



AI HAJAR

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Geological Society of Oman

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President's message

Dear GSO Members,

It is a great pleasure to address you in this issue of Al Hajar on behalf of the new GSO executive committee. I would like to express my great appreciation to the previous committee members for their tremendous effort to make GSO a well-known society in the region. Despite the many publications and events that GSO has issued and organized in the past years, we still have many goals to achieve. Conservation of Oman's geological wonders is always a top priority. We have just completed a thorough proposal to protect the most important geological sites in the country and we will follow this up with the authorities to make it a reality.

GSO has also established communication with the Ministry of Education to revise the current geological syllabus and propose changes that might lead to additional focus on the geology of Oman in the school books. On the same line, Mr. Talal Al Ma'mary, GSO's representative for school's exhibitions, recently sat up the display tables and geological models in Al Sharqiya School Exhibition in the Wilayat of Ibra. We look forward to replicate this achievement in the other governorates.

Getting GSO's website alive again is certainly a fore-

most priority. Dr. Othman Al Harrasi is our new website champion. The committee has agreed on the main points we want the new updated website to include. We intend to make it more interactive and informative. The next months will hopefully reveal a more attractive website. We also look forward for a GSO page in the public newspapers including the Observer. Things are moving toward a monthly page that publicizes our activities as well as educating the public about Oman's geology. GSO is dedicated to continue organizing geological talks, fieldtrips and workshops. We already have four fieldtrips planned from Oct to Dec 2013, as well as two technical workshops about the clastic reservoirs and the structural setting of hydrocarbon fields in Oman.

My fellow members of the Geological Society of Oman: the new executive committee would like to kindly request your participation in achieving our aim and delivering our tasks, to continue the never ending success of the society.

Dr. Mohammed Al Kindi
GSO President



Note from the Editor

Welcome to the 19th Edition of Al Hajar. It has been more than a year since the last edition. This delay is mainly caused by the lack of submitted articles from our members. It is also related to the change of editors in the last few months. While expressing our apologies for this delay, we would like to emphasize the importance of keeping Al Hajar Newsletter alive. We are particularly keen to receive submissions related to technical, business and leisure geoscience topics. These could be for examples focused on:

- Geological sites from Oman and/or around the world.
- Profile of person or geological institute, centre etc...
- Review of geological publications (articles, books etc...).
- Review of GSO activities, talks and field trips.
- List of the latest publications on Oman Geology.
- Latest news from GSO's principal sponsors, Oman exploration and/or production news: business and technical.
- Latest news from the different contractors and operators.
- Youngsters corner: Overview, review and simple explanation of the Oman stratigraphy, geological concepts, methods and techniques.
- Calendar and/or events list of the GSO (talks and fieldtrips) and other affiliated institutes such as SQU, EAGE, AAPG....
- Geo Fun, Earth Quiz, Jokes & Cartoons..

In this edition we introduce the new GSO executive Committee (2013-2015) with biography. Also we are reviewing several field trips held by GSO: A journey in Wadi Daiqa and Wadi Al Sareen, Jabal Jaalan fieldtrip and GSO field trip to Dhofar.

Thanks to Simon Tull for submitting his paper "Petroleum Geology of the Ara Group, South Oman Salt Basin" which added a great value to this addition.

I hope you will enjoy reading this edition. As always, any comments about the newsletter or contributions of articles are most welcome.

Yousuf Al Sinani
GSO Editor



The GSO announced its new committee

As part of its democratic practice, the Geological Society of Oman (GSO) has announced its new committee for the period 2013-2017. The GSO was formed in year 2000 and formally established in the year 2001 under the Ministerial order 79/2001. The GSO is a nongovernmental organisation (NGO) which aims at gathering all geoscientists under one umbrella. Its main activities include fieldtrips to geological outcrops, geology-related talks, exhibitions, geo-tourism and some geological consultancy. Members of the GSO can benefit from the reduced rates on GSO-sponsored fieldtrips, publications and workshops. Students may join for free for the first year and reduced rates for subsequent years.

The Geological Society of Oman holds an election meeting every two years. The new committee consists of twelve members; the president, vice president, secretary, treasurer, editor of Al-Hajar newsletter, executive director, membership officer, and 4 committee members.



The new **GSO president** is Dr. Mohammed Al Kindi who graduated with a BSc in Physics and Geology from Aberdeen University in 2003. Mohammed obtained a PhD from Leeds University in structural geology in 2006, studying the structural evolution and fracture pattern of the Salakh Arch in the Oman Mountains and relating the surface observations to subsurface data. Since then, Mohammed has been working in Petroleum Development Oman first as a consultant in structural geology then as a senior production geologist. His main interests include the regional geology of Oman, tectonic evolution of the region and structural setting of hydrocarbon reservoirs. Mohammed has been part of the Geological Society of Oman committee since 2009. He joined the committee as an executive director from 2009 to 2012, then as a president in 2013.



The **vice president** Dr. Ibrahim Al-Ismaili Has 10 years experience in the oil and gas industry. He worked with PDO in both exploration department maturing gas plays and in production supporting drilling operations and modeling. Expertise includes seismic interpretation, geological modeling and geophysical surveillance. Ibrahim has worked as both geologist and geophysicist. Ibrahim has been part of the Geological Society of Oman committee since 2009. He joined the committee as a committee member from 2009 to 2012, then took the vice president role in 2013. Ibrahim is also a member of international geoscience and petroleum societies, e.g. SEG, SPE & EAGE.



The **secretary** Saif Al-Azri is graduated with bachelor's degree from the Sultan Qaboos University majoring in geophysics in 2010. Then he got a scholarship from the Petroleum Development Oman (PDO) to complete the MSc in the Curtin University of Technology in 2011. Since then, Saif has been working in the Reservoir Geophysics Team assisting exploration and development activities in PDO. In addition to tectonic evaluation of Oman he is also interested in the Basin development, Regional geology of Arabian Peninsula and sequence stratigraphy of the region.



The **treasurer** Salim Al-Shuaili graduated with a BSc in Geology from Sultan Qaboos University in 2006. He started his career with service companies with a total of six years experience as a Borehole Image Geologist. Then in September 2012 he moved to Petroleum Development Oman as Borehole Image focal point.



The GSO **editor** Yousuf Al Sinani has 12 years experience in the oil and gas industry. Graduated with bachelor's degree in Geology from Sultan Qaboos University in 2000. Subsequently he joined Reservoir Laboratories; Co. LLC as an Area Supervisor for 6 years. Then Yousuf join Petroleum Development Oman first as an operation geologist then as a senior production geologist. He has published various research pieces of research in rock stability of Muscat Area. Yousuf has been part of the Geological Society of Oman committee since 2006. He joined the committee as a GSO secretary from 2006 to 2008, then as a Treasurer from 2008 to 2013 and now as GSO editor. Yousuf is a member of the international Association of Sedimentologists (IAS), the Society of Core Analysts (SCA), American Association of Petroleum Geologist (AAPG) and The Society of Petroleum Engineers (SPE).



The **executive director** Dr. Mutasim Al-Ghammari graduated with BCs (Hons.) from Leeds University, UK in 2007. He obtained a PhD in Palynology in 2010 from Sheffield University, UK. Mutasim worked as Exploration stratigrapher in PDO in 2011, and a year later he took a new role in PDO's Study Centre as a Production Geologist.



The **Membership officer** Husam Al-Rawahi studied Earth Sciences in Sultan Qaboos University and Graduated in 2010. He worked for a short period in Target Oil Field services company and then moved to Development of Oman (PDO) to hold the position of a Sedimentologist in Geological services team. Husam is the Membership officer representative in the GSO committee.



The head of research subcommittee Dr. Issam Al-Barram joined GSO in 2002. Issam graduated with a BSc (Hons.) in Geology from Leeds University, UK in 2005. He then obtained his PhD from Sheffield University, UK in 2009. His PhD research was on investigating the palynofacies and palynology of the Carboniferous-Permian Al Khlata Formation. Issam is currently working as Exploration Stratigrapher in PDO.



The **research subcommittee member** Dr. Said Al-Bulushi is employed by Petroleum Development Oman (PDO) and currently works as an Exploration Geologist in the Conventional Oil Team. Prior to that (2010-2012) he worked as a Production Geologist in PDO's Study Centre (Reservoir Solutions and Consultancy Team). Said obtained his PhD in Basin Analysis and Petroleum Geoscience in 2010 from the University of Manchester (UK). His PhD research was aimed to understand the fundamental factors controlling lithofacies variability and organic-matter enrichment in the carbonate-dominated, fine-grained sediments of the Upper Cretaceous Natih-B Member, North Oman. Said received his MSc in Earth Sciences in 2005 from Sultan Qaboos University (with a research project focused on the "Infracambrian" carbonates of the Qarn Alam and Qarat Kibrit Salt Domes, Central Oman) and BSc in Resource and Applied Geology in 2002 from the University of Birmingham (UK). He is a member of the AAPG, EAGE, GSO (Committee Member since 2013), IAS, and SEPM. His particular areas of interest include carbonate petroleum systems, sedimentology of carbonates and organic matter, sequence stratigraphy, and reservoir characterisation. Said has participated in several international conferences and published two peer-reviewed papers related to his PhD research.



GSO's **Website champion** Dr. Othman Al-Harrasi received his BSc in Geophysics from Leeds University in 2007. He obtained a PhD from the University of Bristol in reservoir seismology, studying the micro-earthquake activities (microseismic) observed in a petroleum field in Oman and utilizing them for reservoir characterization. Othman has been working for Petroleum Development Oman as Production Seismologist and now working as QI geophysicist. His main interests are on rock physics, fractured reservoir characterization and the applications of microseismic monitoring.



The **committee member** Ali Al-Jardani is one of the founders of Target oilfield services LLC which is one of the leading Omani companies in its domains both locally and internationally. He currently holds the position of COO at Target Oilfield Services. He has more than 17 years experience as operations manager, geologist, modeling and software engineer with worldwide experience. He has substantial Middle East and Oman familiarity. Ali has managed and executed many projects in Oman and internationally.

A journey in Wadi Daiqa and Wadi Al Sareen (A Fieldtrip by Alan and Felicity Heward)

Written by Mohammed Al Kindi, Photos by Yousuf Al Sinani

Wadi Daiqa is one of the most spectacular Wadis in Oman. Its name has most likely been derived from the Arabic adjective (*dayiq*), which means narrow. The narrow gorge and steep flanks of the Eastern Al Hajar in Wadi Daiqa have promoted the establishment of the largest dam in the region with a capacity to store 100 million cubic metres of water and a catchment area of around 350 hectares. The lake formed by this dam will soon provide water to the Capital.

Over the last few years, Alan Heward has surveyed Wadi Daiqa and the nearby wadis and found a number of interesting geological features. He led two fieldtrips to the area in Oct 2008 and Jan 2009. Some of these features were covered by the newly formed lake of the dam. However Alan, managed to find similar features on the flanks of the mountain away from the lake. He actually also managed to find possible Al Khilata dropstones and Gharif petrified wood. Alan kindly accepted GSO's invitation to lead another fieldtrip to the area in Oct 2012. Only people adequately fit were allowed to join because the trip includes a walk of about 6kms, often up and down the mountain. We visited Wadi Daiqa in the first day and Wadi Al Sareen in the second day. The fieldtrip mostly focused on the outcrops of the Cambro-Ordovician Amdeh Formation.

The name 'Amdeh' was originally restricted by Lees (1928) to the thick succession of relatively undeformed quartzites that crop out in the south-west and west of the Saih Hatat. However, Glennie et al. (1974) changed the definition to include the Hatat Metamorphics. Recently the Hatat Metamorphics have been raised to Formation status (Hatat Formation) and have been shown to be the oldest rocks outcropping in the Saih Hatat (eg. Le Métour et al., 1986). The Amdeh Formation unconformably overlies the dolomites of the Precambrian Hijam Formation (Huqf Supergroup) and is unconformably overlain by a thick succession of limestones, clastics and volcanics of the Permian Saiq Formation. The Amdeh Formation is largely contemporaneous with the upper part of the Haima Supergroup, however direct correlation with the Haima is currently not possible. Amdeh Formation can be subdivided into five informally defined members, first proposed by Lovelock et al. (1981) and slightly modified by the BRGM mapping of the area (eg. Le Métour et al., 1986).. The formation is divided to five members, from Amdeh 1 (base) to Amdeh 5 (top).

Although the nature of the material from which the dates have been derived lacks high resolution, the earliest Amdeh specimens are at least contemporaneous with the oldest occurrence of *Sacabambaspis* (known also from Australia and South America). The sediments of the Amdeh Formation represent shallow water deposition, within a mixed Skolithos-Cruziana ichnofacies containing trace fossils of both suspension- and deposit-feeding tracemakers (e.g. *Cruziana* and *Daedalus*). and, in association with the trilobites *Neseuretus* and *Ogyginus*, the bivalved mollusc *Redonia*, crinoid remains and orthoconic nautiloids, are indicative of nearshore conditions. The fragments of "*Sacabambaspis*" in wadi Daiqa are the oldest known group of vertebrates with extensive biomineralisation of the dermoskeleton. Their presence in Oman greatly extend the palaeogeographical distribution of the clade around the periGondwanan margin.



Fragment (headshield) of Sacabambaspis, Ordovician Fish, from Wadi Daiqa



A fragment of trilobite



Cruziana trace fossils on the bottoms of sandstone beds. Cruziana are the burrowing / sediment feeding traces of trilobites and a common in the Amdeh 3 and 4/5 in intervals where there are thin interbeds of sand and shale. They are again indicators of relatively shallow marine shelfal environments



A closer view of one of the beds with sparse Skolithos burrows from top to bottom of the ~1 m thick bed. Skolithos is a relatively shallow marine shelfal trace of a suspension feeding organism. Are they escape burrows during emplacement of the sand bed or just homes to suspension feeders? The traces in the Amdeh are often horizontally ridged and frequently rotated into any deformational cleavage present. Skolithos is limited to the M Shales and U Qtzts of Lovelock et al. (Am3 and 4).



Wave Ripples in Amdeh Formation again indicating shallow marine environment



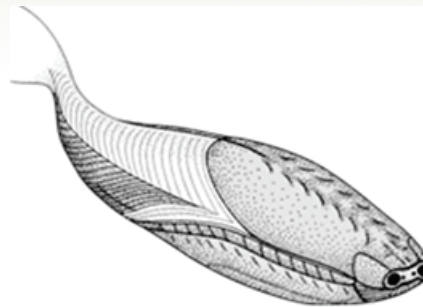
Daduelus trace fossils.



Nodular orthocone (orthoconic nautiloid) carbonate in Am4/5 wadi Daiqa.



Some ancient drawings of possibly the Arabian Al Tahr from Wadi Al Sareen natural reserve in Saih Hatat.



A reconstruction of the Sacabambaspis fish

After a long walk of more than 5km in quest to find the Ordovician Fish, Sacabambaspis, it was nice to use the recent fish in the lake of the Daiqa Dam for fish massage. It must be said that the Ordovician fish looked actually even bigger than the recent ones in this lake.



A group photo from the first day.



Alan teaching us how to sniff the Ordovician Fish.



A group photo from the second day.



Petroleum Geology of the Ara Group, South Oman Salt Basin Simon Tull, Petroleum Development Oman

(Paper submitted to Al Hajar Journal, June 2012)

Introduction

The Ara Group is of late Pre-Cambrian to early Cambrian age (548 to 536 Myr) and occurs widely in the subsurface of the Sultanate of Oman. Partial equivalents of the Ara Group can be found at outcrop in the Huqf area of east Oman and at Al Jabal Al Akhdar in the north (Bowring et al., 2007; Forbes et al., 2010). The Ara is equivalent to the Hormuz Series of Iran and Pakistan; together the Ara and Hormuz form a major salt province of crucial importance to the structural development and hydrocarbon potential of the region.

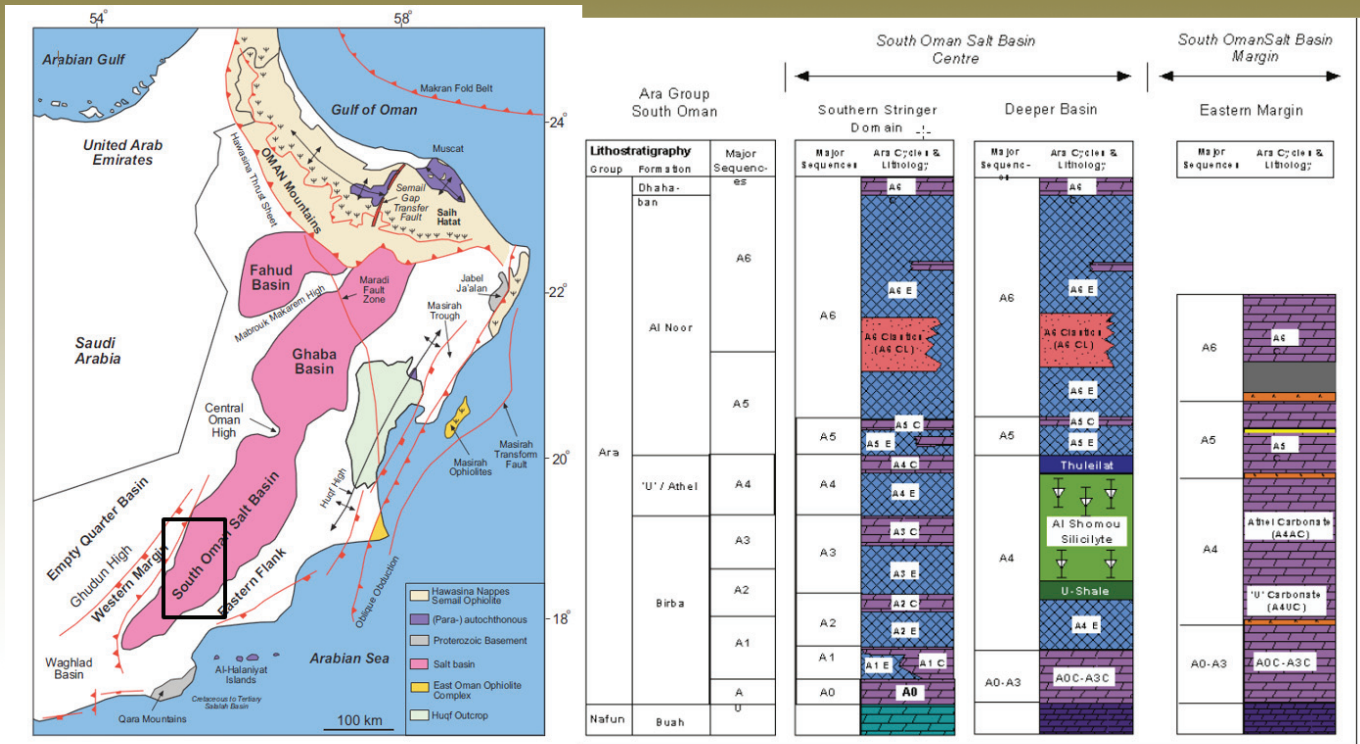
Hydrocarbons were first discovered in the Ara Group of the South Oman Salt Basin (SOSB) in the 1970s. An accelerated phase of exploration and appraisal since the late 1990s has resulted in the discovery of significant volumes of oil and gas, and the Ara now forms an important part of Oman's hydrocarbon portfolio (Al Siyabi, 2005).

This paper provides an introduction to the petroleum geology of the Ara Group, focusing in particular on the reservoirs and the influences that depositional setting, diagenesis and structural evolution have had on their development.

Tectonostratigraphy

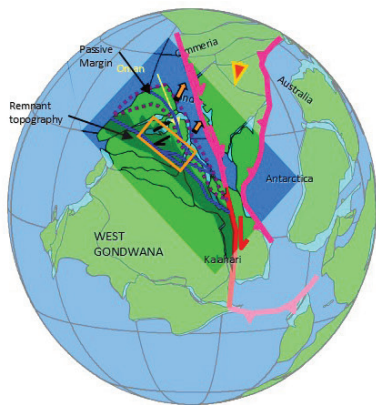
The Ara Group of the SOSB consists of an alternating series of carbonates and evaporites(1) . Six such cycles have been recognized in the subsurface, the carbonate parts of the cycles are referred to as the A2C, A3C and so on, and the evaporite parts of the cycles are referred to as the A2E and A3E etc (Figure 1). The Ara was deposited in a series of tectonically active, transpressional basins associated with the suturing of east and west Gondwana during the Malagasy Orogeny (Stuart-Smith & Romine, 2003; Figure 2). The transition from a passive to active margin setting imparts a strong structural control on the development of the Ara, with areas of deeper and shallower water developing over evolving tilted basement blocks (Figure 3). Climate is inferred to have been warm and arid, with the evaporites representing periods of marine isolation during phases of relative marine lowstand. In contrast with other carbonate-evaporite systems such as the Zechstein Basin of NW Europe (Tucker, 1991), where lowstand evaporites form basin-centred wedges, the Ara evaporites onlap the intervening carbonates and must have been deposited during phases of rapid tectonic subsidence. The carbonates are thought to have been deposited under relatively normal marine conditions. Platform geometries are varied; a long term addition of accommodation space on which smaller-scale cyclicity is superimposed resulted in back-stepping of successively younger platforms which thus become more areally restricted and increasingly dominated by relatively fine-grained, deeper water depositional facies. There is also an upward increase in clastic content through the Ara, as a collisional belt developed to the west and sediment was shed into the basin. Ara deposition was eventually terminated as the basin was flooded by clastics of the Nimr Group. Eventually, continuing uplift resulted in an unconformity that separates the Ara and Nimr clastics from sandstones and conglomerates of the Haima Group. Structural deformation and sediment loading by the Haima clastics resulted in large scale halokinesis of the Ara Salt (Figure 3). The more brittle slabs (or "stringers") of carbonate were deformed along with the salt, and in many cases are strongly folded and faulted.

(1)The U Shale, Thuleilat Shale and intervening Athel Silicyte (chert) are basinal equivalents of the Ara platformal carbonates shown on Figure 1 are important both as reservoirs and source rocks but are not the focus of this paper

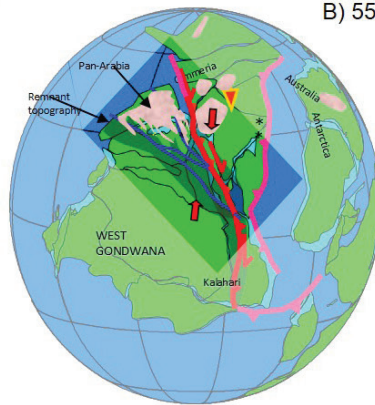


After Al-Siyabi 2003

Figure 1

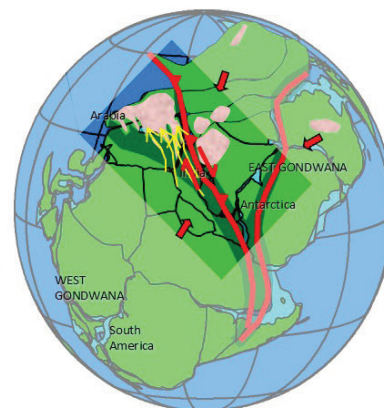


A) 630-550 Ma, Oman Passive Margin. Passive margin conditions in Oman, setting the scene for development of the Ara basins



B) 550-540 Ma, Early Malagasy Orogeny, Formation of salt basins

C) 540-510 Ma Late Malagasy Orogeny, Salt mobilization by depositional loading results followed by uplift and deformation of the Ara Group



After Stuart-Smith & Romine 2003

Figure 2

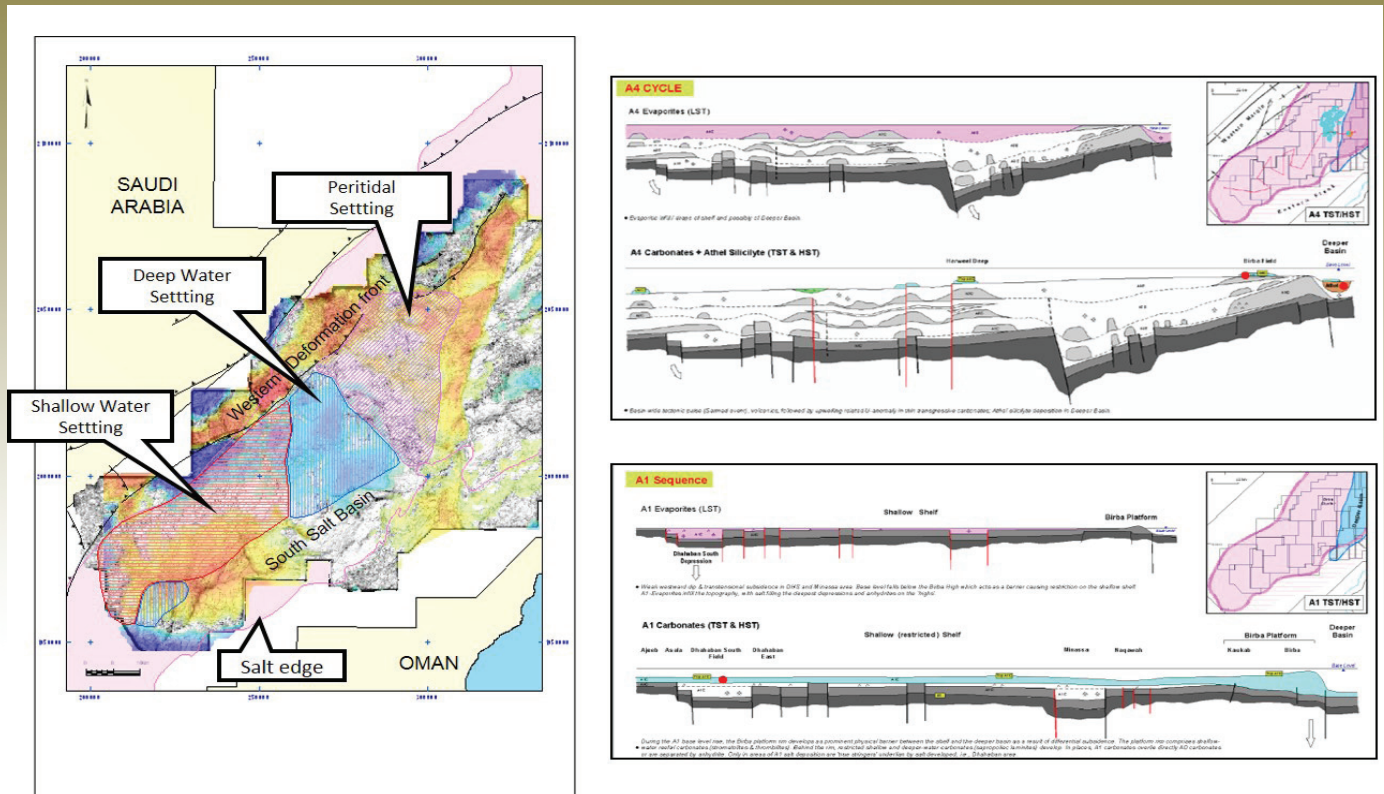


Figure 3

The Ara Play

The Ara Play consists of a "self-contained" combination of source (carbonate mudstones?), seal (evaporites) and reservoir rocks (limestones and dolomites?). Since the carbonates are entirely enclosed in salt and since halokinesis pre-dated hydrocarbon expulsion (maximum burial temperatures were achieved during deposition of the Cambrian-Silurian Haima Group) it is believed that the stringer reservoirs were largely self-sourcing. However, very few potential source rocks have been identified within the stringers and an "exterior" source rock contribution from - for example - the sub-salt Nafun Group, is considered a possibility (Kowalewski et al., 2009). Whichever is the case, geochemical studies suggest that these source rocks contain sulphur-rich kerogens of marine planktonic origin. These have generated mainly volatile oils (average API 38°, viscosity 0.87 cP) and gas which are characterized by large amounts of acid contaminants (average H₂S 4%, CO₂ 6.5%).

As implied above, the hydrocarbons in the carbonate stringers are stratigraphically (only stratigraphic or also structural traps?) trapped by their enclosing evaporites. Deformation is such that the stringers commonly have structural reliefs of several hundreds of metres. Hydrocarbon column heights appear to be limited by the effectiveness of hydrocarbon generation and expulsion, and traps are typically only 50-70% filled. Because they are sealed by evaporites, the stringer reservoirs are commonly over-pressured. However, grounding of the Haima clastics (Angudan unconformity) against the sub-salt sequence means that some? sub-salt reservoirs (the A1C in Figure 2) are hydrostatically pressured. Similarly, where the A2E salt is thin or absent, the A2C stringer reservoirs may also be hydrostatically pressured. To complicate matters further, the stringer reservoirs are variably over-pressured suggesting that some have been affected by fluid leakage.

The reservoirs themselves consist of a wide variety of variably dolomitized microbial (thrombolitic, stromatolitic) boundstones, peloidal packstones-grainstones and mudstones. Although these depositional facies are common to all of the stringers, there are significant differences between the reservoirs with respect to the proportions in which they occur and with respect to their vertical and areal lateral organization. The sub-salt A1C reservoirs are different again, particularly with regard to platform geometry and the presence of facies indicative of supratidal deposition and subaerial exposure - these are notably absent from the stringer reservoirs.

The remaining part of this paper focuses on the differences between the intra-salt stringer reservoirs and the sub-salt reservoirs and the key factors controlling reservoir development - depositional facies, diagenesis and structural deformation.

Reservoir Development

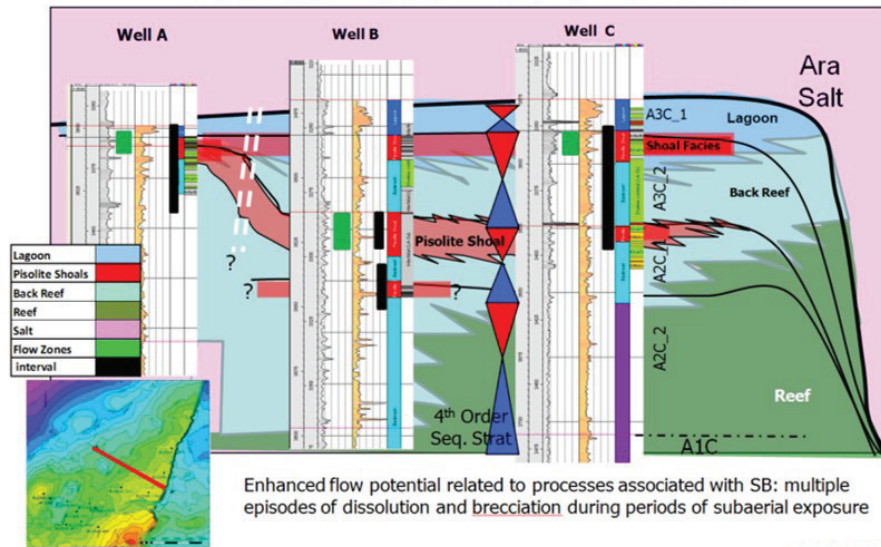
Sub-salt reservoirs

The sub-salt A0C-A1C interval of the Birba Formation consists of a 400 m thick carbonate platform succession that overlies laterally continuous carbonates of the Buah Formation (Figures 1 and 3). The basal A0C unit consists of shales and volcanic ash beds overlain by carbonates, marking the onset of active tectonic conditions as the underlying Buah platform broke up. Subsequently, the Birba Formation shelf edge (A1C on Figure 1) developed as a prominent physical barrier between the shelf and deeper basin. Behind the shelf edge, periodic marine isolation resulted in the deposition of alternating carbonates and evaporites. In proximal settings, the evaporitic intervals are represented by unconformities, marked by very shallow water / emergent depositional facies that include calcretes, tepee structures and pisolitic grainstones (Figure 4). Production logging suggests that these form high permeability (Darcy scale) pathways that dominate flow. Early porosity creation/enhancement may be associated with the infiltration of meteoric waters, probably during subaerial exposure, resulting in dissolution of grains, matrix and cements. However, petrographic data indicates that the majority of secondary vuggy macroporosity was created through the dissolution of dolomite, anhydrite and silica which is thought to be related to a later dissolution phase associated with the migration of corrosive burial fluids - possibly in advance of hydrocarbon charge. Although this modified the earlier pore system, it appears not to have fundamentally changed the relationship between cycle top facies and high flow capacity.

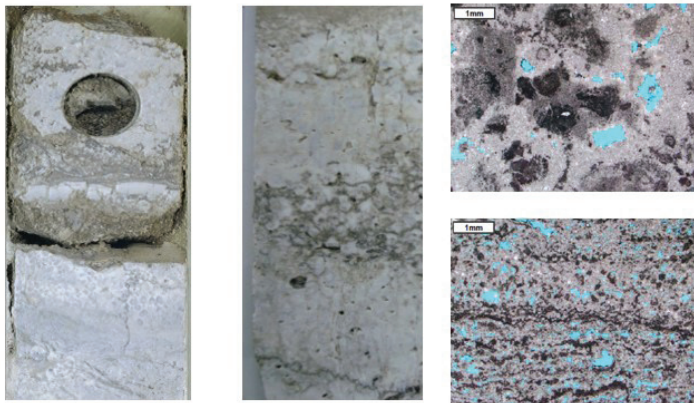
Matrix and vuggy permeability is enhanced by the development of open fractures. FMI-scale and core-scale fractures are mainly electrically conductive and, in contrast with most fractures within the stringer reservoirs, do not appear to be mineralized. These fractures, along with the vugs, appear to play a significant role in explaining the observation that well test permeabilities are substantially higher than those suggested by core data. Although the majority of well tests suggest "matrix" behaviour (i.e. fractures provide a boost to matrix permeability), dual porosity behaviour indicative of a more significant fracture system has also been observed.

The presence in the A1C of a high permeability vuggy-fractured pore system associated with emergent cycle top facies is in marked contrast to the intrasalt stringer reservoirs where such features are absent. The other significant difference between the two is that the A1C has a large attached edge aquifer which provides natural pressure support; the preferred development option for the sub-salt play is thus by natural waterflood.

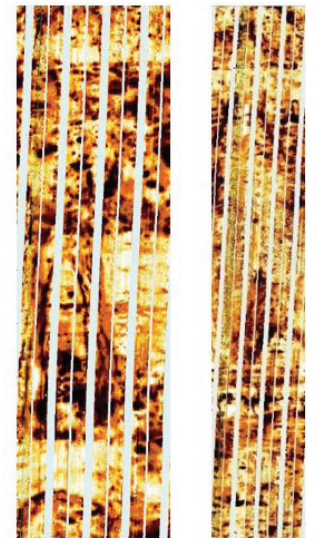
A Basal Ara Carbonate (BAC) shelf Margin depositional concept



B



C



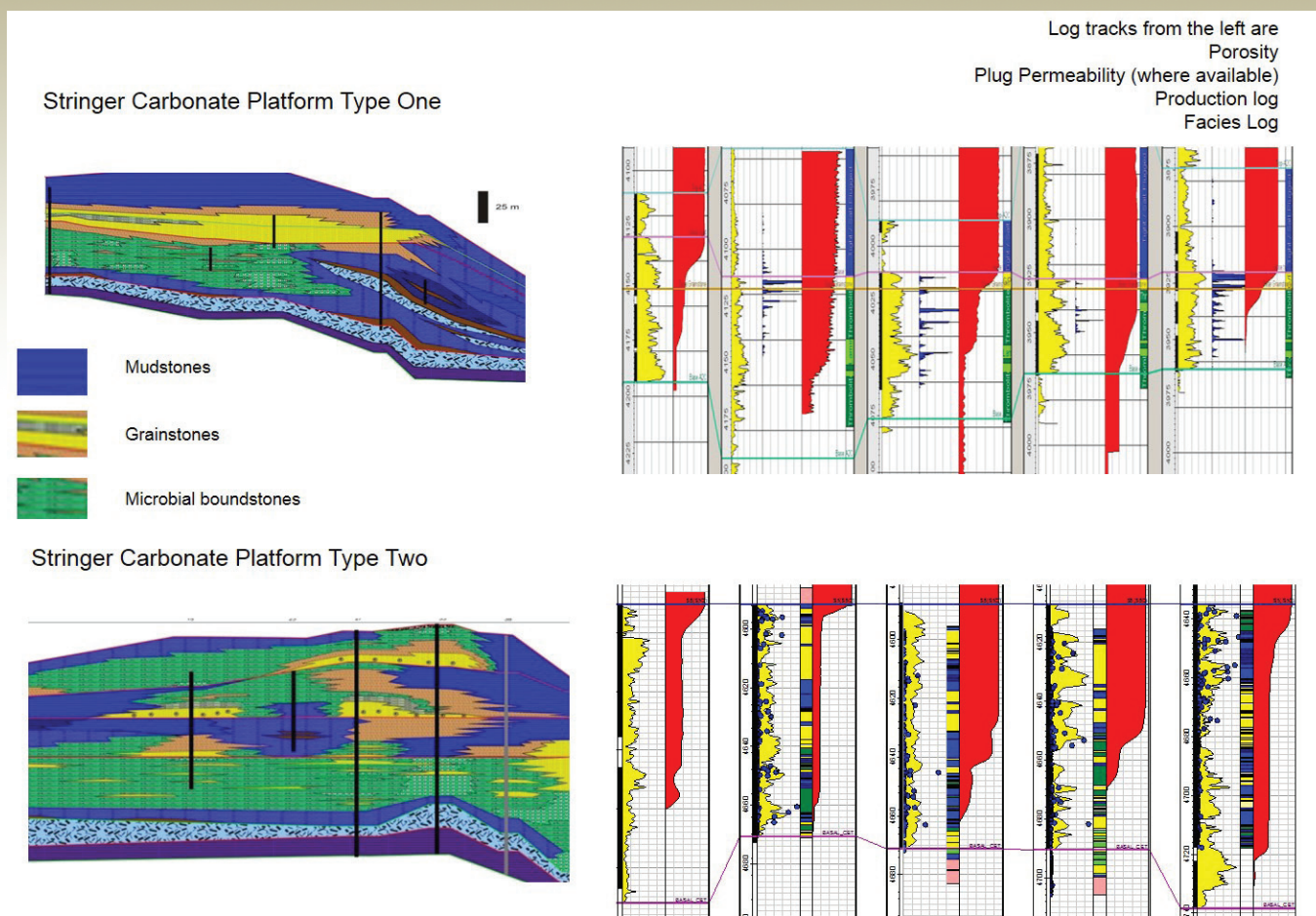
After Amthor et al., 2012

Figure 4

Intra-salt stringer reservoirs

Two of the most important intrasalt stringer platform types, amongst the many that have been identified, are illustrated in Figure 5. Platform Type One is characterized by an upward transition from laterally continuous transgressive mudstones, through a microbial bank complex capped by peloidal grainstones and packstones into mudstone facies. This succession is directly reflected in porosity and permeability data, which show that the microbial and grainstone complexes have the best reservoir quality; thus the mudstones, which have very low porosities, show little or no contribution on production logs. The same pattern is observed consistently in wells which are many hundreds of metres apart. Platform Type Two has a similar upward transition from mudstones into a microbial bank complex, but the upper part of platform is much more variable, and grainstone, microbial and mudstone facies bodies much more difficult to trace from well to well. The result is illustrated by production logs which again shown inflow from grainstone and microbial units - but these are now developed towards the reservoir base, at the top, in the middle, or some combination thereof.

It was noted above that younger platforms tend to have a higher proportion of deeper water, fine-grained facies than older platforms. This is illustrated in Figure 6 for an A2C and an overlying A3C reservoir from a single field in South Oman. The A2C platform has a major contribution from microbial and grainstone facies, whereas the A3C is dominated by muddier facies. The impact is illustrated by plug permeability data for the two reservoirs. Whereas the A2C shows maximum permeabilities in the Darcy range, maximum values in the A3C are only a few tens of milliDarcies.



After Grotzinger 2003

Figure 5

Diagenesis has had a major impact on reservoir quality in the stringer reservoirs, as it has the sub-salt reservoirs. Dolomitization and leaching of primary pores are major controls on reservoir quality. In particular, the best reservoir quality appears to be where early diagenetic coarse, euhedral dolomite crystals have preserved or enhanced primary fabrics in the microbial and grainstone facies. Later diagenetic phases, which include dolomite, calcite, anhydrite, halite and bitumen are porosity destructive. The water legs of many of the stringer reservoirs show evidence of reservoir quality degradation, due to preferential cementation and bitumen plugging.

In contrast with the subsalt reservoirs, there is no enhancement in rock quality due to fracturing in the intra-salt reservoirs. Indeed, almost all fractures seen on borehole image logs and in core are filled with salt. Well test and pressure data suggest that many seismic-scale faults are permeability baffles. In extreme cases, where multiple faults sets cross-cut each other, the reservoirs may be compartmentalized.

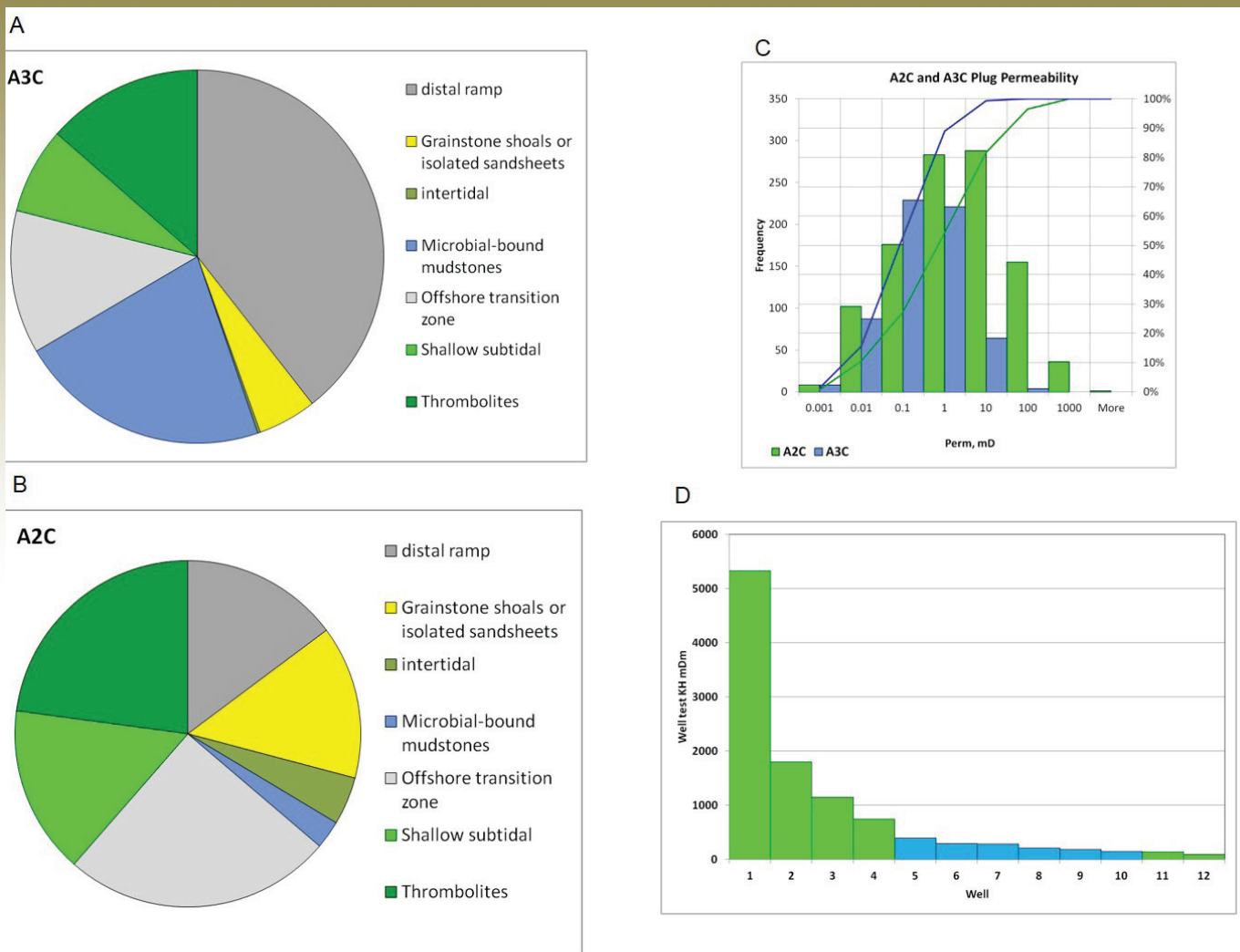


Figure 6

Because they are enclosed in salt, and because water leg porosities and permeabilities are poor, the stringer reservoirs lack aquifer pressure support. For this reason, and to substantially increase recovery beyond that provided by natural depletion, the stringer reservoirs are being developed by water-flood and by gas-flood. Vertical contrasts in permeability (controlled by facies and diagenesis) and areal heterogeneities (controlled, for example, by baffling or sealing faults) are key geological factors influencing the efficiency of these secondary recovery methods.

Summary

The Ara Group consists of an alternating sequence of evaporites and carbonates. Their deposition and subsequent deformation is linked to development in an active tectonic setting related to the assembly of the Gondwana supercontinent at the transition from the PreCambrian to Cambrian. The Ara contains two types of reservoir. Sub-salt platform carbonates contain cycle-capping vuggy-fractured layers which create high permeability pathways. These are developed at a number of levels throughout the reservoir and are expected to create an efficient sweep pattern for water encroaching from a large edge aquifer. In contrast, intra-salt stringer reservoirs lack natural aquifer support and are being developed by secondary recovery methods where sweep is influenced by vertical and areal heterogeneities that result from the interaction of deposi-

tional facies, diagenesis and faults. As well as influencing reservoir development, the salt layers associated with the carbonates act as seals, and have had a major control on subsurface pressures, temperatures and reservoir fluid chemistry.

Acknowledgments

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Jabal Ja'alan Trip

By Abdulrahman Al Harthy

In an attempt to increase awareness of some of the least known stratigraphic intervals in Oman GSO has organized a trip to the Palaeogene deposits of Jabal Ja'alan area, south of Sur. The focus was mainly on the late Palaeocene Abat Formation and the Eocene Musawa Formation. The trip leaders were Abdulrahman Al-Harthy and Ali Al-Rajhi who was unable to join the trip because of arrival of new baby during the same period. Ali has recently finished his PhD on the upper member of Musawa Formation.

The first stop was dedicated to look at the resedimented carbonates of Abat Formation. Several repetitive beds of planktonic-rich wackestone alternate with shale that are gradually changing to coarser-grained resedimented carbonate stacked on top of each other. Laterally possible contemporaneous gully-fills can be seen. An interesting type of algae known as Peyssonnelid is also hosted in these rocks. This represents part of the margin of an extensive epeiric carbonate platform that dominated the Arabian Peninsula during late Palaeocene to Early Eocene which deposited the famous Um Er Radhuma Formation. Participants were enthusiastic to climb these outcrops and explore more about their facies.

The participants then examined the gradual transition

of facies from planktonic wackestone and shales to foraminiferal packstones and grainstones and the shutting down of the carbonate factory and influx of siliclastics of the Musawa Formation with its fining upward cycles of fluvial sandstones capped by palaeosols.

Participants stayed at Al-Dhabi Guesthouse in Jaalan Bani Bu Ali. The second morning was dedicated to examine the lower and upper parts of the upper member of the Musawa Formation. The participants were excited to see the fluviodeltaic conglomerate bar showing fining upward cycles above which dense rootlets horizon was a testimonial of bar top stabilization by vegetation during the late Eocene time.

As hot climate is approaching slowly by the end of March almost any small water pond would dry rapidly. However, with the exceptional rains that took place recently acidic pools were still challenging evaporation from the continuously increasing temperature. Here participants walked the coarsening upward cycles developed due to mouth bar sedimentation in front of the prograding delta that was making its way northwards (towards Sur). Textbook example of coarsening upward cycles that are separated by coal seams of different grades were examined. Since the basin was not deeply buried the coal are sub-bituminous grade with high sulfur content.



Neoproterozoic glacial deposits and basement outcrops in Mirbat Plain, the Dhofar Mountains

By Othman Al Harrasi

The Geological Society of Oman organized a scientific journey to the mountains of Dhofar Governorate in the period from 24 to 26 of October 2013. The trip was under the sponsorship of Oman Air. Oman Air provided return tickets from Muscat to Salalah for all participants in the trip, totaling 22 people.

The trip aimed to explore the geological formations in the province of Dhofar and revealed some of the mystery about the origin and age of some of the types of rocks in the area. The trip was led by David Alsop a geological expert working in Petroleum Development Oman and Dr. Mohamed Al Kindi president of the Geological Society of Oman. A group of geological scientists participated in the trip including scientists from petroleum companies, the department of Earth Sciences in Sultan Qaboos University and the German University of Technology in Oman. On the first day of the trip, participants visited the Wilayat of Mirbat to study the components of the glacial sedimentary rocks that date back to more than 700 million years ago and therefore these are the oldest types of sedimentary rocks in the Sultanate. The participants studied the nature and characteristics of cracks and crevasses in the area and tried to explain how they formed. The deposition of these rocks occurred during ice age, which passed by earth in the distant past.

On the second day of the journey, participants went to the area of Hadbeen in the Wilayat of Sadahto study the forms of semi-oval of rocks found on the beach and tried to explain methods of erosion which led to the formation of rocks in this manner. In the immediate vicinity of Had been, participants also studied volcanic dikes, igneous rocks and metamor-



Sponsored by Oman Air

phic units as well as the types of minerals found in the region. After that, the team visited the sinkhole of Tawi Atair, one of the largest sinkhole in the world which was formed possibly after the collapse of pre-existing cave's roof.

At the end of the trip participants visited the Museum of the Frankincense Land to know the history of the province and the wealth of diverse civilizational heritage.

It is worth mentioning that the Geological Society of Oman is one of the first professional association established in the Sultanate. It aims to preserve the heritage and diversity of geological uniqueness of the Sultanate and educate the community of the importance of preservation and its role in enriching tourism, known as geotourism. The Geological Society of Oman has been involved in many projects and studies about Oman geology and it provides geological consulting to the ministries and institutions. It has a large base of members, numbered nearly a thousand members in the past year. The members' list includes geological experts, researchers, students and those interested in Oman's geology.



Group photo of participants in the fieldtrip in front of a boulder formed of glacial sediments in Mirbat. These glacial sedimentary rocks, known as diamictite, are dated back to more than 700 million years in the period when the Earth was probably completely or partially covered with ice.



Members of the Geological Society of Oman discussing the depositions of glaciers and how these deposits in the province of Dhofar can only be seen in few places in the world



Scratches caused by glacial ice sheets that carved in the rock bed below



Discussion of igneous rocks in Hadbeen, the Wilayat of Sadah, which stand out on the surface of one of the most beautiful beaches in the Sultanate



Igneous rocks on the shore of Hadbeen appear on fantastic forms and represents an attraction for many types of bird life on the shores



Volcanic dikes and metamorphic and igneous rocks that formed during the accretion of the Arabian Plate



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