constraints. 1. Dey et al. (2017, 2018); 2. Nelson et al. (2014); 3. Basu et al. (2008); Mukhopadhyay and Matin (2020); 4. Chaudhuri et al. (2018); 5. Ghosh et al. (2015); 6. Sunilkumar et al., (1996); 7. Topno et al. (2018); 8. Mukhopadhyay et al., (2020); 9. Srivastava et al. (2018).

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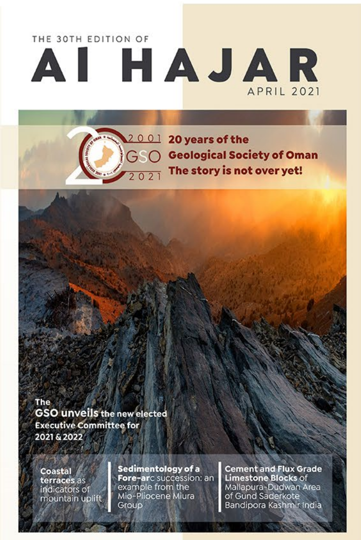
GSO Executive Election 2021 & 2022

16 JUN 2021

Arranged meet with the Imperial Barrels Award winners from Sultan Qaboos University



2 MAY 2021

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الجمعية الجيولوجية العمانية
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28 JUL 2021

GSO celebrated the 20th anniversary and launched the new GSO Logo

29 AUG 2021

Arranged the GSO Committee & Members Engagement's Session

20 SEP 2021

Arranged Arabic Talk about "the visit of Oman Caves Exploration Team to the Cave of Khusvit Fujit at Yemen"

31 AUG 2021

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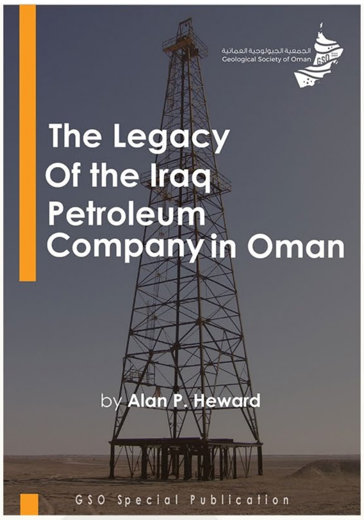

21 SEP 2021

Published the first GSO Special Publication about "The Legacy of the Iraq Petroleum Company in Oman"

27 OCT 2021

GSO Talk about "What Role Stands for the Geoscientist in ESG and Sustainability?" By Ms. Rumaitha Al Busaidi

3 NOV 2021

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30 OCT 2021

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GSO Talk about " International Reporting Cods for Exploration Results, Mineral and Resources and Reserves Definitions" By Mr. Samer Hmoud

PASSIVE SEISMIC MONITORING

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1. Sultan Qaboos University

1. WHAT IS PASSIVE SEISMIC MONITORING

Microseismic monitoring has recently seen a rapid expansion in its utilization for various industrial applications. Conventionally, microseismicity refers to an earthquake of magnitude less than 2.0. These are, therefore, events that can be detected using sensitive seismic instruments. In the oil industry, the technique is still growing. This method has great potential in the characterization and exploitation of unconventional resources existing in various parts of the world. The processing workflow in microseismic data analysis is quite similar to the well-established methods available in earthquake seismology.

2. OBJECTIVES OF PASSIVE SEISMIC MONITORING

Passive seismic monitoring aims to provide near real-time distributions of microseismic events location and their magnitudes in the reservoir units and the overlying layers related to fluid injection, hydraulic fracking and hydrocarbon production.

The geometry of events can be used to infer how pore pressure changes in response to injection and production activities. It may also indicate bypassed oil zones close to treatment wells through areas of low seismicity. Microseismic monitoring can help in the assessment of earthquake hazards and risks to surface and subsurface infrastructure. If events magnitudes exceed a certain threshold, the oilfield operator would temporarily cease the injection or fracking program until the seismicity drops below a threshold (e.g., zero and 2 Mw in the United Kingdom and Canada, respectively). After shutdown, the operator conducts a geomechanical assessment to understand the reason for large-magnitude events. Seismic retrofitting must be considered if events' magnitudes are frequently above the threshold. A critical success point in field development plans is integrating microseismic analysis with surface surveillance data (GPR, Optical leveling and InSAR measurements) to delineate reservoir characteristics dynamically through space and time. High seismicity zones well presumably show a positive correlation with steam injection areas.

Events show clustering parallel to maximum principal stress direction and microseismic cloud orientation indicate how fractures develop during hydraulic fracking. Rocks volume expansion due to steam injection should be localized within the reservoir zones with a minimum impact on the overlying seal layer, leading to caprock breach.

3. APPLICATIONS

Many industries use microseismic monitoring. The list below outlines some of its applications:

1. Mining industry for disaster prediction
2. Geothermal investigation for energy generation
3. Carbon capture storage to reduce greenhouse effect
4. Heavy oil reservoir monitoring
5. Underground tunnel construction
6. Reservoir dam monitoring
7. Nuclear waste storage
8. Wellbore stability

Microcosmic monitoring was successfully applied to numerous fields to gain critical information about their geological and structural properties. For example, Walters and Zoback (2013) monitored cyclic steam injection into a heavy oil field. The field experienced measurable surface deformation above the reservoir zone. The microseismic events were concentrated within the reservoir zones and were attributed to the reactivation of shallow faults. (Duhault et al., 2018) mapped microseismic events in a very tight clastic Cardium Halo play in Alberta with an average porosity as low as 2%. Their study highlighted methodologies to enhance oil production and increase the ultimate recovery.

Hydraulic fracture stimulation (HFS) has recently seen a rise in use, particularly in North America. Hydraulic fracturing is the main reason the USA has overtaken Saudi Arabia as the largest gas producer, and it will soon also be the largest oil exporter in the world. It is principally used to enhance fluid flow into production wells by increasing effective reservoir permeability.

It involves the fluid injection into the reservoir rock at high volumes and rates to create fractures. Proppant, usually a sand material, is added to the mixture to keep the fracture open during or after fracturing treatment. The mixture is created so that the proppants travel as far as possible into the induced fractures and clear the pathways for fluid flow into the production wellhead.

In recent years, due to an increase in hydraulic fracturing operations, especially in North America, there has been a growing fear from the public and media about the damage hydraulic fracturing can cause to the environment. Numerous studies correlate between hydraulic fracturing and different negative impacts such as contamination of groundwater and earthquakes happening at proximity to sites experiencing hydraulic fracturing Microseismic monitoring is useful for both regulators and operators. Regulatory measurements are set to manage the fracturing operation to mitigate any associated seismic risks. For instance, the traffic light regulation in which continuous monitoring of fracturing job is conducted and the operation is either stopped, amended, or continued based on a threshold magnitude.

4. METHODOLOGY

The validity and reliability of microseismic events are scrutinized based on how accurately the data are acquired and processed. Therefore, it is essential to understand how to acquire microseismic data and process them to enhance SNR and to achieve the desired deliverables.

4.1 MICROSEISMIC DATA ACQUISITION

Microseismic data acquisition can be made using different array configurations based on field development requirements, as well as operational, geological, and economic constraints. Ideally, a surface and downhole arrays configuration gives more accurate hypocentral location results (Figure 1).

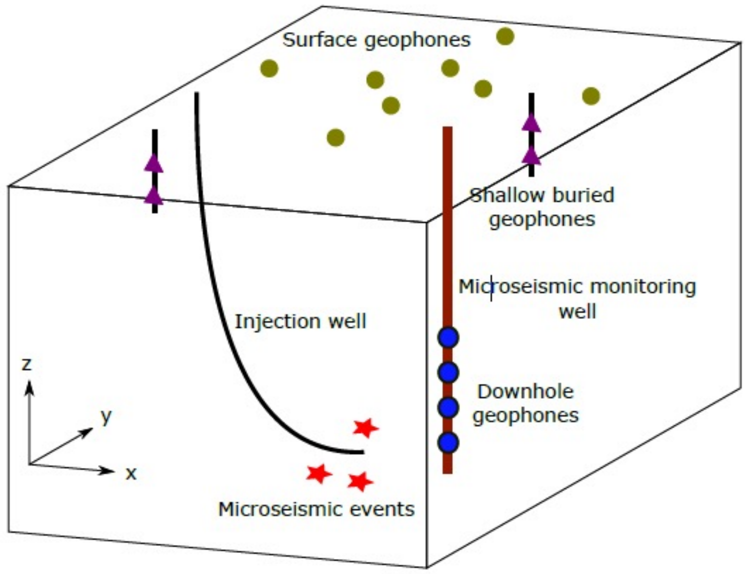

Figure 1: The figure shows three different microseismic array configurations. Downhole arrays are placed in a monitoring well close to the injection wells to detect as many events as possible.

Downhole geophone arrays usually have higher SNR than shallow geophones. However, they suffer from inherent 180± ambiguity in microseismic location when the events are detected by only one vertical well, as is usually the case in hydraulic fracturing jobs. They are also more expensive than shallow installations because of the requirement to drill monitoring wells.

Additionally, compared to surface arrays, deep arrays provide inadequate coverage of the radiated seismic waveforms from different directions (sampling of the focal sphere). Therefore, focal mechanism or moment tensor inversion techniques do not provide a unique solution with downhole arrays. Surface arrays can be deployed with hundreds of geophones at a lower cost than buried or downhole arrays. Surface arrays can potentially locate microseismic events using semblance stacking techniques without the need for first arrival picking because a large number of geophones are spread across the surface with a wide aperture.

Surface and near-surface arrays require static correction to eliminate the low-velocity effects of the unconsolidated surface layer and topographic variations. Downhole arrays are more sensitive to lateral velocity variation than surface arrays since the ray path has a higher horizontal component in their travel path. Hence, downhole arrays can better be suited to detect fracture-induced anisotropy. Figure 2 shows a record of a microseismic event from 3 downhole wells. First arrival energies of P and S-wave can only be detected in well 7.

4.2 PREPROCESSING MICROSEISMIC EVENTS

4.2.1 FILTERING

In this stage, the data is first filtered using various techniques to enhance SNR (e.g., Bandpass filter). Filtering must not be destructive to the true trace amplitude since amplitude data are used to derive additional information like source mechanism apart from the microseismic event location. Figure 3 shows two graphs. The left one is an original trace before filtering, whereas the right one is the same trace after applying the bandpass and notch filter.

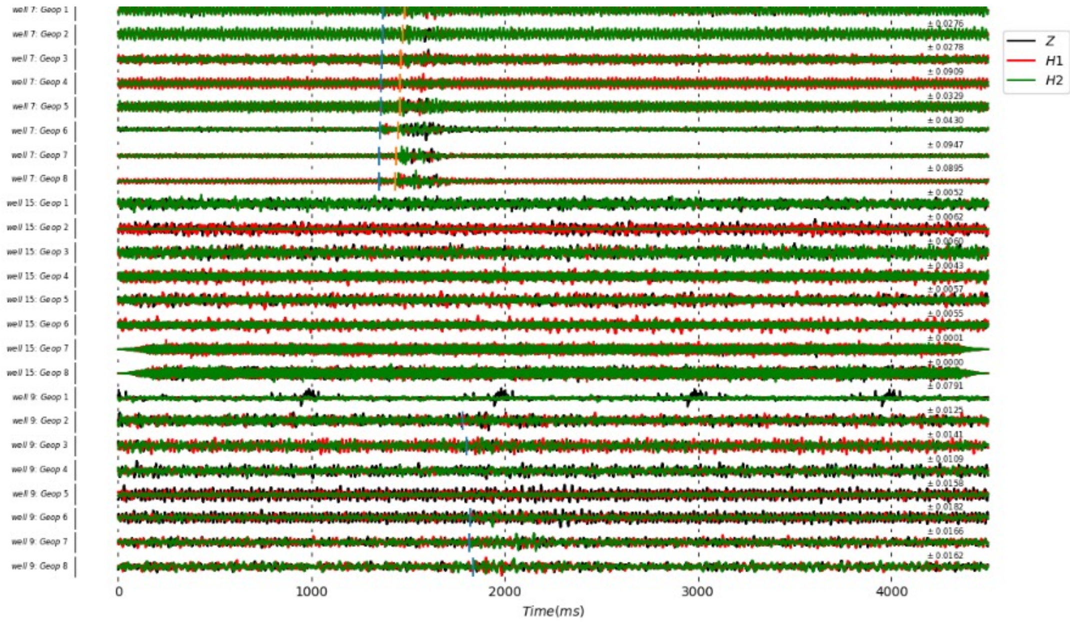

Figure 2: A record of a microseismic event by three different wells, each is having eight 3-component geophones

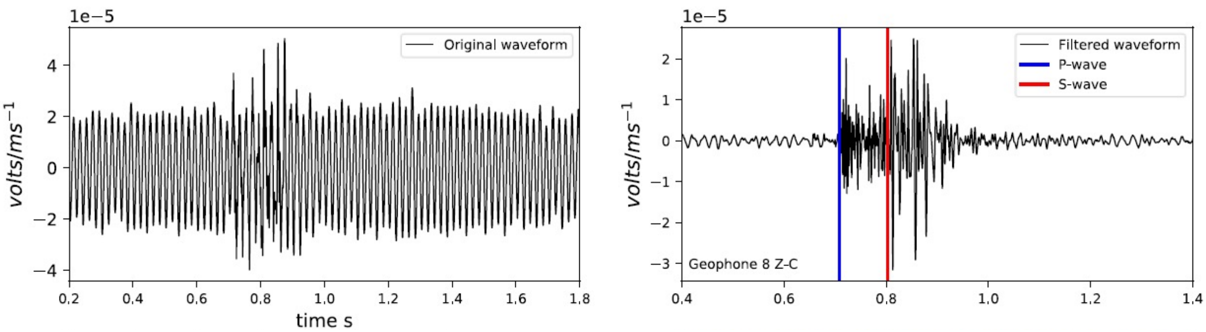

Figure 3: An example of a trace before (left) and after filtering (right).

4.2.2 SENSOR ORIENTATION DETERMINATION

When deploying geophones in a well, they can freely rotate. However, to locate events and to determine seismic phase arrival types, geophone orientation must be known. Orienting geophones can be performed using a controlled shot (a vibroseis). Figure 4 shows the orientation of a sensor from a gimbaled geophones in one microseismic well. Here, eight different vibrator shots are made, and the orientation from all shots must coincide for each sensor. For example, the accuracy of orientation at geophone 8 has high uncertainty.

4.2.3 FIRST ARRIVAL PICKING

Locating microseismic events requires knowledge of arrival time and the velocity model of the subsurface. Due to the large number of events usually recorded during microseismic monitoring, automatic method of picking are becoming more common. There are several methods of auto-picking and the method of STA/LTA ratio is a common one. The method calculates the ratio of the average amplitudes between short-term trailing windows and the long-term leading window. When this ratio is greater than a predefined value, an arrival-time will be determined (Figure 5).

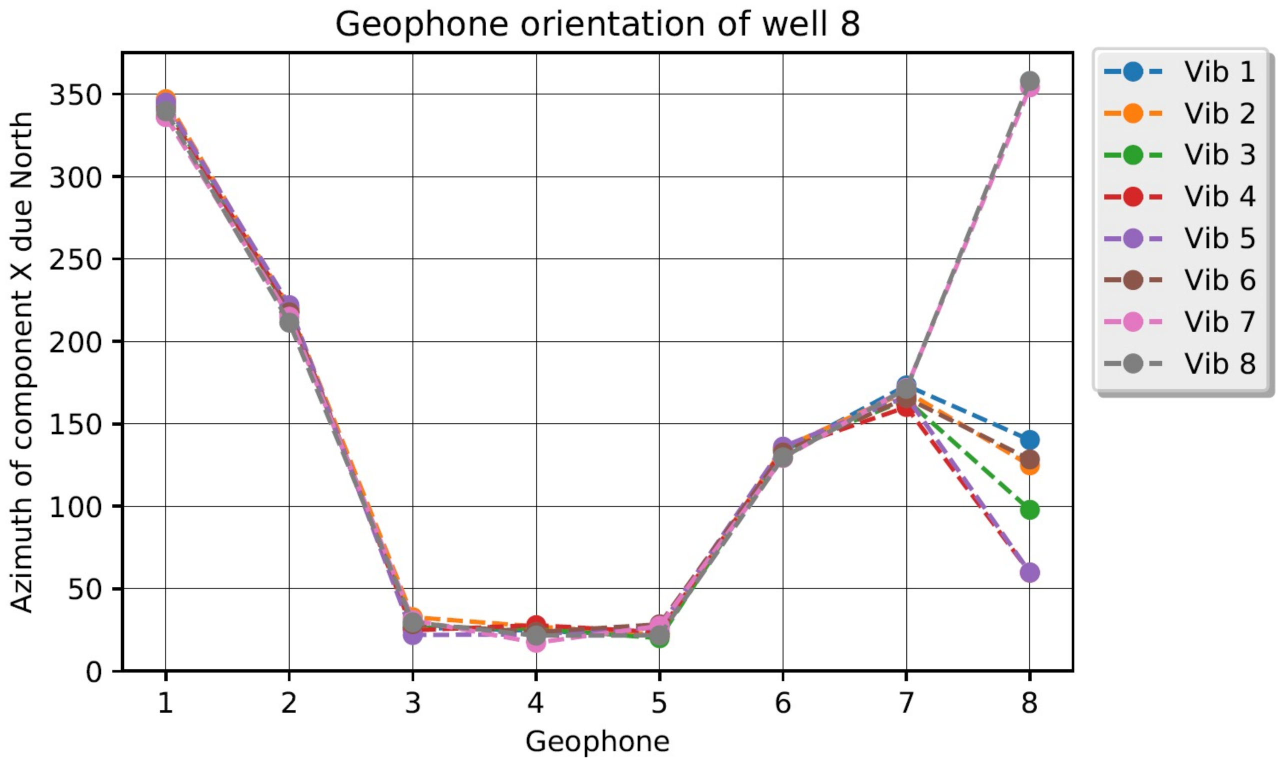

Figure 4: Orientation result at a well containing eight 3C gimbaled geophones.

4.2.4 VELOCITY MODELING

Building a velocity model of the subsurface is considered one of the most challenging tasks in microseismic monitoring. The usual inputs are either a calibration shot or sonic logs. The velocity model can be a 1D model for horizontally layered subsurface rock having no significant lateral velocity variation. However, for complex tectonic settings, 3D velocity model are the preferred choice. Figure 6 shows a 1D velocity model having four zones of variable thicknesses (right). The left chart of Figure 6 shows the travel times from a source (the red star in the left figure). P-wave (black) is ahead of S-wave (green).

4.2.5 LOCATING MICROSEISMIC EVENTS

Travel time and velocity models are used to determine the location of microseismic events. It is vital to access the uncertainty of location results and quantify location error for each event. Sometimes the location algorithm used affects greatly the accuracy of location results. It might be necessary to use a 3D velocity model and update both travel times and the velocity model in the inversion process.

Figure 7 shows microseismic events linearly clustered at right angle to minimum stress direction (James T Rutledge & Phillips, 2003; Jim T Rutledge et al., 2004)

5. INTERPRETATION

Microseismic interpretation is a broad term that encapsulates the analysis of the microseismic events' clusters to infer induced fracture network geometry, length, and width. It examines the creation of new faults or the reactivation of preexisting ones. Additionally, the interpretation can be expanded to analyze the microseismic source parameters such as magnitude, focal mechanism, stress drop, and fault radius. Downie et al., (2010) show that events' magnitudes can infer whether faults are contributing to the observed dimension of the microseismic cloud.

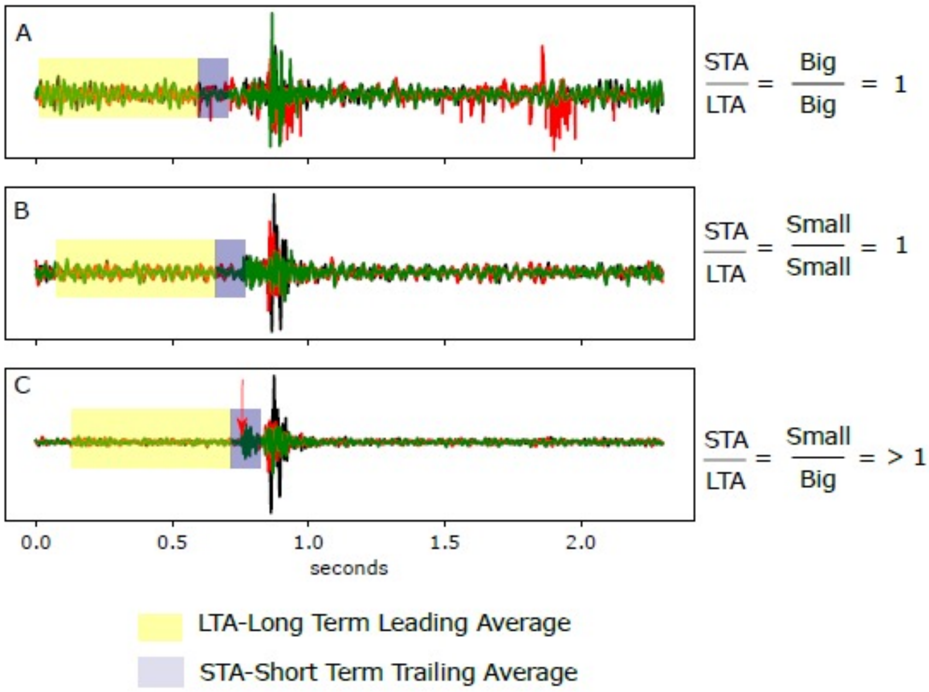

Figure 5: Illustration of the auto-picking method. The solid horizontal line is the zero-amplitude reference line. In this example, C triggers an arrival time

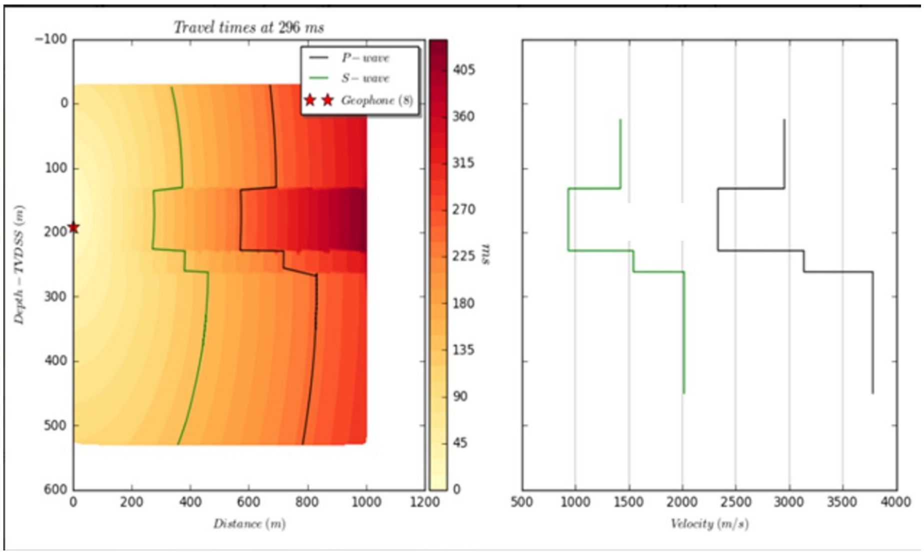

Figure 6: A 1D velocity model representing 4 layers of constant velocities (right). Travel time modeling (left) of P- and S-wave of the velocity model to the right.

They state that events' magnitudes can evaluate induced fracture behavior. Cipolla et al., (2011) state that microseismic analysis should not only be limited to hypocenter location investigation and source parameter analysis but preferably include geomechanical modeling and must be well integrated with the volumes of hydrocarbons produced and steam injected into the reservoir units.

Microseismic events cluster and surface seismic attributes such as inversion of seismic reflection data when combined can evaluate why seismic clouds concentrate at specific zones in the reservoir. Advanced techniques of shear wave splitting, and moment tensor inversion are nowadays common practice in most microseismic monitoring projects.

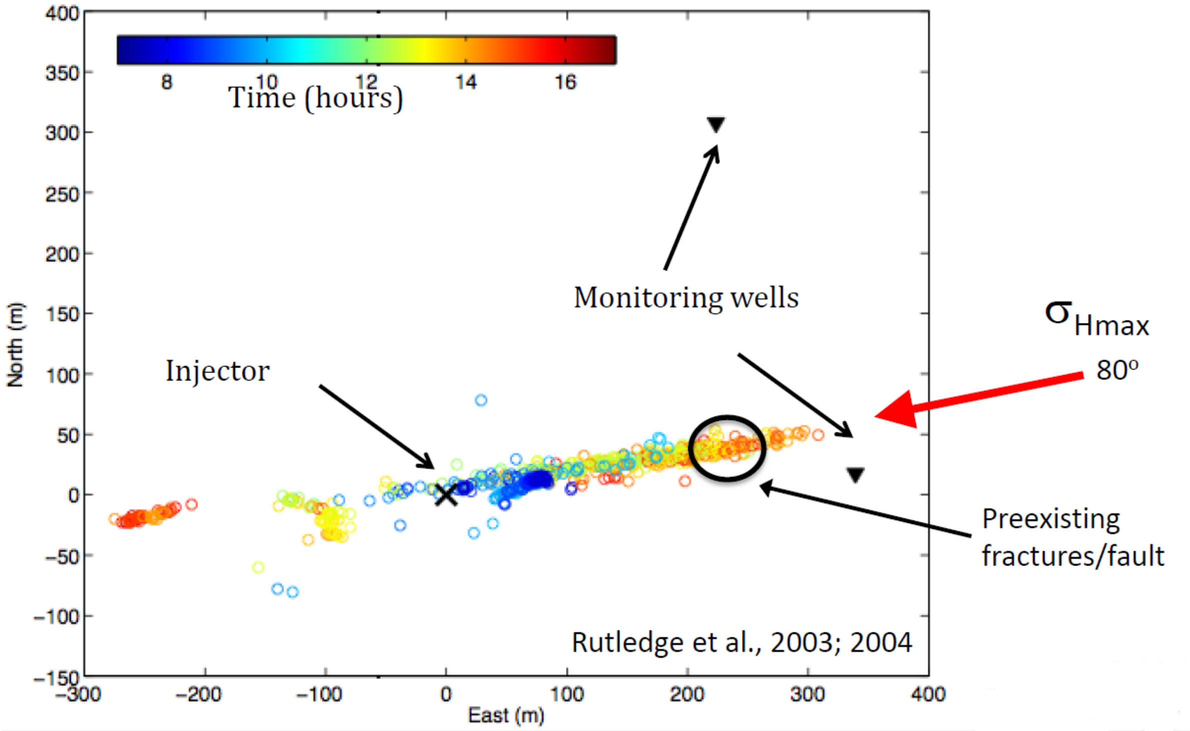

Figure 7 microseismic events linearly clustered at right angle to minimum stress direction (James T Rutledge & Phillips, 2003; Jim T Rutledge et al., 2004)

Shear wave splitting analysis can infer reservoir velocity anisotropy and determine fracture length and width (Al-Harrasi et al., 2011; De Meersman et al., 2009; Teanby et al., 2004). Verdon & Kendall, (2011) mapped multiple aligned fracture sets using shear wave splitting. Kendall et al., (2011) provide various potential applications of microseismic monitoring in the oil and gas industry of which this thesis focuses on:

1. Identifying induced faults or fractures orientation
2. Evaluating the stress direction
3. Integrating reservoir surface deformation with injection volumes and microseismic clouds
4. Assessing caprock integrity
5. Magnitude estimation and assessment to seismic hazard

6. MICROSEISMIC MONITORING PROGRAMS IN OMAN

Permanent microseismic monitoring campaigns in Oman started during the late 90s targeting oil development projects in various operating companies.

Some of these programs were still at that time in the pilot stage, and others were in the initial development phase.During the next decade, they proved very successful in achieving field development goals and delivering critical answers to confronted challenges in optimizing and maximizing hydrocarbon production. These projects provided geoscientists and engineers with the knowledge to make better decisions towards optimized field development plans. The technology has currently seen growth in utilization at different oilfields in Oman, ranging from shallow reservoirs (heavy oil) to deeply buried ones (tight rocks). In the north and central Oman, the targeted reservoir units are carbonate rocks, while in the south of Oman, they are clastic rocks. The development plans for these fields are water, steam, or chemical injections.Short period hydraulic fracturing jobs, however, started quite later in 2010. Their primary purpose is quite different from permanent monitoring.

They deliberately aim to break apart the rock to create fractures for oil and gas to flow easier into the production wells. The permanent microseismic monitoring targets deep gas fields. The reservoir types addressed by the hydraulic fracturing are mostly clastic tight rocks.

The permanent microseismic monitoring and hydraulic fracturing planning and execution involve first a feasibility study whereby numerical simulations are conducted to evaluate events' detectability and uncertainties. The next step is to prepare the surface arrays' layout or find suitable injection or production wells to be converted into microseismic monitoring well. Before starting the actual monitoring programs, the vibrator shots are acquired, if necessary, the sonic logs are prepared, and the noise level is measured. The typical challenges confronted in the planning phase are finding nearby monitoring well, harsh topography for surface arrays, and the high temperature of the reservoir rock, which could damage the sensors. High temperatures in the reservoir zone below 3500 m resulted in the failure of some monitoring projects in Oman. Noise is also a very crucial challenge since most fields are under continuous operations. The type of noises in these fields usually are drilling, injection, and surface civil noise. Several challenges are also present in the processing phase. For example, the reliability and the quality of vibrator and controlled perforation shots are sometimes poor for geophone orientation and velocity modeling, respectively. It is also relatively cumbersome to generate an accurate velocity model for highly complex structural reservoirs having heterogeneous facies proportions. The sonic logs are usually scarce and only limited to the reservoir zone, making the velocity model's quality questionable. Nowadays, the industry dedicates more attention toward integrating microseismic results with geologic, petrophysical, geomechanical, and active seismic data to bring engineering deliverables for better injection and production wells placement and field development and completion design.

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INTERNATIONAL NEWS

MIDDLE EAST

IRAQ

On 5 September 2021, it was announced that TotalEnergies SE had signed a 30-year USD 27 billion agreement with the Iraqi Ministry of Oil to co-operate on four energy-related projects in the country. The projects include the development of the Ratawi oil field (currently operated by Basra Oil Company) in Basra Province, the development of a 600 MMcfg/d hub at Ratwai which will capture and process associated gas from the Ratawi, Majnoon, Luhais, West Qurna and Tuba fields, known as the Gas Growth Integrated Project (GGIP).

TURKEY

Turkiye Petrolleri A.O. (TPAO) announced on 30 October 2021 that it has made 26 hydrocarbon discoveries during the first 10 months of 2021. It was reported that 60 MMboe of reserves have been discovered during the year, including the Sakarya North gas discovery in the Black Sea. Among the 26 onshore discoveries, 16 are located in the Zagros Fold Belt towards the southeast of the country, six discoveries towards the northwest of the country in Thrace Basin, three are located in the central part of the country and one towards the western part.

SAUDIA ARABIA & QATAR

Saudi Arabia has outlined its commitment to meet a net zero CO_2 emissions target by 2060, without diminishing its position as a leading producer of hydrocarbons.

Crown prince Mohammed bin Salman recently announced that the government intends to invest over USD 180 billion in climate initiatives during the forthcoming decade, whilst continuing to invest in oil, gas, and associated projects. It appears increasingly likely that unconventional gas developments will play a key role in the kingdom's plan to export 4 million tonnes a year (MMtpa) of hydrogen products by 2030.

The Minister of State for Energy Affairs, President and CEO of Qatar Petroleum (QP) HE Saad Al Kaabi held a press conference in October 2021 to announce the change of name and rebranding of his company to QatarEnergy (QE). He stated that the name change reflected a new corporate strategy that will focus upon energy efficiency and environment-friendly technology such as carbon dioxide (CO_2) sequestration.

UAE

Occidental Petroleum is appraising its first oil discovery within the Onshore Block 3 concession in Abu Dhabi. It made the 2020 discovery with only its second exploratory well within the block, shortly before completing an extensive 3D seismic acquisition campaign.

Sharjah National Oil Company and partner Eni intend to initiate the appraisal and development of the Mahani structure within the onshore Block B concession toward the end of 2021.

The co-venturers announced that their first wildcat had successfully tested gas and condensate in early 2020 and more recently awarded Saipem a USD 28 million contract to drill the back-to-back wells.

YEMEN

Octavia Energy acquired a 75% working interest in the onshore Damis Block S-1 from Petsec Energy in April 2021, intending to bring the An Nagyah oil field back onstream following an extended period of Force Majeure. The company is seeking government support to recommence field operations and restart production.

Gallo Oil has obtained approval for an extension of its onshore Al Armah Block 13 exploration license in the Jiza-Qamar Basin to May 2022. The concession is located within the Al Mahara Governorate, which extends up to the border with Oman.

Calvalley Petroleum has completed the first seismic survey to be acquired in Yemen since the evacuation of field crews in 2014. It completed the second tranche of 3D acquisition within its Malik Block 9 concession during June 2021 following the successful resumption of block production operations in March 2019.

OMAN

The Ministry of Energy and Minerals (MEM) announced through a social media release that it has launched the offering of three blocks in the Oman 2021 Licensing Round. The round, launched on 8 August 2021, comprises two onshore blocks (Block 38 and Block 66) in the west of the country and one offshore block (Block 23) in the east of Oman. The round was set to close on 30 November 2021 with bid submissions requested before 13:00 Oman local time; this has now been extended to 31 March 2022.

- Block 38 lies in the far southwest of the country on the Oman-Yemen border. The block covers an area of approximately 17,400 sq km and was previously 100% owned and operated by Frontier Resources Oman Ltd. It was relinquished in 2016 after Frontier failed to attract a farm-in partner for the block.

- Block 66 covers an area of approximately 4,900 sq km and was recently relinquished by MOL West Oman B.V. Ltd (MOL). MOL had planned to drill its third exploration well, Men'nah 1, in 2020 however the spud date was indefinitely delayed due to the COVID-2019 outbreak. Two previous exploration wells drilled by MOL in the block had been unsuccessful.

- Block 23 is a newly created block that has been carved out of the southern part of open Block 22; it lies to the east of offshore Block 50 which contains Masirah Oil's Yumna field.

EOG Resources Inc is understood to have completed drilling activity at its first exploration well in the onshore Block 36 (Fasad) license. The well is undersood to have been spud in late July 2021 and the rig is thought to have left the well site location on around 22 October 2021, moving to a second planned exploration well in Block 36; the second exploration well is thought to have been spudded around 23 October 2021.

In early November 2021, Tethys Oil Oman Onshore Ltd, a wholly owned subsidiary of Tethys Oil AB announced in its Q3 and nine months report for the period ending 30 September 2021, the company is close to commencing a 3D seismic acquisition campaign in the central area of the onshore Block 56 (Mudawrat), which straddles the Eastern Flank Sub-basin (Oman Basin) and the Oman Tertiary Basin; Tethys also plans to drill an exploration well in the block by the end of the year. The survey is expected to commence before the end of 2021. The company is also close to commencing a 3D seismic acquisition campaign in the central area of the onshore Block 58 (Qatbeet), in the Ghudun-Khasfah High Sub-basin (Oman Basin). The survey is expected to commence before the end of 2021.

CC Energy Development S.A.L. (Oman) Ltd (CCED) is thought to have completed activity at the Safi 1 exploration well, Huqf Arch (Oman Basin), in Block 04 (Ghunaim) licence. A press release in August 2021 by Tethys Oil, one of its partners in Block 04, reported that production testing was ongoing during Q2 2021.

Odin Energi A/S is understood to be looking for a partner in the onshore 1,390 sq km Block 15 (Jebel Aswad) licence. The farm-out offering is understood to have been announced in April 2021 by Holt Energy Advisors, appointed as advisor for the offering, with interests accepted from around June 2021. As of early October 2021, it is understood that some companies have shown interest in Block 15, data room reviews are underway; a deal is planned to be closed by the end of the year.

INDIAN SUB-CONTINENT

PAKISTAN

It was reported in mid-November 2021 that United Energy Pakistan (UEP) has discovered gas from the Mulaki West 1 exploratory well within the Khorewah ML onshore licence (Lower Indus Basin). The company had conducted testing and it is reported to have flowed gas from the 'Middle Sands' unit of the Cretaceous Lower Goru Formation. It was reported on 11 November 2021 UEP also has discovered gas and condensates in the Turk South 1 exploratory well within the same licence. The company had carried out testing in the 'Upper Sands' unit of Cretaceous Lower Goru Formation.

Pakistan Petroleum Ltd (PPL) reported in the 2020-21 annual report on 4 October 2021 that it is in the process of acquiring full interest and operatorship from Eni Pakistan Ltd in the Eastern Offshore Indus-C EL (Indus Delta) shallow water offshore exploration licence.

Eni is in the process of leaving the country - it had earlier signed an agreement with Prime International Oil & Gas Company on 9 March 2021 for selling most of its onshore oil and gas exploration and production assets in Pakistan and it is already relinquishing its remaining assets in the country.

INDIA

On 12 November 2021, Oil and Natural Gas Corporation Limited (ONGC) reported in its results for Q2 FY 2021-22, that it has made an oil and gas discovery in the South Velpuru 2 (SVLAB) exploration well within the Godavari Onland ML block (Krishna-Godavari Basin); the Indian financial year is from April to March. The company noted that the well had reached TD at a depth of 4,445 m. During testing, SVLAB flowed gas from three objects in the Golapalli Formation. It is also understood that an interval in the Tirupati Formation has flowed oil and gas.

In late October 2021, it was understood that Exxon Mobil Corporation (US) is looking to purchase stakes in some of the deepwater fields/assets of ONGC. Indian Petroleum Secretary Shri Tarun Kapoor noted at the 2021 India Energy Forum by CERAWeek, hosted by IHS Markit, that ExxonMobil is in discussion with ONGC to invest in ONGC's Indian east coast deepwater assets and has been evaluating the data.

The Indian Government, through its upstream regulator the Directorate General of Hydrocarbons (DGH) released the list of bidders who participated in the Open Acreage Licensing Programme Bid Round-VI (OALP-VI). The government had closed submission of bids for OALP-VI on 6 October 2021; bids were made by ONGC, Sun Petrochemicals Pvt. Ltd. (SunPetro) and Oil India Limited (OIL). On 6 August 2021, the DGH launched OALP-VI, offering 21 blocks with a total area of approximately 35,346 sq km, in 11 sedimentary basins. OALP-VI included 15 onshore blocks and six offshore blocks: four shallow water blocks and two ultra-deepwater blocks.

On 22 September 2021, the DGH launched a Special Coalbed Methane (CBM) Bid Round 2021, under OALP. The bid round is offering 15 onshore CBM blocks in four sedimentary basins. Category wise, all the four basins are under Category-III (prospective basins). The submission of bids on the DGH e-bidding portal will commence from 20 January 2022 and the deadline for submission of bids is 20 February 2022. The DGH announced that it has extended the bids submission deadline for the third bidding round of the Discovered Small Fields Bid Round (DSF-III), up to 31 January 2022. The DGH also noted that the submission of bids on the DSF e-bidding portal will commence from 15 December 2021. ONGC has launched its second bidding round, provisionally named as ONGC Marginal Nomination Fields (MNF) Bid Round 2021, under the Production Enhancement Contract (PEC) model. The company has released its Notice Inviting Offer (NIO) on 18 August 2021. It is understood from media reports that the company is offering 11 onshore contract areas, comprising its 43 small producing fields. These fields are believed to be from ONGC nomination fields, which were awarded by the Indian Government on a nomination basis, and are located in the onshore parts of Cambay, Krishna-Godavari, Cauvery and Assam Shelf basins. The deadline to submit bids for the PEC tender is 3 December 2021.

SAHARAN AFRICA

EGYPT

On 16 November 2021, EGAS announced the opening of the 2021 Limited Bid-Round for a unique block on offer, North King Mariut Offshore, in the western part of the Nile Delta Basin. North King Mariut extends between the North Marina and the West Nile Delta blocks in water depth between 500 and 2,100 m. It includes five discoveries found in Upper Miocene to Pliocene units. The closing date of this limited bid round is January 16, 2022.

On 27 October 2021, Eni reported the successful completion of the Meleiha Southwest 4 new-field wildcat in the Southwest Meleiha block, Northern Egypt Basin. The well, which encountered oil and gas from the Cenomanian Bahariya Formation. In late October 2021, Eni announced the successful drilling of Jasmin West 1, a new-field wildcat in the Meleiha (Dev) block, Northern Egypt Basin. The well encountered hydrocarbon pay in the Jurassic sandstones of the Khatatba formation. The production tests yielded a flow of light oil and associated gas, with good petrophysical properties.

In early October 2021, Chevron disclosed plans to farm-out its four offshore exploration acreages in Egypt. The company operates Narges, North Dabaa and North Sidi Barani in the Mediterranean waters and Block 1 in the Red Sea. Narges straddles the Nile Delta and Levantine basins. It includes Rose 1, a non-commercial gas discovery made by Eni in 2011 in the Pliocene Kafr El Sheikh Formation.

LIBYA

The Russian firm Tatneft is back to performing exploration drilling in Libya with the spudding of the B-002-082/4 appraisal on 15 September 2021 in Ghadames Basin. Tatneft already suspended this well in February 2011 due to the country geopolitical instability and lack of security. B-002-082/4 is targetting the Ouan Kasa Formation of Lower Devonian. The Area 082 (Block 4) block includes two discoveries made in 2009 and 2010.

In late 2021, Medco Energi Internasional Tbk (Medco) reported that it was still in the process of divesting its assets in Libya. The Indonesian firm will this way fully exit Libya with "no intention to continue to seek another opportunity in the country".

TUNISIA

On 8 November 2021 Eni spudded the Ambar 1 exploratory well in the Borj El Khadra block. Eni has drilled two other wells in the area before: Tiaret 1 which came up dry in 1981 and Siah El Touil 1 which had gas shows in 2008.

The gas shows were encountered in tight Ordovician sandstones. The objectives of the Ambar 1 well will likely be in the Acacus Formation and the Ordovician. On 1 April 2021, the Tunisian Directorate General of Hydrocarbons confirmed that Eni will leave Tunisia to concentrate on more profitable hydrocarbon exploration and production elsewhere like Egypt and Mozambique. The company's current contracts in Tunisia allow a sale of its interests to a third party provided it has a similar financial and technical level. So far, no company has applied for Eni's assets.

In February 2021 industry sources indicated that Entreprise Tunisienne dActivites Petrolieres (ETAP) is planning to drill the Chaal 2 exploration well in the Chaal block in the second half of 2021. This is a departure from earlier plans to re-enter and side track the Chaal 1 well. Additional geology and seismic studies during 2020 confirmed that the Bir Ali Ben Khalifa structure was the most prospective but that for optimal results it was better to drill from a new location. ETAP in October 2021, was promoting the country's open blocks that are available to companies for direct negotiations. The Department of Energy of Tunisia indicates that the bids relating to prospection and/or exploration permit granting should be submitted to the General Manager of Energy with the name and address of the tender. Bid opening and bid evaluation will be done during the fourth week following the considered quarter.

ALGERIA

On 2 November 2021 the Minister of Energy and Mines, Mohamed Arkab, presented before the finance commission of the parliament. He said that Algeria intended to drill 860 exploration wells in the period 2021 to 2025. This represents an average of 172 wells per year. This level of activity will be enabled by a new dynamic created following the activation of the new hydrocarbon law. Available data shows that the highest exploration drilling activity in the past five years was in 2017.

On 10 November 2021, Eni spudded the HDLE-1 exploration well in the Zemlet El Arbi block. In early October 2021 industry sources indicated that Eni plans further exploration drilling on the exploration acreage it holds in partnership with Sonatrach, namely the Sif Fatima II, Zemlet El Arbi and Ourhoud II blocks.

As of September 2021, available information suggests that by August 2021 the new hydrocarbon law became applicable with the last implementing rules being finalized. This opens the door to the launch of a bid round. On 13 September 2021, Sonatrach CEO Toufik Hakkar pointed out on local radio that there would be an exploration push in the southeast of the country in partnership with IOC's. This could be an indication of what will be offered in a coming bid round: exploration acreage in the Illizi and Berkine basins. So far nothing has been said about the timing of a bid round.

MOROCCO

According to an official press release on 11 October 2021, the Dakhla Atlantique reconnaissance licence received all the necessary approvals and was officially awarded to Ratio Petroleum Energy, through its subsidiary Ratio Gibraltar (Ratio), operating the contract with 75% WI with partner ONHYM 25% (carried). The 109,000 sq km block is located in the Aaiun-Tarfaya Basin in water depths of about 3,000 m, 300 km south of Boujdour city.

After announcing its plans to drill the Moulouya 4 prospect in July 2021, Predator Oil & Gas (Predator) reported in late September 2021 new drilling plans at Guercif Onshore licence, Guercif Basin. The Operator also disclosed three new prospects identified within the four blocks covering the licence: Moulouya 2, MOU-NE, and TR-1.

MAURITANIA

As of late October 2021, ExxonMobil's relinquishment of blocks C-14, C-17 and C-22 had become effective.

ExxonMobil will relinquish its Mauritanian exploration assets consisting of blocks C-14, C-17 and C-22. Blocks C-14, C-17 and C-22 cover around 38,000 sq km in the MSGBC Basin 200 km off the Mauritanian coast in water depths of 1,000 to 3,000 m. C-14 lies outboard of Kosmos C-13, it is undrilled. C-17 lies outboard of Total's former C-18 and C-9 blocks, it is undrilled. C-22 lies outboard of Total's former C-18, it contains the Flamant 1 well which was abandoned, dry, by Dana in 2006. The seismic surveys reportedly did not identify hydrocarbon prospects worth drilling, therefore the company decided to withdraw.

NIGER

Operator Savannah Energy Ltd (previously named Savannah Petroleum) is expected to resume drilling exploration wells in 2022, CEO Andrew Knott reported in late 2020. The British company intends to continue its exploration campaign after the "R3 East Project" goes on production, possibly in late 2021.

CHAD

Glencore plc (Glencore) is to sell Badila and Mangara fields in the Doba basin to Perenco. The news, reported on 4 November 2021, that Glencore reached an agreement with Perenco to sell its producing assets in Chad.

Savannah Energy plc (Savannah) makes progress to buy ExxonMobil's assets in Chad (Chari licence) and Cameroon (pipeline). In early October 2021, Savannah Energy's CEO, Andrew Knott, was in Chad to visit Esso Chad's (Esso) Komé production site given Savannah's acquisition of Esso's Chadian upstream and midstream assets. Mr Knott said in several interviews that, due to regulatory restrictions, he could not provide any more details on the transaction, but it seems clear that it is advancing in good terms, despite some disruptions caused by workers' protests at the site. Savannah already reported on 30 September 2021 that the advanced exclusive discussions were in progress with ExxonMobil's Chadian subsidiary, Esso Chad, to acquire the major's entire upstream and midstream asset portfolio in Chad.

SUDAN & SOUTH SUDAN

The Government of Sudan envisages a bid round. Industry sources indicated that as of September 2021, the Sudanese Ministry of Petroleum (MOP) was still planning a bid round that would include both onshore and offshore blocks. According to some sources, some companies would have already expressed their interest, but the administrative issues are delaying the launching of the bidding. As of late March 2021, it was understood that a bid round could be organized in the second half of 2021.

Industry sources reported in late October 2021 that Petronas, through its filial Petroliam Nasional Bhd, was planning to sell its South Sudanese assets and exit the country. Petronas is part of the Dar Petroleum Operating Co (DPOC) group, which operates Block 3 and Block 7 in Melut Basin. Petronas is also a partner in the Greater Pioneer Operating Co (GPOC), a consortium formed by the CNPC, ONGC and the state-owned company Nilepet. It operates the blocks Unity 1A, Unity 1B, Heglig 2A and Kaikang 4 in the Muglad Basin. The MOP is not aware of Petronas departing from South Sudan. Despite MOP's denial, it is worth remarking that last August 2020, the Managing Director of Nilepet, Chol Den Thon Abel, had announced that the state company would take over CNPC's assets in the DPOC group in 2027 when the contract expired. It was then understood that the takeover would include Petronas and the rest of the partners in the group. On 1 July 2021, Petronas reportedly said that the company would not participate in the 2021 bid round for exploration acreage due to challenging market conditions.

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