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President's Address

Dear GSO Members,

On behalf of the GSO Executive Committee I welcome you to the 2009-2010 GSO activity season; already we have started the seminars and field trips and look forward to more of both through the winter.

In addition, by year end GSO will have completed the documentary film entitled 'Geology of Oman' and made significant improvements to the GSO website that include an electronic voting section, member to member messaging system, web-based field trip registration, confirmation and payments, membership profile and status update plus other minor news and activities sections.

Here in Oman, our school-based workshops program has started with one scheduled workshop for the Dhahira region in December 2009 whilst internationally, GSO is coordinating with Geo2010 committee to run pre- and post-conference field trips in Oman as well as participat-

ing in the technical steering committee.

In terms of activity for the future, the Geologic Conservation Committee is still awaiting a decision from the Ministry of Commerce and Industries on the award of the geological sites documentation project.

And with respect to future activities, I would like remind you that the GSO AGM has been moved to January 2010 at the request of the Ministry of Social Development. The specific date will be announce at later stage.

To end I would like to extended my thanks to all GSO members and I encourage them to take an active role in the society. At the same time I would like to give special thanks to all the members of the Executive Committee for their dedication and commitment. Their silent hard work is making GSO a distinguished organization both locally and internationally.

Regards,

Dr. Mahmood Saif Al Mahrooqi
GSO – President

Note from the Editor

Dear Reader,

Welcome to the 15th Edition of Al Hajar. This, as promised, comprises the second part of 'Current Research in Oman' theme and focuses on the 'soft rocks'! In addition we also publish an obituary for Mike Hughes Clark who died earlier this year. Mike was one of the founding fathers of Oman's geology and it is clear to see from the detailed and warm memories that he was truly respected. I'm sure you will join me in offerereng sincere condolences to his wife and family for their loss.

Additionally, we have the regular features; a global round up of activity from IHS and the current schedule for upcoming lectures and field trips. Note within the next few months we are very pleased to host luctures from Prof. Ken Glennie, Prof. Pat Corbett , Prof. Mike Searle, Dr. Goesta Hoffman and Dr Tariq Cheema as part of our program. Please check the listings for dates. Regarding field trips, please update your diaries thus; Snowball Earth moves back

to January whilst the Fara trip moves back to February. Also, owing to the popularity of the Wadi Jizzi trip we will run a repeat performance in February. I would kindly ask that we have at least one volunteer per trip to write an article – as exemplified in this edition by by Janos Urai of GUTech. They don't need to be long or detailed – just enough to relate the facts and let those not able to attend enjoy also – as well as generating interest in repeat trips!

Many thanks again to all those who have contributed. Your efforts are much appreciated.

Enjoy reading & as always, please come back to me with any comments or suggestions you may have for improvement.

Best regards,
Caroline

Michael (Mike) William Hughes Clarke (1931 - 2008)

Jan Schreurs, PDO

Many geologists currently working in Oman will never have met Mike Hughes Clarke in person, yet in one way or another they will have come across one of the important publications that form his geological inheritance. He supported Ken Glennie and his group mapping the Oman Mountains in the 1960's, leading to the monumental "Geology of the Oman Mountains" (more about that by Ken himself below). In the 1980's the exploration for oil in Oman was booming. To ensure that everybody was talking about the same rocks it became timely to publish a sound description and definition of Oman's rock units. That became the "Stratigraphy and Rock Unit nomenclature in the oil-producing area of interior Oman", published in 1988. Alan Heward provides an alternative version of PDO's sudden desire to publish its stratigraphy: "The mid 1980s was a time when Japanese companies like JAPEX and JPDO were active exploring in Oman and there was a danger that PDO's unpublished formations might be superseded by rock units that few of us could pronounce, let alone spell".

Mike's most visible work is "Oman's Geological Heritage", published in 1990, written for a wide public and beautifully illustrated with photographs and drawings. The book saw a second edition, edited by Ken Glennie in 2006, but most of the original book survived and stood the test of time. He was also responsible for the geology section of Oman's Natural History useum. His clarity of thought and communication shows through. Mike was also instrumental in the publication of the PDO map of the Huqf in the mid 1980s. It was during a low level flight to check some of the details that the Al Khlata striated pavement at Ain Hindi was spotted. As PDO's stratigraphic Guru he recognized the uncertainties in zoning the Al Khlata glacial sediments due to extensive reworking, It was probably his guidance that lies behind the workable Al Khlata P units (for Production) as opposed to strict zones with palynological samples.

His life story was influenced strongly by con-



Mike Hughes Clarke, 1990. Farewell to Oman, photograph courtesy of Salim Al-Maskery.

tracting polio in his youth and an accident that damaged his ankle. With a weak leg he had to move away from field geology into the realm of the more benign laboratory-based micropalaeontology. After completing a PhD on Albian ostracods in 1957 at the University College of London, he joined Shell in The Netherlands. He remained loyal to Shell for his entire geological career. Alan Lord in his obituary for the Geological Society (London) fittingly described him as not being an oilman but as a scholar working in the industry. To capture Mike Hughes Clarke as a geologist and as a person it is best to hand the pen to some of us who had the privilege to work with him.

Ken Glennie

(father of Oman Geology, Honorary Professor at Aberdeen University):

I first met Mike in 1963/64, when we had both been posted to the Shell Research Laboratory (KSEPL) in Rijswijk, the Netherlands, to undertake geological research. Mike was a palaeontologist who had recently returned from working as part of Shell's contribution to the 'Consortium' in Iran, where most of the rocks he dealt with were carbonates, so he worked closely with the Carbonate Research Group. When, in the Summer of 1966, I was asked to lead a team mapping the Geology of the Oman Mountains, Mike more or less volunteered to join us as our stratigrapher. This was approved although he did not start until the beginning of January 1967. Because of a desperate shortage of accommodation for married staff in Oman, Mike and his wife Cynthia were sent to Doha where PDO's Exploration management was based. There, he set up a small laboratory employing Rashid who spent his days making thin sections from the samples that we sent him from Oman. In all, Mike studied over 11,000 thin sections (Rashid often making several extra sections if Mike thought that, from its lithology, it should contain a useful microfossil. He also studied a further 2000 from samples collected during earlier PDO surveys. This way he developed a very detailed stratigraphy; within the Hawasina he separated faunas re-worked from the Hajar Super Group from those that lived in the Hawasina ocean – thereby giving us both ages of deposition as well as probable age and facies of reworked fossils. He was also able to recognise/support the many environments of deposition defined by the field geologists; he erected ten microfossil zones from Permian to latest Cretaceous in both the Hawasina and those autochthonous rocks we studied (Hajar Super Group & Aruma Group).

At that time, PDO imported a lot of Western-type food for the expatriates, which arrived by plane via Doha. The planes went back empty so we were able to send our samples from the PDO landing strip at Azaiba very cheaply. To get a 'feeling' for the geol-

ogy, Mike was able to join us in the field on three or four occasions over the next 18 months.

After completion of our field work in Oman (April 1968), we went to see what we thought should be the 'other side' of the Sumail (New Tethys) Ocean, which we thought to be in the Makran area of SE Iran. Mike joined us there where we spent two months in the field and another month working our way along the Zagros 'Crush Zone'. Studying especially the rock units of the Neyriz & Kermanshah areas, we began to realise that they were very similar to those of the Hawasina/Sumail of Oman. We were still on the same side of the Sumail/New Tethys Ocean as in Oman but the geology not only differed in detail but was much more complex in Iran. Back in Rijswijk, we had to write up our report on the project (KNGMG 1974). The younger members of our team were soon sent abroad again to gain more oil-related experience elsewhere, so completion of the final report was left to me with very considerable help from Mike, who was back in the Carbonate Research Team. I then saw very little of Mike until the beginning of 1986. By then, Mike was back in Oman as Chief Stratigrapher. As official geological map makers to the State, BRGM has asked him if he would audit the quality of their work on Oman Geology. Pleading overwork, he recommended that I should be asked to do it. Accordingly, I spent two weeks with BRGM geologists looking at key field sections with them within the Mountains. That was followed by spending a couple of weeks with the Royal Geographical Expedition to the Wahiba Sands, which Mike & Cynthia (who used to be a geologist with BP before marrying Mike) were also able to attend in part – he persuaded PDO to let me have a company Landrover pick-up for the occasion (only 1300 cc, the weight to power ration was so poor that I had the greatest difficulty in climbing even the gentler western slopes of the bigger dunes). From then on I saw little of Mike and Cynthia, but they visited me in Ballater (Scotland) around 1989. I know that with increasing age he became less and less mobile and the last time I spoke to him on the phone (late

2006) he said he could no longer manage to get to the magnificent study he had built at the end of his garden. He still managed to drive his large car and had installed automatic gates. He then broke his other hip and was persuaded to move back to England (Stratford on Avon) into a care home. He died two years later.

Andy Wood

(Ex-Shell Country Chairman and General Manager of Shell Development Oman)

“Early in career I had the great privilege to work in the office immediately adjacent to Mike in PDO. Those were exciting times - for PDO as it coincided with the opening up of South Oman for exploration and for myself as this was my first posting outside The Hague. Mike was working as a kind of roving regional geologist at the time and effectively acted as a mentor to us young explorers who were very wet behind the ears. Mike obviously loved his work and his infectious enthusiasm for Oman and its geology rubbed off on all of us. He was always willing to drop what he was doing to bounce ideas around on the evolution of the rather unique Eastern Flank of the South Oman Salt Basin, open to good ideas but equally adept at telling us if our ideas were at variance with the facts!

By that time, his links with Oman were already long-established as he was one of the Shell team of geologists who had unraveled the geology of the Hajar mountains back in the 1960s - a seminal piece of work that has stood the test of time and the accumulation of much, much more data that was available to Mike and the rest of the team (who included at the time such other luminaries as -now Sir- Mark Moody-Stuart and Professor Ken Glennie).

For any geologist to have worked in Oman is a privilege; to have worked with Mike an honour. He will be sadly missed by a generation - now many of them retired - for whom he was a great source of early inspiration.”

Mohamed Al Harthy

(the founding member of the Geological Society of Oman and Principal Geologist/Business Opportunity Manager New Business Development for Shell in Dubai):

“ Mike Hughes Clark was a fine English gentleman, a keen geologist and a scholar I’ve had the pleasure to be acquainted with. He was an excellent regional geologist with an enquiring mind and many ideas. Mike is probably the one person who influenced and later facilitated shaping my career most as a geologist. He interviewed me as a new graduate when I applied for an exploration position in Petroleum Development Oman (PDO) in the 1980’s. I am grateful to him.

I have seen many professional geoscientists benefiting enormously from Mike’s generosity and overriding enthusiasm for anything to do with sedimentology, stratigraphy and the geology of Oman. His analysis and clarity of thought were second to none, and his generous and warm nature made one feel very humble.

Teaching is an important part of Mike’s legacy. One of the exciting exchanges I had with Mike was during the in-house training courses proposed by him and organised by PDO, where experienced geoscience staff and young geoscience professionals interacted in talks, workshop, and field work.

As a mentor, I would remember him for his enthusiasm, inspiration, insightful and gentle criticism, and for listening! He introduced me to the geology of Oman, the geology of Arabia and the modern Sabkha of the Trucial Arabian Gulf as an analogue to the Permian Khuff carbonate geology. Through a number of field trips, he taught me how to appreciate scale when looking at the geological environments and sedimentary facies. He showed me the importance of the ‘present as the key to the past’. The Oman Mountains, the desert interior, the wadi terraces and the beach wave cuts along the coastal areas from Muscat to Sur and the coastal sabkha in Abu Dhabi, were his favourite field areas and outdoor museums.

I remember when he was about to retire he showed me a picture of his house on top of the Miocene limestone cliff in Gozo. As he

was describing it to me, he seemed more enthusiastic about the geology than the house that he is going to live in.

Mike was very generous with his knowledge and never hesitated to help, advise and support people. He will live long in the hearts of those who knew him and in the mind of many who read his papers and books: he engraved not only his name in the geological heritage of Oman but supported many to craft their names along his."

Salim Al-Maskery

(General Manager Shuram Oil and Gas)

Salim showed me many nice photographs from his private collection featuring Mike. We selected Mike in a very characteristic pose for this story. It was taken at the end of Mike's "farewell fieldtrip" in 1990, just before leaving Oman, actually waving goodbye to all at the end of the trip. This is how Salim remembers Mike who left a huge imprint on his life. It was Mike who hired Salim into PDO, simply because he recognized passion and enthusiasm for geology. Salim mentions that in these early days: "my English was very poor, and I did not know too much about Geology either, but Mike took me anyhow. He trained me to become a field geologist. Everything I know I owe to him; he was my teacher, my master, and I was as a son to him...". Salim was one of six Omanis selected by Mike to become PDO geologists, including Ali Al Kindy (now retired), Mohamed Al Harthy (the very same Mohamed of the story above), Nasser Al Lamki (retired), Mohamed Al Lamki (still working in PDO as hydrogeologist) and Mashour Al Harsusi (passed away). He extended his stay in PDO by 9 months to complete their training. Mike had rightly recognized that geology in Oman could only truly live and develop if it would be taken-up as early as possible by Omanis. Salim also explains that PDO's famous logo is most likely also the brainchild of Mike. It is not the big ammonite that most people think it is, but one of the small microscopic fossils (e.g., formaminera) that Mike was so familiar with. According to Salim: "his dream was that Oman's magnificent field geological work would be carried on by one of us. That's why I became a field geologist in PDO

exploration and later founded Shuram as my own company. You can say that his dream became my dream. For that I will be for ever very grateful...."

John Freake

(one of Mike's Shell former colleagues).

I joined Shell in 1960 as a Palynologist, and met Mike and Cynthia in The Hague, Holland on their return from a tour in Iran. I was a wet-behind-the-ears geological graduate from UCL somewhat lost amongst lots of Dutch, Swiss and other nationalities & no Brits! Mike appeared one day. He was employed as a Micropaleontologist, dressed like a real Englishman & with a mischievous sense of humour. Suddenly I felt a little more at home and this was the start of a long friendship with "huge Clarke" as his Dutch colleagues called him.

We worked in the Pal Lab on Groenhovenstraat, a series of converted town-houses attached to the main BIPM head office, and was run along strict Dutch autocratic lines. Rules abounded and woe-betide those that didn't conform! We did most of the time, but management could never quite get it's head round Mike's dress code of smart blazer, sports tie and deer stalker. He even migrated to a bow tie over time just to keep the pressure up!

Working on binocular microscopes most of the day was tiring, and being a practical sort of chap Mike acquired a set of moulded rubber eye pieces that he said helped his fatigue. It was only when I interrupted him one day and a head looked up with 2 black eyes that I realised he had discovered a new form of rest!

He was a great thinker and reader, his science fiction library was impressive.

Geologists have a saying "the present is the key to the past". That very much applied to Mike who was a keen observer of marine ecology, in particular carbonate sedimentation. He joined the Shell Carbonate Research group, snorkeling in the waters of the Persian Gulf in the late 1960's. He developed into a world authority on carbonate environments and was loaned out to a Royal Commission on the Australian Great Barrier Reef to teach lawyers what the reef was about. It is partly due to his ef-

forts that the entire area is now preserved. And of course he became pretty good at predicting ancient carbonate sediments, such as rudists, but that's a story that Geophysicists wax lyrical over and will not be told here!

Mike stayed loyal to his geological interests and resisted efforts to join the Management race. He avoided whenever he could political aspects of finding oil and gas, and could quickly express frustration over a decision or interpretation that did not honour the geological facts. His way of expressing his professional position was to tease visitors with a notice on the office wall "Don't confuse me with the facts, I've made up my mind!

We always wanted to work together but the somewhat autocratic system that subcontracted head office staff to Shell Operating Companies abroad was not to be influenced! This was a challenge for Mike, who arranged for me to double-blind analyse some Persian Gulf samples to justify the addition of a Palynologist i.e. me, to the Persian Gulf Carbonate team. (They needed a buddy diver for Gene Shinn anyway & I fitted that criteria). The analysis was spot-on and Mike tried his influence on the system. The next thing I knew was I was on my way to Alberta, Canada; talk about being banished "out in the cold".

Our ways parted for quite some years during which time Mike joined the Oman Mountain Research Group, led by Ken Glennie, covered already by no other than Ken himself in this compilation of Mike's life.

His ability to portray geological processes with photographs, diagrams and arm waving was second to none and appreciated by all his colleagues in the industry that were fortunate enough to be meet him.

Earth Scientist...teacher....lecturer.....mentor.....author.....sailor.....gent.....friend
Mike, I listened and learnt.....thank you, it was great fun!

Mike retired to Gozo, a small island next to Malta in the middle of the Mediterranean, where he published a number of works. According to his daughter, Sarah, he tried to match the standards of his famous Oman geology book. Without the resources of a large oil company that proved much more difficult. He spent a fortune renting time on military helicopters and friend's Cessnas to try and get the birds-view photographs that characterise "Oman's Geological Heritage". That led to his book "Limestone Isles in a Crystal Sea, the Geology of the Maltese Islands", published in 2002. According to John Freake, "this book brought him into the orbit of archeology where his interests took off into interdisciplinary areas in search of catastrophic events that caused the disappearance of various peoples in and around the Mediterranean. His geological thoughts covering the period 5000 to 800 BC were published in the book "Malta Before History", his last publication". Sarah explains that "he did not receive royalties on any of his work hoping that he was doing his bit to help the Maltese who had been so friendly to him and to get them interested in their own geological heritage".

That's very much the heritage he also gave to Oman and the Geological community at large. In that spirit we want to remember him. Our thoughts are with his wife Cynthia, daughter Sarah and son John.

Jan Schreurs, with many thanks to Ken Glennie, Andy Wood, Mohamed Al Harthy, Salim Al-Maskery and John Freake for their memories and to Alan Heward for additional reflections.

Fara Formation

Carlos Fonseca- Rivera

The Fara Formation is a small sliver of the Ara Group in the Oman Mountains that contains the record of an important period of geologic history and of the evolution of life in the early stages of the planet. Accurate dating of these rocks obtained back in 2000, indicate these were deposited around 544 +/- 3 million years ago, and therefore contain the record of the last 1-2 million years of the Late Precambrian eon just before the largest life explosion our planet has witnessed.

Sediments of similar age are found in the subsurface where they form oil and gas reservoirs of economic importance to Oman. The majority of these reservoirs, also known as stringers, are dolomitised slabs of platform-tidal facies encased in salt that were deposited in restricted evaporitic conditions. An exception to

grained sediments with local occurrences of chert and that has been the focus of study and debate since its discovery. The occurrence of these siliceous deposits has been difficult to predict in the subsurface and the understanding of its origin is undoubtedly the key factor for the future of its exploitation success. The Fara Formation, with its interlayered cherts, dolomites, tuffs and sands provides, if not an analogue for the Athel silicilyte, with a piece of the puzzle that tells us what was happening in Oman during deposition of the Ara Formation, 1000 km away from the reservoirs those are producing today.

The outcrop of the Fara Formation occurs along Wadi Bani Awf, 9 km into the wadi from the main road to Rustaq and covers a limited triangular-shaped area of 2.2 x 1 km. The



Figure 1. View of lower member of Fara Formation looking eastwards across the road of Wadi Bani Awf. Several subunits can be correlated across the wadi. Cherts have a ribbon texture and interlayered with episodic maroon dolomitic flows and concretions.

Fara Formation was described and divided in 3 members by Rabu in 1988, it was later dated by McCarron and Brasier in 2000 and further described by Nicholas in 1999 (unpublished). The Fara Formation in Wadi Bani Awf lies paraconformably on the Buah Formation that represents a carbonate platform facies deposited around 550 Ma. In the Jabel Akhdar area the Buah displays facies that go from high-energy shallow environments (above wave base) on the east (Wadi Hajir)

the stringers is the Athel "silicilyte" that consists of monotonous laminated, silicified, fine-

to slope facies on the west (Wadi Bani Awf) where it is characterized by bituminous black



Figure 2. Laminated black chert of lower member of Fara Formation. Laminations are low angle to planar with some intervals representing deposition under traction associated to distal flows. Size of pen 12 cm long.



Figure 3. High density mass flow interpreted as part of talus deposits at the contact between the second and lower member of the Fara Formation and related to cannibalization of the lower member. Blocks are angular to sub-rounded and chiefly composed of exhumed dolomite and chert concretions in a coarse sandstone matrix. Flow direction interpreted to be from left to right at an oblique angle from viewer. Hammer for scale.

shales, slope breccias and slumps associated with rapid subsidence of the platform margin (McCarron 2000, Cozzi et al, 2004). The overlying Fara Formation is at an apparently conformable angle but the basal sediments mark a lithological change with the occurrence of tuffs, carbonate mass flow deposits and chert beds. The lowermost member of the Fara represents a continuation of the subsidence of the platform and represents talus deposits where cherts represent background sedimentation of fine grained sediments and distal turbidites. The conspicuous occurrence of carbonate mass flow deposits composed of exhumed blocks of algal boundstones and grainstones indicate the carbonate factory was still active and exporting material downslope during episodic drops in the relative sea-level and are potential hiatuses in sedimentation. Field observations indicate mass flow deposits were point sourced from both east and west and converged into the N-S axis of the basin. The onset of the second member of the Fara is marked by the occurrence of eastwards downlapping clinoforms of carbonate breccias onto chert and tuffs sediments that is likely related to a potential sequence boundary. The third member of the Fara is chiefly composed of tuffs deposited as gravity flows with common convolute bedding. Overall, the Fara in Wadi Bani Awf represents a downslope sequence with fluctuation in individual bed thickness over a short distance and a dynamic sea-bottom where slumps and gravity flows filled channels and scars,

healed and gave rise to uneven topography. The occurrence of cherts and dolomites indicates a complex diagenetic history that resembles that of other well known siliceous formations such as the Monterey in California. The dolomites represent early diagenetic events likely associated to reducing and methanogenic bacteria before major compaction took place. The cherts on the other hand range from early to late diagenesis depending on their detrital content, temperature and fluid migration and interaction through matrix and fractures. Several questions remain to be answered in the Fara Formation such as; the precursor of the cherts, the proximity of the volcanic arc, the role of bacterial mats in the development of the laminated rocks, and the source rock potential of the sediments. What we can see of the Fara, is just a window of a complex basin where clastics, volcanics and carbonates met and it may turn out to be a valuable piece of the puzzle needed to understand the different depositional environments that existed during deposition of the Ara Group in Oman.

Characterization of Khuff Geobodies in Outcrop and Subsurface of Oman

Bastian Kohrer, Tom Aigner (University of Tübingen) and Michael Poppelreiter (QSRTC)

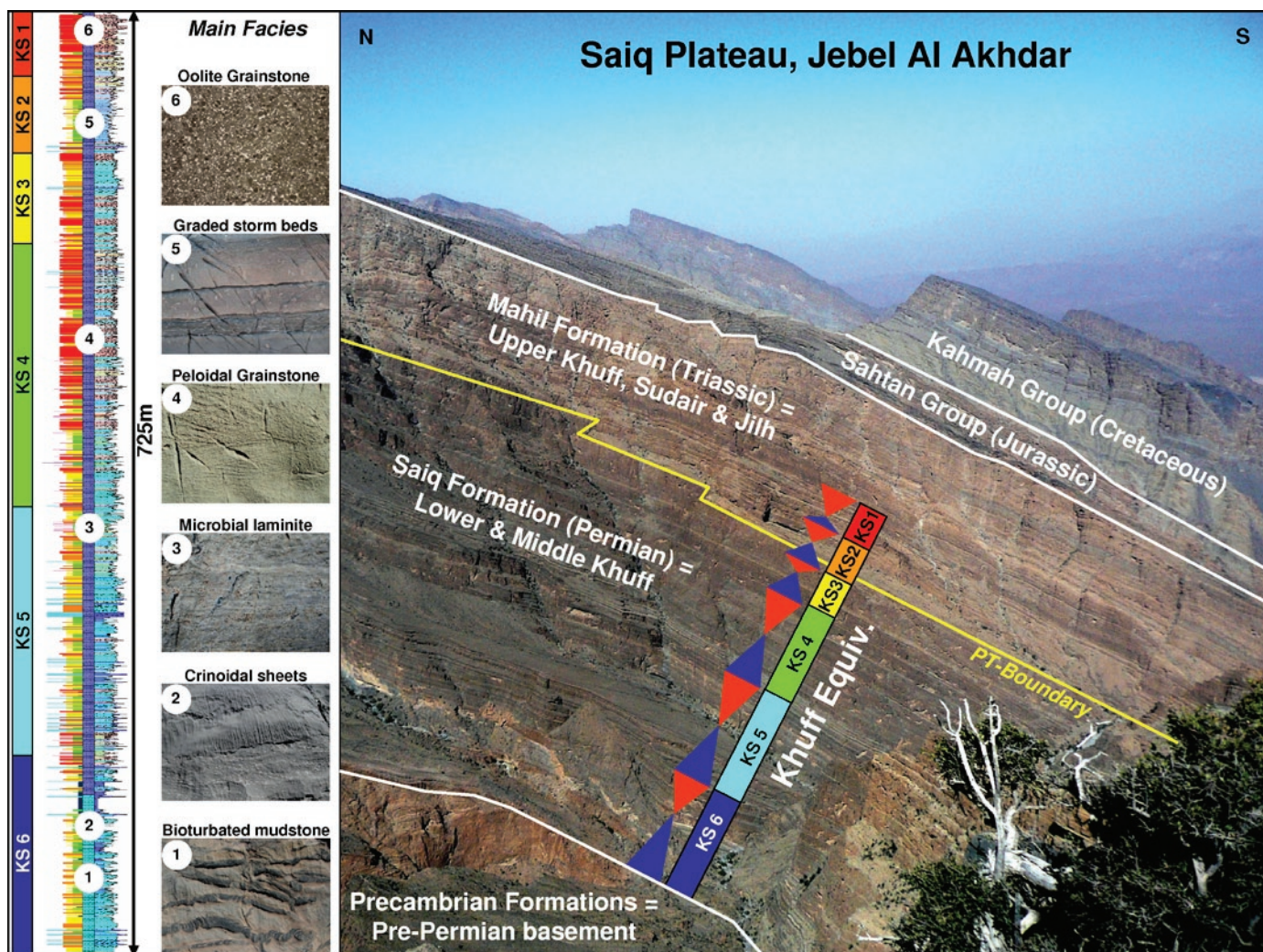
Introduction

The Middle Permian-Early Triassic Khuff Formation is one of the most important reservoir intervals in the Middle East. The apparently simple, layer-cake type reservoir architecture strongly contrasts with the large permeability ranges (i.e. 10's of mD to 1000's of mD) commonly observed in producing Khuff fields (e.g. Pearl blocks of the North Field / Qatar or Yibal / Oman). Current models suggest that depositional geobodies, sequence stratigraphic position and diagenetic overprint generate permeability variations. The geometries of depositional geobodies cannot be derived from seismic or core data due to limitations in

resolution and well spacing.

Therefore, an EMR-project (2007-2010) was set up between the Sedimentary Geology Group of the University of Tübingen/Germany, SHELL (QSRTC) and PDO. Key objectives of this study are:

- 1) To map out primary reservoir heterogeneities (i.e. texture and grain type variations) within Khuff time-equivalent strata in the Oman Mountains from outcrop- to exploration-scale;
- 2) To install a regionally applicable stratigraphic framework of the Khuff Formation based on an integration of bio-, chemo-, litho- and sequence stratigraphy;



Pre-Permian to Cretaceous section exposed on the Saiq Plateau (Jebel Al Akhdar). The Khuff time-equivalent strata (Saiq and Mahil Formation) has been subdivided into six third-order sequences (KS 1 shown in red to KS 6 shown in dark blue).

3) To establish a conceptual depositional model of the Khuff Formation in the Oman Mountains that highlights nature and dimensions of reservoir sweet spots on various scales.

In the final stage of the project, outcrop data will be directly linked to available subsurface data from Northern Oman.

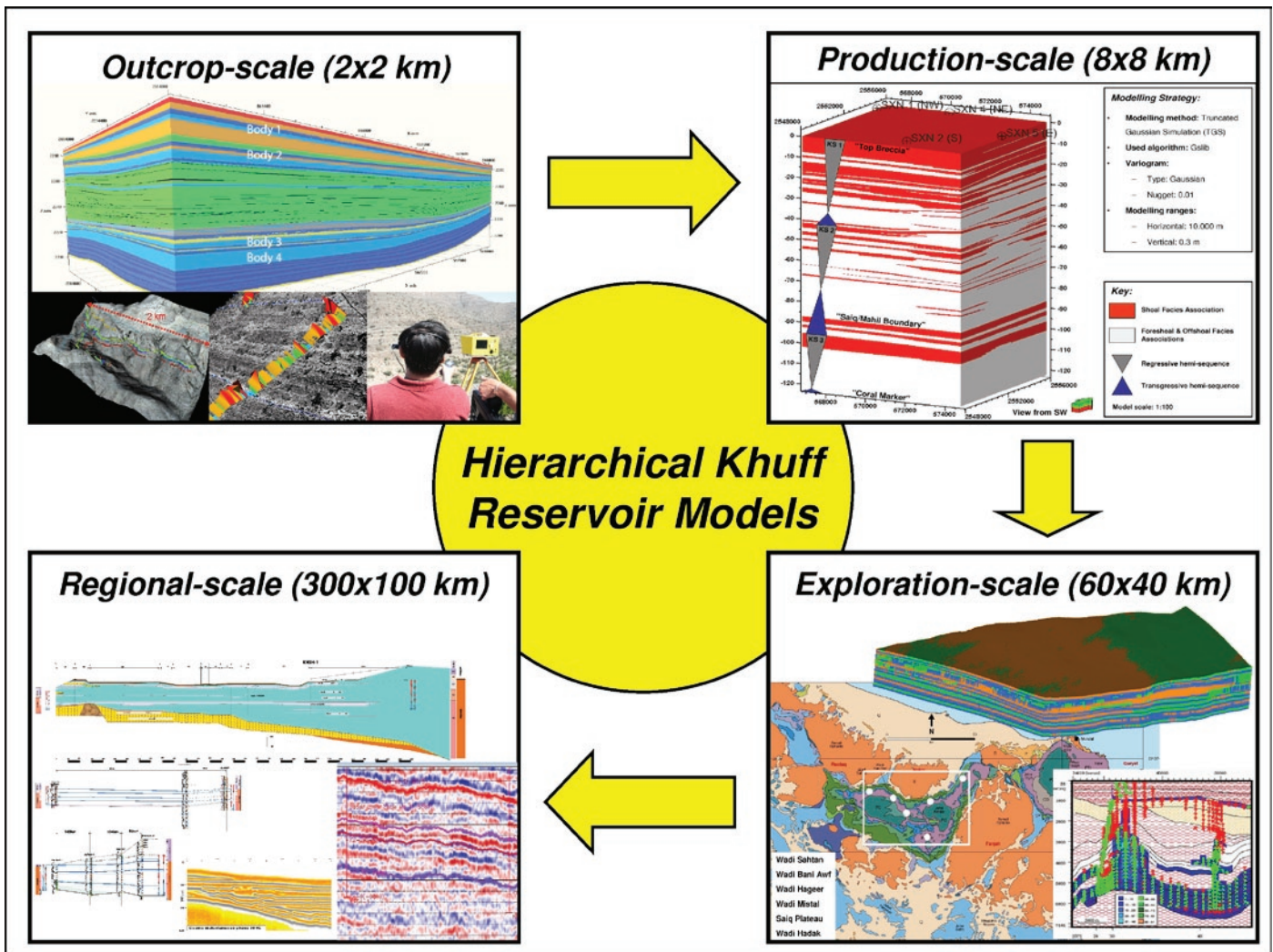
First results of the study can be used to optimize placement of development wells in Shell's Pearl blocks drilled within the next few years and to support exploration and production effort in adjacent areas (e.g. Yibal). It further provides a valuable learning and development data set.

Methods

Outcrop data has already been acquired in parts of the Oman Mountains (Saiq Plateau, Wadi Sahtan and Wadi Bani Awf). Future work will cover other wadis. Each of the Khuff out-

crop sections is worked from 1D to 3D. The 1D-analysis includes detailed sedimentological (1:100) and spectral GR (0.5m resolution) logging. Rock samples for stratigraphic (biostratigraphy, stable isotope and microfacies) analysis are collected every few meters. Facies and stratigraphic data are synthesized in a Khuff facies and cycle atlas to link outcrop and subsurface data. All data is displayed and recorded in WellCAD format to establish robust type sections of each of the Khuff outcrops. 1D-sections are correlated by using all available stratigraphic information (biostratigraphy, chemostratigraphy, marker beds and facies cycles) to map out the Khuff stratigraphic architecture.

The 2D-analysis, so far conducted on the Saiq Plateau, included mapping of major stratigraphic surfaces along the outcrop wall with



A hierarchical (“Russian-doll”) approach is chosen in order to link static outcrop- and exploration-scale 3D-reservoir models of the Khuff Formation. In the final stage of the project, available subsurface data is integrated to link outcrop to subcrop on a Northern Oman-scale.



Group discussion on the Permian-Triassic Boundary (Saiq Plateau). Outcrop workshops and field trips to the Jebel Al Akhdar outcrops are offered from QSRTC and PDO in regular time intervals. For further information please contact Michael Poppelreiter (QSRTC, m.poppelreiter@shell.com) or Joachim Amthor (PDO, Joachim.JE.Amthor@pdo.co.om).

high-resolution RTK-GPS technology. Digital outcrop mapping is proposed as technology that seamlessly links surface and subsurface data as outcrops are recorded and modeled like analogous subsurface scenarios. Additionally, LIDAR scans from well-exposed intervals were taken.

Data generated during 1D and 2D analysis was used to construct hierarchical static 3D-reservoir models from outcrop- to exploration-scale using Petrel software. These provide valuable 3D-information on the dimensions of geobodies of the Khuff Formation. For the Saiq Plateau outcrop, a very high-resolution digital elevation model (Quickbird) was used to visualize and drape the outcrop data. Digital outcrop data was acquired to test the impact of reservoir architecture and fluid flow. Outcrop models were partly populated with analog subsurface petrophysical and fluid properties.

First results

1. Stratigraphic framework:

First complete sedimentological-stratigraphic descriptions of well-accessible and laterally extensive outcrops of the Permian Saiq and Triassic Mahil Formations (Khuff time-equivalents) in the Oman Mountains can be used as new calibration points of the Khuff on the Ara-

bian platform (Fig. 1). Khuff outcrops in the Oman Mountains are mainly dominated by grain-dominated textures, representing the storm-dominated shoal to foreshoal section of the Khuff carbonate ramp. The most important reservoir facies are oolitic, peloidal and skeletal grainstones. Beds are commonly normally graded with grainy textures at the base and mm-scale mud-drapes at the top. Bundles of such graded beds form small-scale cycles bound by cm-thick muddy layers. These constitute potential flow barriers. The interpreted depositional setting is in accordance with the assumed paleogeographic location within the unrestricted marine carbonate shelf some 150 km away from the edge of the Arabian platform.

Several stratigraphic methods such as lithostratigraphic marker beds, facies cycles, bio- and chemostratigraphy were used to establish a sequence stratigraphic framework, aiming to consistently link Khuff surface and subsurface stratigraphy in Oman. The investigated sections were subdivided into six 3rd-order sequences (KS 6 – KS 1) (Fig. 1). This sequence stratigraphic framework may further be used to consistently correlate Khuff reservoir intervals across the Middle East.

2. Hierarchical static reservoir models:

Based on 1D and 2D observations and interpretations, 3D-static reservoir models on different scales were generated to better understand reservoir heterogeneities in layer-cake type epeiric reservoirs (Fig. 2).

A digital outcrop model of Upper Khuff time-equivalent strata (KS 3-2) on the Saiq Plateau was used to develop a 2x2 km reservoir model based on field observations (outcrop-scale). Walked-out reservoir bodies show general layer-cake geometries of grainstone bodies. However, reservoir bodies tend to have a standard deviation of 13% in thickness. This variability may impact reservoir volume calculations in producing Khuff reservoirs.

An 8x8 km Upper Khuff (KS3-1) static reservoir model (production-scale) revealed importance of cyclicity on reservoir geometries. Considerable differences regarding percentage, thickness and lateral extend of individual grainstone geobodies within different KS-intervals were observed in the outcrop.

Following the concept of "hierarchical reservoir models" (Fig. 2), a 60x40 km model (exploration-scale) of the Khuff Formation is currently in preparation to show systematic lateral facies changes and evaluate the effect of potential paleohighs on reservoir quality distribution and stratigraphic architecture.

Finally, outcrop and subsurface data from Northern Oman will be linked to evaluate the seismic expression of paleohigh- and low geometries on a 300x100-scale (regional correlation) as well as predict reservoir sweet spots from available outcrop and subsurface data-sets.

3. Dynamic simulation and synthetic seismic

from outcrop:

In QSRTC, digital outcrop data was acquired to test the impact of reservoir architecture on fluid flow. The static 3D-outcrop model (2x2 km) was populated with analog subsurface petrophysical and fluid properties using the established Khuff facies scheme. The impact of location and length-scales of permeability barriers on fluid flow were tested by applying various scale-up and layering schemes, allowing the selection of the optimal grid dimensions for producing Khuff fields in the region. First results of the dynamic modeling procedure indicate that reservoir architecture of storm-dominated systems impacts especially low permeability reservoirs. The case of near wellbore condensate drop-out on relative permeability can be significantly more dominant than the effects of the incorporation of increased geological resolution. Further work needs to be done to capture all the learnings that this new modeling approach may yield.

Acknowledgments

Many people are involved in the realization of this EMR study. The authors would like to thank Michael Zeller, Christoph Schneider, Daniel Bendias and Michael Obermeier (University of Tübingen) who hugely contributed to the progress of this project. Among Shell, Erwin Adams, Paul Milroy and Gert-Jan Reijnders are especially thanked for assistance in many ways. We are further grateful to the PDO-Team: Joachim Amthor, Jan Schreurs, Gordon Forbes, Claus von Winterfeld, Aly Brandenburg, Gordon Coy and Sulaiman Al-Kindy. Holger Forke (Univ. of Berlin), Daniel Vachard (Univ. of Lille), Jörg Mattner (GeoTech, Bahrain), Sylvain Richoz (Univ. of Vienna) and Deborah Blieftrick (Badley Ashton) are thanked for sharing their knowledge of the Khuff. We are much obliged to Shuram Oil and Gas (Muscat) for logistics and save field work.

Permian Silicified Wood in Oman

Petra Matysova & Tomas Grygar (Czech Republic Academy of Science)

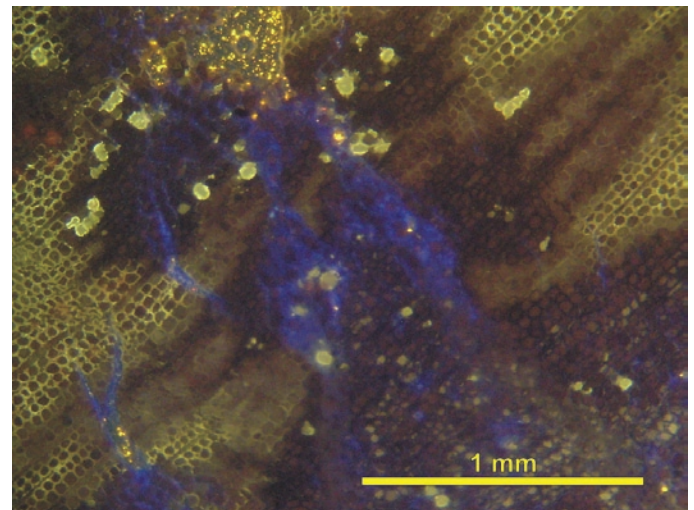
Who would have guessed that even a long boring queue for coffee between sessions of the European Palaeobotanical Congress in Prague, Czech Republic, 2006 could bear such juicy fruit? In the Congress, I (PM) presented the results of our work on Czech silicified stems formed during the Carboniferous/Permian transition. It was not my lecture but my accidental meeting with Gordon Forbes (Petroleum Develop-

By the end of 2006, Gordon had sent us several silicified specimens from the Upper Gharif Formation in the Huqf Area, east Oman. Since the end of 1990's, the silicified wood from Huqf had already been studied by French palaeobotanists, Jean Broutin and Martine Berthelin (Université Paris, France), who performed very detailed and reliable work on taxonomy, however, their interpretation that



A large silicified trunk and remnants of fossiliferous sandstone weathered off on the desert surface.

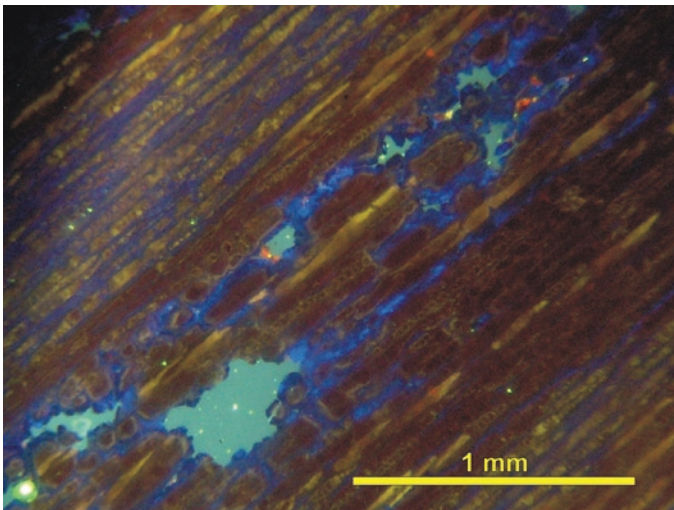
ment Oman) in the city called "heart of Europe" and our short but enthusiastic chat about our work that became the culprit of our later field trip to Arabia. And that's it; since that very moment we kicked off our e-mail correspondence on Omani silicified wood and a new interdisciplinary collaboration emerged unexpectedly from nowhere. That's the beginning of this story.



Hot Cathodoluminescence of Early Permian *Dadoxylon* sp., Museum für Naturkunde, Chemnitz (Germany). Notice totally different, yellow-brownish and short-lived bluish CL shades than in the Omani wood.



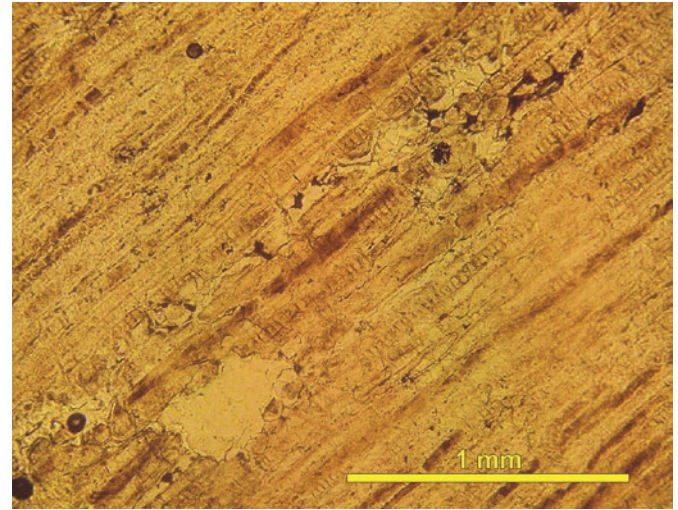
Polarized light microscopy; hyperblastic textures of quartz crystals (#O2; longitudinal radial cut).



CL image of Czech *Dadoxylon* sp. wood silicified in river alluvia (Intra Sudetic Basin) with strong diagenetic overprint: the primary silica mass with stable brick-red CL is suppressed by secondary mass with transient blue CL, transient yellow CL probably due to hydrothermal quartz (longitudinal tangential cut).

the lack of regular growth rings in these gymnosperms (Coniferophyta, Ginkgophyta, and Pteridospermophyta) manifests non-seasonal humid warm climate during the tree growth contrasts with the view that the Upper Gharif Fm. was deposited under a seasonally dry climate. Actually, according to the current state of the art, palaeoenvironmental reconstruction from tree-rings has two limits: the tree-ring formation in the upper Palaeozoic and early Mesozoic was taxon specific, but what is more serious: it is really not clear when gymnosperms developed the handy skill of forming two types of wood, i.e. growth rings.

During 2007 we subjected the Huqf silicified wood to the same set of analytical techniques as other specimens of silicified plant matter we have gathered from various localities (Czech Republic, Germany, France, Brazil, Arizona, Mongolia, Sumatra, Antarctica). These include: light and electron microscopies, X-ray diffraction, and hot cathodoluminescence (CL) imaging, based on the light emission after electron beam excitation. There were few particularities, which surprised us: moganite presence in one specimen and pure quartz with a weak bluish violet CL in the rest. After our continuing study of other specimens from several world localities, we spotted that quartz with such weak CL is typical for wood silicified in river alluvia under a seasonal cli-



Normal light microscopy of *Dadoxylon* sp. from the Intra Sudetic Basin, Czech republic

mate with very small later diagenetic overprints. Moganite really astonished us: usually this metastable form of silica originates from non-crystalline precursors, and actually in silicified wood it commonly occurs after burial of the plant debris by volcanoclastics. Concerning the silicification (a kind of permineralization), many questions still remain unresolved, even apparently simple sounding ones. For instance: how did the silicification proceed, under which conditions, and why? Why do we have alternations of sediments with coal seams and sediments with silicified



From left: Alan, Petra, embedded silicified log 'in situ' in river alluvia (fluvial sediments), Tomas.

wood in fluvial clastics (free of any volcanic components and without any signs of hydrothermal processes) in the entire Upper Pennsylvanian and Lower Permian in the basins of



Sampling of the Gharif Fm. (Tomas & Alan).

the Bohemian Massif, Czech Republic? Already in the 1960's, some Czech geologists, e.g. Vladimir Skocek, cited changing seasonality in precipitation for these cycles, and a detailed analysis of climate-sensitive sediment components of that period consistently confirms this hypothesis, although it is still waiting for rigorous approval. Of course, there are at least two further but very different modes of silicification, perhaps better known to the scientific public: plant burial in volcanic fallouts and plant immersion in hot springs. All of these completely different environments deal with a different concentration of dissolved $H_4SiO_4^0$ and the results – silicified plants – seem at the first sight rather similar. Fortunately, the fossils from every locality bear their own specifics, particularly in the detailed mineralogy of the mineral mass and the original plant anatomy preservation. We decided to decode the mineral matter in silicified stems by accessible instrumental analytical techniques and contribute to understanding this fascinating preservation process the results of which we can observe even after a few hundred mil-

lion years.

Let's move to the end of October 2008. One PhD student frenetically interested in silicified stems particularly of the Permo-Carboniferous age and her colleague, an analytical chemist, who is trying to expand his interests into geosciences, both standing somewhere in between the distinct scientific disciplines, are coming to Muscat. The aim of their journey is clear: to present results of our interdisciplinary work done on the plant permineralizations, to start collaboration with Omani geologists, consult the Omani objects of our study, take part in field work in the interior desert looking for silicified wood and palaeosols and learn some basics on Omani geology and settings of the fossiliferous strata. Actually, the lack of detailed information on geological settings for silicified wood is the most serious bottleneck to understanding the silicification process. Palaeobotanists rarely pay attention to the sedimentology of fossiliferous strata and their palaeoenvironmental reconstructions are mostly based on taxonomy assignments and plant anatomical studies. However, we believe that the fact that plant material has been silicified must mean something about the environment. But what? To answer that "simple" question, much fieldwork and many discussions across discipline boundaries are essential, such as those we were happy to conduct in the field trip in 2008 in Huqf.

Here is the 30th October 2008 snapshot: Never been to Middle East, we are leaving Prague, at that time a very cold city (about $10^{\circ}C$ in day) with a miserable wet late autumn atmosphere. With summer clothes and sunglasses in our luggage we are feeling a bit weird among the other Prague citizens, who are dressed in winter overcoats, and hoping that Gordon speaks the truth about the Omani weather. And indeed, landing in the paradise named the Sultanate of Oman we are catapulted into another world. Enchanted by the hot, exotic, seawater saturated air, two gazing Central Europeans are starting their trip in Muscat, assimilating the thermal shock, and preparing for the desert journey.

Who wouldn't go to Omani desert with Alan,

his wife Felicity, and Gordon? It was a great idea and we were lucky to have such guides. Their admirable practical skills changed our four-day trip to the desert, which to be sincere - we were a bit afraid of, into a picnic with fresh fruit and ice (of course, only during the 1st day), barbecues (each evening), plenty of well chilled drinks (whenever we were thirsty), that allowed the two Europeans to survive the temperature contrast, enjoy the local geology and absorb the sought-after knowledge. The trip was planned mostly according to two fieldtrip guides published in 2005 by Alan and Omar Al Ja'aidi (GSO Guide:011 and fieldtrip organized for 24th IAS meeting) and according to Alan's sense of orientation. Spending four days alternately in a car, on sand or other sediments as much under the sun as under the leadership of experienced Alan, we found our bodies and minds more capable than we ever thought. The fact that the silicified stems in Huqf can sometimes be found in the original fossiliferous strata is marvellous: it is rather exceptional in the Czech Republic and many other places with much more humid climate, where most of the silicified trunks weather out and are scattered within the unconsolidated Quaternary debris. Alan and Gordon brought us to the outcrops of the overbank fines and buried floodplain palaeosols with silicified trunks looking like pieces of fresh trees with branches and imprints of bark.

The field trip to Huqf in Oman further strengthened our belief that silicified stems, trunks or wood (each term means something different from the palaeobotanical point of view) from fluvial siliciclastics, are really unique palaeoenvironmental indicators. They also reflect the whole story from plant origin until the time we collect them at the land surface. The original plant can be taxonomically assigned, i.e., the wood morphotaxon can be identified. The basic assignment to the group of plants is usually enough: an exact taxonomical name is much less important because of a usually doubtful preservation of anatomy and unknown palaeoenvironmental contributions of the individual taxa. To have had the chance to pass to the river channel, the original trees probably grew in the riparian environment, where water was not the growth-limiting factor and hence the

"seasonal stress" to the plant was much weaker than apparent from the plant taxa and the regional climate. The most relevant taphonomical observation, i.e., what happened to the sample since the plant died, is obvious from the state of the trunk preservation. In the basins of the Bohemian Massif, practically only chipped trunks or bigger branches often cut into pieces and always without bark or side branches (or their imprints) are found, indicating a longer transport of the original plant material. Contrarily, the wood in Huqf Area was much less mechanically damaged; probably the overbank fines buried trees that had been growing very nearby. The silicification in fluvial sediments required a burial in the material containing a sufficient amount of labile siliciclastics of sand to gravel size fractions, providing a source of silica for the silicification under a fluctuating water table. Feldspars were that source for the Huqf silicified wood: not only K-feldspars but even plagioclase, which are still ubiquitous in the coarser Upper Gharif sediments. In fact the reworked Al Khlata glacial sediments with physically weathered granite were the parent rock for the Upper Gharif sequence. The existence of large concentrations of feldspars in the Upper Gharif fluvial sediments is contradictory to the palaeobotanical hypothesis of a warm humid climate inferred from the tree ring study. The feldspars would be weathered very quickly in a humid warm climate and probably already in the river watershed, not to mention the alluvium.

The palaeobotanists soon recognized that preservation of the plant anatomy was not very good and that they could hardly use their holistic approach in studying taxonomy of our samples, the "Holy Grail" of palaeobotanists (i.e. joining various morphotaxa to one whole plant; in other word 'whole-plant concept') but it did not mean that fragmented material itself would not be worth studying. Let's decode fragments of information step by step and decipher overprints. It's worth it!

In summary, our prime aims were:

1. to learn about settings under which silicification in the Upper Gharif Fm. proceeded, and
2. to evaluate the palaeoenvironmental significance of wood silicified in river alluvia.

Our field work and consequent study has revealed:

1. the initial step of silicification must have occurred very quickly, close to where the trees grew as evidenced by their intact and uncompacted nature,
2. the silicification process was enabled by a sufficient source of dissolved silica in the groundwater resulting from the chemical weathering of the abundant feldspars from the physically reworked Al Khlata, and
3. the lack of tree rings may indicate that the trees grew in an unstressed environment (at least locally) with potentially little seasonality and that following from 2. the incomplete weathering of the feldspars points towards a dry (or cool) rather than humid (or warm) climate.

We would like to use this occasion and finish this report by a note apparently not related to geosciences. In Czech Republic, the silicified stems paid dearly for being assigned as a world unique object at the end of 19th century: the local people as well as collectors from abroad severely devastated the original wood localities, and currently it is hardly possible to find silicified stems in the originally studied, once famous and rich localities. Fortunately, some pieces passed to

the museum collections, but the silicified stems in the original fossiliferous sediments are much more valuable because no museum collection is free of uncertainties of the origin and settings of the specimens. During our field trip in the Huqf we were frightened by the information that some local private enterprise applied for the permission to mine and sell the silicified wood. We know from the Czech Republic how deep is the damage done to the geological heritage by "economically" thinking people. Let's celebrate your new Omani wood localities and new logs (do you know that we found „Forbesia plant“?) as much as the older ones and, please, try to do your best to maintain the localities as much as you can because it is the Omani national heritage, which will once be recognized by broader society!

At the very end we would like to acknowledge PDO and GSO for their great, not only financial, support, Jean Broutin for lending us a part of their set of samples and last but not least to Gordon Forbes and Alan & Felicity Heward for all their professional and personal help, and PDO & GSO members we met for their great hospitality. We thank Caroline Hern and GSO for the possibility to present our results and publish this contribution. Travel costs of the journey from Prague to Oman were partly funded by Grant Agency of ASCR (project No. KJB301110704).

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Quaternary Dunes of Ras al Hamra

Ed Follows(PDO/AFPC) & Ken Glennie (Hon. Prof, Dept .Geology, Aberdeen University)

The spectacularly up ended and eroded limestone pinnacles in the Ras Al Hamra (RAH) Camp area of Qurum provide a graphic analogue to the turbulence of the price of oil over recent months or even with the plots of cyclicity associated with the analysis of climate (Figure 1). The impacts of anthropogenic carbon dioxide emissions on melting polar icesheets and the recent coastal developments in Oman have even the lay populace discussing climates and life on earth of the past, present and future. As enthusiasts of geology we are unlikely not to be involved in such discussions and so it is opportune to reflect on the learning opportunities that surround us, for closer study of the rocks of climate change and, so reinforced, to encourage others to do likewise.

The dipping RAH camp limestones are, on closer inspection, blanketed with an uneven layer of pale brown sandstone. And it is this rock that is dissected in this article. Technically, the sandstone is aeolianite, a rock formed by the lithification of wind blown sand deposits, first described by Glennie & Gökdog in 1998. The evidence for a wind-blown origin is seen in the high angle dips of the cross strata and intersecting trough cross beds (Figure 2) of very uniformly sorted but alternating fine-medium sized grains forming striped laminae

(Figure 3). Perhaps the clincher is the geometry of the aeolianite deposits around camp, that hide the limestone bedding, for example smoothing out the slope between the fire station and Lazak bitumen company. Very similar banks of wind-blown sand pile up against the Huqf escarpments today.

The relationship between the older limestones and the overlying aeolianite, blanketing in the classic sense of unconformity, is most commonly clearly exposed in the coastal outcrops of the camp area. The sand infills the pre-existing relief of the limestone at all scales. Behind the PDO RAH club squash courts, the aeolianite infills the tubular weathering structures of the karsted limestones and, further east, down on the small bay behind the main RAH club beach, the sandstones infill around the limestone beach boulders t that look remarkably similar to the modern examples only metres away (Figure 4). At the same location, the aeolianite contains large 30cm+ limestone clasts which, sensu stricto, would indicate not a wind origin but perhaps a flash flood – like our wadis today (Figure 5). But beware! Not shown in Figure 5 is a cover of boulders and pebbles of Cenozoic limestone that has slid down from the exposures above. These older boulders will show no evidence

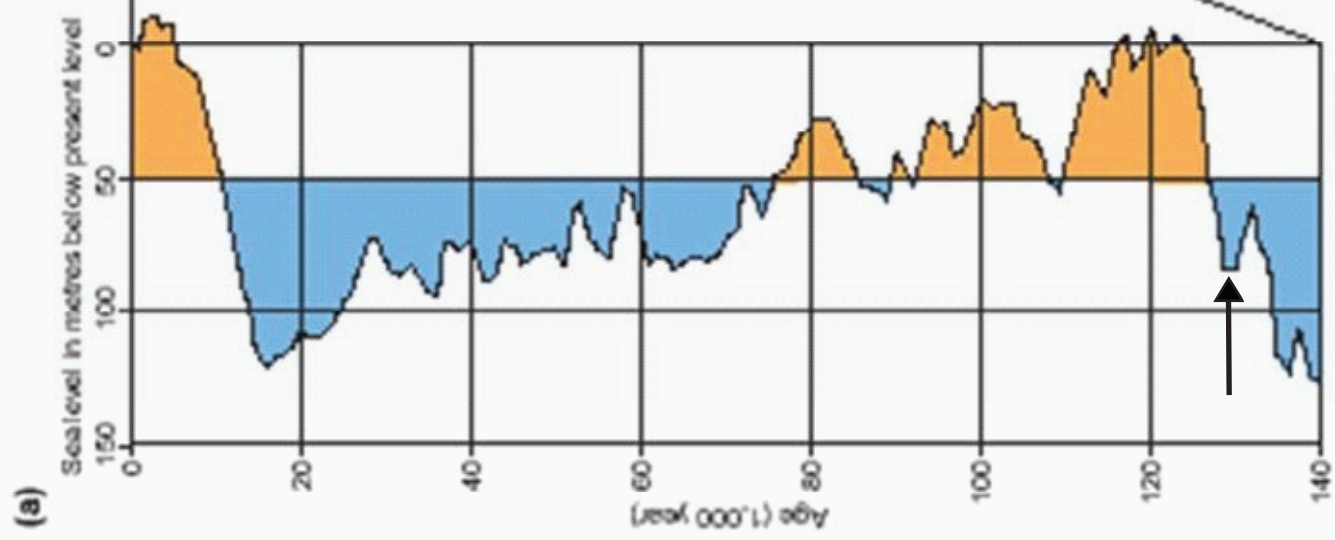


Figure 1. Oxygen-isotope sea-level history for the past 140 Ka. Based on Shackleton (1987). Arrow – the Aeolianites in RAH camp.



Figure 2. Dramatic trough cross bedding structures in the commonly misnamed Spinney's Quarry. The actual Spinney's Quarry is behind the Technical Library.



Figure 3. The fine and medium grain size alternations over a cm scale

cators for what might be in store for us with a turn for the worse in climate instability.

So where did all this sand come from? The age 130000 years ago ties up well with a past near-glacial maximum. Water locked into polar ice reduced the sea level to somewhere in the region of 60 to perhaps 130 metres lower than it is today. In Qurum, the blanketing nature of these deposits indicates the landscape then was similar to that of today. But as Pascal Richard pointed out using his



Figure 3. The location of the sample with the 130000 year date -behind the cliff with blue arrow; the 30cm + clast is black arrow centre in the photo

of the Quaternary age of the underlying aeolianite.

Unconformities prompt the question - how old are these wind deposits? Answering this requires the specialist application of optically stimulated luminescence which has been generously conducted for Ken by Ashok Singhvi (e.g. Glennie, 2005; Glennie & Singhvi, 2002; Glennie et al., 2002) in India for over a decade. The magic age? 130000 years +/- a week! So these rocks are very relevant indi-

fish detecting sonar, there is a major break in slope some 10 km offshore from the PDO office. The fall in sea level had begun some 50,000 years earlier reaching a maximum of -120 m 20,000 years earlier and was now rising again rapidly but rather erratically, reaching about our present level 5000 years later. Thus any exposed sediments would have been relatively uncemented and easily transportable. The association with ice ages

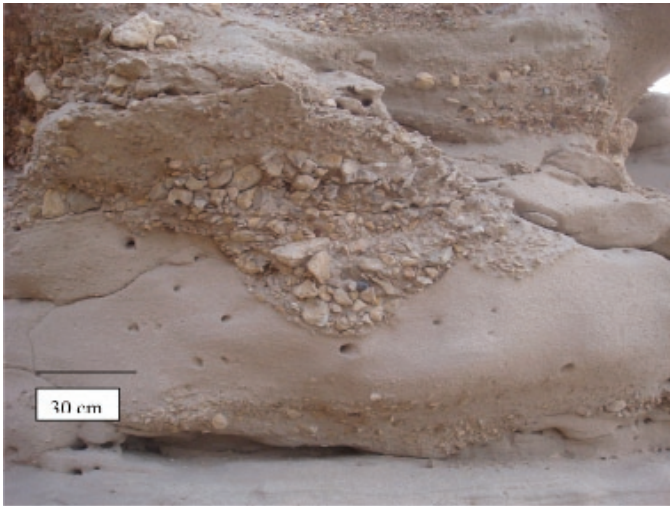


Figure 5. Local pebble-filled scour – common on the east side of the beach. Clearly not all these Quaternary sands are wind blown.

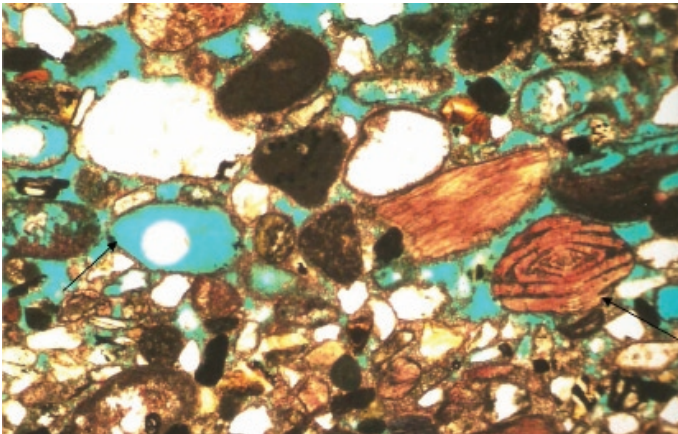


Figure 6. Fine (base) medium (upper 2/3s of photo) laminated sand. The arrowed fragment of nummulite shows reworking of rounded fossil benthonic foraminifera fragments derived from the limestones below. Calcitic shell fragment just above, thin cement fringe. Second arrow points to a fragment (likely aragonite) that has completely dissolved in the meteoric dissolution processes leaving behind its more resilient coating of micrite envelope and thin cement fringe. The white circle in the blue is an air bubble in the blue epoxy resin used to highlight the porosity present in the sample.

and falls in sea level is well demonstrated to be tied to stronger winds, some of which would have been from the north and therefore onshore. Thus the winds would have had a field day sweeping the debris off the exposed continental slope. Perhaps an analogue slope break would be the 120m terrace which is so prominent above the Capital Area housing today because, apart from the new Government building, the terrace remains uninhabited. Note however that although cut by the sea, this 120m terrace was uplifted by the rising Al Hajar mountains.

With such a major sea level change one would expect to see carbonate aeolianites showing up all over coastal areas. Closer inspection of the background rocks in the holiday brochures in Cancun, Bermuda, Majorca soon proves this to be the case. So if the sand was reworked from the shelf in the present day offshore area to the north of here, we would expect to see evidence of that in the sand grain content. It fizzes well with dilute HCl. It is a carbonate aeolianite. There are dark grains present too that are unlikely to react. The microscope reveals the variety in the grains. As foretold by the acid, many are car-

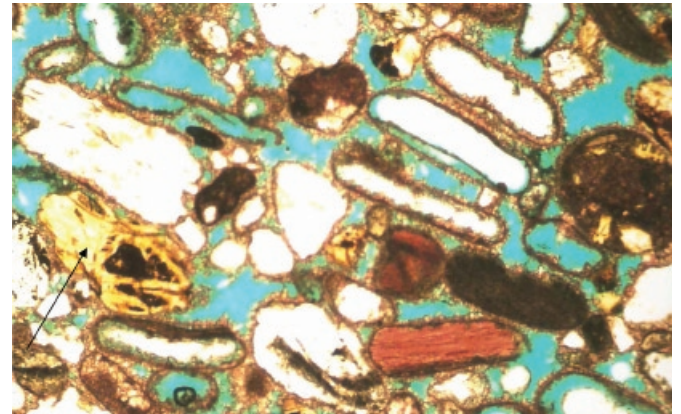


Figure 7. A weathered ophiolite clast arrowed with pale green mineralisation of the original grain. Right side – a stacked grain collection, that may all of have once been aragonite fragments

bonates. The selection visible in these pictures reflects the location of their sampling. Typically in the land samples one would see abundant miliolids with their characteristic triangular shape likely to have been part of the Quaternary fauna. In these coastal (Figure 4) samples these forams are scarce. There are odd nummulite fragments (Figure 6) and operculina which in may be mainly represented by the flat cement-fringed outlines, both of which were reworked from the Paleogene limestones. Not just foraminifera but also a variety of shell, echinoderm (stained pink with Alizarin red S) and rock fragments are present. The clear white patches are likely to be quartz derived from the Amdeh in Saih Hatat and probably reworked locally from the limestones nearby during the heavier rain of the succeeding interglacial. The weathered green mottled textures look like ophiolite

grains already altering to clays (Figure 7).

With many of the grains it is impossible to tell their origin with any certainty. They occur only as a ghostly rim of tiny sparite crystals – the critical cement holding these grains in place and stopping them blowing away. A product of meteoric diagenesis, happening on the land following aeolianite deposition, these samples would probably show pendent cements if orientated. Look more closely and you can see pale brown rims around the grain outlines – these are micritisation rims likely formed earlier in the original marine environment. Some micrite rims may even show relict borings on shell fragments. It is remarkable that these grains have been dissolved internally (?Aragonite in contrast to the surviving more resistant calcite) to leave their fragile coats behind, and these coats are not broken and compacted. Since being deposited at Ras al Hamra, these sands have probably been subjected to two phases of higher rainfall to account for this leaching; the first during the interglacial around 120,000 years ago, and the second during the so-called 'Climatic Optimum' between about 9,000 and 6,000 years ago when

rainfall in desert areas is known to have been much higher than now. Of course all the blue is the dye used to highlight the porosity present in the sample – here both inter and intragranular porosity. Ed had a sample of aeolianite measured from Cyprus at 20D permeability – needless to say the Rijswijk lab didn't get that many samples like this. The RAH camp exposures take another turn. The local quarries and abundant pits in the ground represent the removal of blocks to build houses. Alan Heward pointed out the aeolianites in the walls of the houses in old Muscat during the recent renovations. The rock is a great insulator trapping a large volume of air and keeping the buildings cool in summer and warm in winter – much more effective than our present day concrete. So a further carbon footprint and climate thought – how much C is locked up in these aeolianites and what a great way to learn from the insulation concept presented by these rocks to improve our current building materials and prevent further liberation of C (less air conditioning, less CH₄ oxidisation, less warming).

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International News

Ken White (IHS)



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GENERAL

India's Economic Times is reporting that Reliance Industries Ltd (RIL) is preparing to farm out interests in several of its overseas exploration blocks. RIL owns exploration interests in a number of countries, including Colombia, Oman, Australia and Yemen through its wholly owned subsidiary Reliance Exploration & Production DMCC (REP DMCC). The divestment strategy is intended to enable Reliance to retain operatorship but minimize the risk in its portfolio. In Oman, RIL was awarded an EPSA in 2007 for the 23,850 sq km Quriyat Coast Offshore Block 41 concession in the northern part of the country. The company also operates the contiguous 21,440 sq km Batinah Coast Offshore Block 18 concession, where it has acquired 971km of 2D and 2,048 sq km of marine 3D seismic data. Both deepwater/transition blocks had originally been offered as part of the Gulf of Oman Licensing Round in 2003. In 2008, RIL received parliamentary ratification for the Production Sharing Agreement (PSA) covering the 7,016 sq km Block 34 (Jeza) and 7,221 sq km Block 37 (Marait), both located in the Jiza-Qamar Basin, eastern Yemen. Under the terms of the PSA, RIL assumed operatorship of both blocks, with Hood Oil Ltd holding the remaining 30% participating interest. Yemen Oil & Gas has a 12% carried interest. It is anticipated that Reliance and Hood will invest US\$ 13 million in the two blocks with a work program that will involve the acquisition of 1,500km of seismic and the drilling of two exploration wells, following the completion of geological and geophysical studies.

INDIA

A new pool discovery has been completed by ONGC in the Sundalbari field in the Tripura-Cachar Basin flowing 5.6 MMcfg/d. The Sundalbari 4 (SDAC) exploration well, drilled in the Large Area onshore concession, was tested in the Miocene, Upper Bhuban Formation perforated at 2,164-2,168m. With gas composed of up to 96.3% methane, it is on a separate fault block within the Sundalbari field.

IRAN

On 24 August 2009, Iran's Oil Minister Gholamhossein Nozari told the Iranian News Agency that over 8.8 billion barrels of crude oil has been discovered in 'four new layers' at the Susangerd oil field, declaring it the largest oil discovery in the country in five years. His comments are interpreted to be a reference to the Susangerd 3 deeper pool wildcat that terminated at a total depth of 5,026m. The National Iranian Oil Company (NIOC) resumed drilling the Susangerd 3 well after testing the Miocene, Asmari Formation in mid-July 2009. The well is being drilled to evaluate the deeper pool potential of multiple objectives within the Jurassic-Cretaceous Khami Group. Iran still harbors plans to boost output by 2015 to 5.3 MMb/d, from the current 4.2 MMb/d.

Initial results from the National Iranian Oil Company (NIOC) Halegan 2 deep gas appraisal suggest the company may have another multi-Tcf find in the southern Iranian gas/condensate play fairway. The Halegan 2 sidetrack was kicked off from 3,925m in February 2009 and drilled to 4,999m after the original wellbore had been terminated at 4,360m following a strong gas kick and then mud losses near the top of the Dalan For-

mation. The original well had been spudded in mid-November 2007, with primary objectives in the Lower Triassic, Kangan and Upper Permian, upper Dalan formations (Khuff equivalent) of the Deh Ram Group. In mid-July 2009, a drillstem test flowed almost 18 MMcfg/d of wet gas through a 1/2" choke from the Permian, upper Dalan Formation. Halegan 1 had been plugged and abandoned as a dry hole in 1974 at a total depth of approximately 2,600m. Notable giant gas/condensate finds in the vicinity include Aghar (8.5 Tcf), Dalan (7.5 Tcf) and Homa (4.7 Tcf).

IRAQ

With a potential of 2.3 to 4.2 billion barrels oil in place and a recovery factor of 50% to 70% due to the highly fractured nature of the reservoirs, Heritage Energy has wasted little time in scheduling its first appraisal to the Miran West 1 discovery. At a location 4km north-east, the Miran West 2 well is due to spud in the fourth quarter of 2009. Testing of Miran West 1 produced 3,640 b/d of 27° API of low sulfur oil from a single reservoir. The flow rate was restricted by surface equipment capacity and Heritage has estimated a productive potential of 8,000 to 10,000 bo/d when the well is placed on production making this a highly significant discovery. Heritage Oil and Genel Enerji are proceeding with merger plans that will create Kurdistan focused giant.

Such is the significance of the latest update from Gulf Keystone with regard to its Shaikan 1 wildcat the Shaikan Block in the Kurdistan Region, the company's shares rose over 70%. Drilling has now reached a depth of 1,710m and has encountered an oil column in excess of 170m within the Sargelu, Alan and Mus formations. At this stage, the company believes this to be a single reservoir and hence an extension of the same discovery announced on 6 August 2009. As previously announced, the Alan and Mus formations were identified as the primary oil-bearing zones of interest for Shaikan 1, with total potential volumes of oil-in-place in excess of 1.5 billion barrels. The openhole log data, together with an extracted core from the new interval, confirm the presence of a extensive fracture system, which appears to be oil saturated throughout. Furthermore, no water

has been encountered. This new data provides Gulf Keystone with grounds for a revised range of oil-in-place volumes of between 1.5 and 3 billion barrels for the oil encountered, thus far.

KUWAIT

The third Kuwait International Petroleum Conference and Exhibition will be held on 14-16 December 2009 in Kuwait City at the Kuwait Hilton Resort. The theme of the conference is "Meeting Energy Demand for Long Term Economic Growth" and will cover topics including economic growth, energy demand, reservoir characterisation, modelling and management, heavy oil/tight gas, drilling and well completion, EOR/IOR and production operations. Local media seem to have picked up on this and report that the Kuwaiti government are planning to revive Project Kuwait, an initiative that has been under discussion for over 12 years, to raise production from Kuwait's northern oil fields to 900,000 bo/d by 2020. In July 2007, newly-appointed chief executive of Kuwait Petroleum Corporation (KPC), Saad Al Shuwayib, reiterated KPC's intention to develop four of Kuwait's northern oil fields through Project Kuwait, but little has happened. The four fields included in the initial plans for Project Kuwait are the giant Raudhatain and Sabriya fields and the smaller Ratqa and Abdalli fields. The project will allegedly be offered to international oil companies through technical service agreements.

PAKISTAN

OGDC has completed an oil and gas discovery on its Nashpa EL in the Potwar Basin. Nashpa 1 was drilled to a total depth of 4,384m and tested in three intervals in the Paleocene Lockhart Formation. The Middle Lockhart flowed 3,000 b/d of 38.8° API crude and 9.7 MMcfg/d on a 32/64" choke. Wellhead flowing pressure was 2,340 psi. The Lower Lockhart tested 145 bo/d (37.75° API) and 400 Mcfg/d on a 32/64" choke with a wellhead flowing pressure of 200 psi. The Upper Lockhart Formation is still to be tested. The well was targeting the Jurassic Datta, Shinawari and Samana Suk formations; the Cretaceous Lumshiwai Formation and the

Lockhart. Due to downhole structural changes, only the Lockhart Formation was encountered.

Oil flowed at the rate of 780 b/d, with 3.5 MMcfg/d, at an exploration well drilled by OGDC on the Sinjhoru EL in the Lower Indus Basin. Baloch 1 was tested in the 32.5m (net) Zone IV of the Cretaceous Massive Sand unit of Lower Goru Formation at 3,254-3,312m. Wellhead pressure was 880 psi through 32/64" choke. One of four zones tested, Zone I (3,409-3,425m), Zone II (3,351-3,359m) and Zone III (3,337-3,338m and 3,328-3,335m) proved to be water bearing. The well was drilled by the Great Wall Drilling Company 4 rig to a total depth of 3,463m.

QATAR

Qatar Petroleum (QP) has signed a five-year Exploration and Production Sharing Agreement (EPSA) for pre-Khuff Formation rights to the 5,649 sq km offshore Block BC with CNOOC. During the initial exploration period, CNOOC will conduct technical studies, acquire, process and interpret 2D and 3D seismic and drill three pre-Khuff exploration wells. It is believed the company will spend around US\$ 100 million to drill the initial three wells. Four offshore concession areas, A, B, C and D had been delineated for a deep exploration bid round initiative during 2008 but although a number of companies attended a data room in Doha, no bids are believed to have been submitted. Blocks B and C were subsequently combined and the deal with CNOOC is the first to be signed in the country that is dedicated to the exploration and production of hydrocarbons from deep pre-Khuff reservoirs.

GDF Suez is making its debut in Qatar exploration with the acquisition of Anadarko Petroleum's 60% interest in offshore Block 4, through the purchase of Anadarko Qatar Block 4 Company LLC. GDF Suez will assume operatorship of the block. The 3,132 sq km block is located

about 40km off the northern coast of Qatar and is adjacent to Anadarko's Block 12, where the Al Rayyan field produces about 17,000 bo/d. During the initial five-year exploration phase, work commitments included seismic reprocessing, acquisition of 2D and 3D data and exploratory drilling. GDF, which has been pursuing a strategy to increase its reserves through global expansion, is making good on an agreement it reached with Qatar Petroleum in January 2008.

SAUDI ARABIA

At its fourth attempt to find commercial reserves, South Rub Al Khali Company Limited (SRAK) said that its Kidan 6 well in the remote Rub' al Khali desert is a gas discovery. Drilled to a total depth of 4,572m, the well encountered two Jurassic, Arab Formation zones. One reservoir flowed up to 50 MMcfg/d of gas, with between 400 bc/d and 1,000 bc/d, while the other flowed at up to 40 MMcfg/d, with 500 bc/d to 1,250 bc/d. The Khuff section of the well was reportedly dry and this might well have led to the termination of drilling activities some 700m shallower than prognosed. SRAK's fifth and sixth wells Zaynan 2 and Umm Quloob 1 are to be active during the second half of 2009. Some question the validity of calling this well a gas discovery as it encountered gas in the Kidan North field reservoirs, the deeper pool objectives remain dry or untested.

SRAK, a 50/50 joint venture between Saudi Aramco and Shell, did not comment on whether the find was commercially viable. Analysts believe the tough commercial terms in the kingdom may prevent it from developing the find. The general view is that for a discovery in the desert to prove commercially viable, it needs to include a large share of condensates, which the companies can market at international rates, and have a relatively low proportion of hydrogen sulphide, which is expensive to process.

With thanks to IHS Energy
 For further information please contact
 Ken White or Stuart Lewis
 e-mail : ken.white@ihsenergy.com
 e-mail : stuart.lewis@ihsenergy.com
 web site : www.ihsenergy.com

Field Trip Report

Saiq Plateau February 2009

Prof. Janos Urai (GuTech)

26 February was a wonderfully clear day and so was the presentation by Jean-Paul Breton of his analysis of the Pre-Permian deformation in the Pre-cambrian rocks of the Saiq Plateau on Jebel Akhdar (Figure 1).



Figure 1 JP Breton explains structure

The tectonic evolution of Oman's basement is not fully understood and contributions to this theme are relevant for both hydrocarbon exploration and basic research. Jean-Paul's recent work here is timely and all participants had a keen interest in the

results!

The trip with 30 participants started at 8.00 at the fort of Birkat al Mawz. We drove up to the Saiq plateau and stopped briefly to look at the famous erosion surface, which is exposed around the town of Saiq (Figure 2). If it would be possible to date this (Pliocene? marine?) surface, we would get a much better constraint for the uplift history of Jebel Akhdar.

The main part of the field trip took us into the Salut and Masirat Ruwajih valleys, with impressively steep roads and an altitude difference of over 1000 m.

Spectacular views of the pre-Permian unconformity at the base of the Permian Saiq formation were followed by detailed study of the basement below this unconformity, in the pre-cambrian Mistal, Mu'aydin and Kharus formations. These show clear evidence of strong tectonic deformation, with fold-



Figure 2 Erosion surface around the town of Saiq

ed early ramps, m- to 100 m- scale folds depending on bed thickness and ma-

chizone and a fracture cleavage is only locally developed in relatively

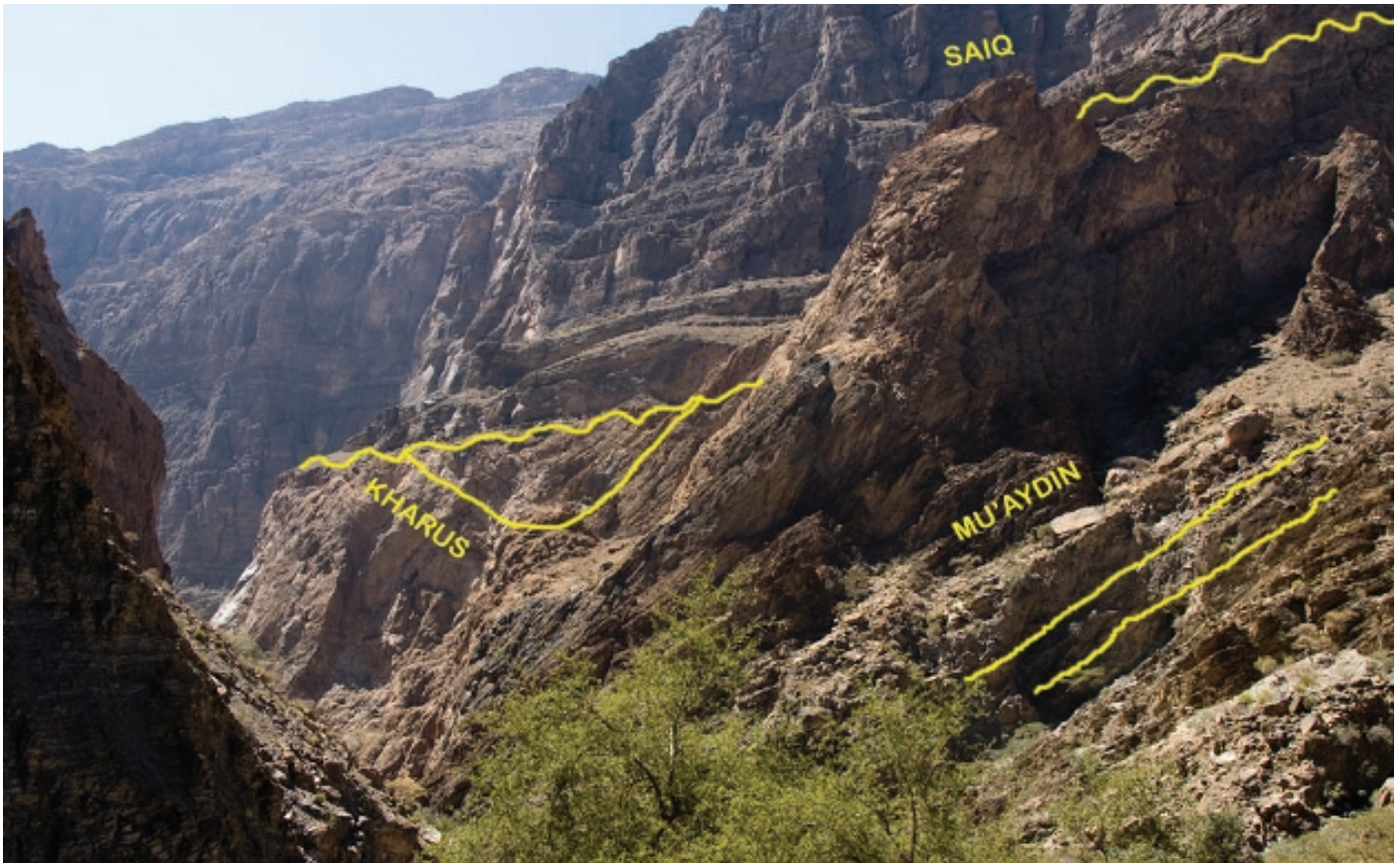


Figure 3 Fold below unconformity

major reverse faults, which postdate the folding (Figure 3). Metamorphic grade never exceeded an-

clay-rich siltstones of the Mu'aydin formation, in the core of tight m-scale folds - as demonstrated by frequent occurrence of pencil cleavage (Figure 4).

Vergence of this deformation is consistently towards the SE and this is consistent with structures in the other major windows in the Jebel Akhdar.

The structures we saw today are in fact very similar to those in low grade foreland fold and thrust belts like the Ardennes-Eifel or the Appalachians. Although these structures in Jebel Akhdar were mapped in earlier studies, their tectonic significance has not been fully recognized.

Jean-Paul concluded the day with a regional interpretation and



Figure 4 Purple siltstone with joints



Group Photo

synthesis, proposing a post- Buah and pre- Permian (Angudan?) orogeny by which much of Oman's basement has been influenced. Clearly much remains

unknown but this new interpretation is an interesting one..... Thanks again Jean-Paul for a wonderful trip and thanks Issa for organizing!

Field Trips

2009/ 2010 Season

November 5th	Structural Geology & Carbonate Facies in the Salakh Arch	Mohammed Kindy, Heiko Hillgartner & Redha Al Lawatia
November 19th	Salt Stringers in the Salt Domes of Central Oman	Zuwena Al-Rawahi
December 10th	Paleogene Palaeoenvironments	Ru Smith
Jan 7th	From Snowball Earth to Hothouse – Oman’s Distant Past	Joachim Amthor
January 13-15th	The Al Khlata & Gharif of the Huqf	Alan Heward
January 19th	Coastal Evolution along the Coastline of Oman - Tectonic Vs. Sea Level Forcing	Dr. G.Hoffman
February 11th & 12th	Sohar Copper Mines and Pillow Lavas of Wadi Jizzi	National Mining Company & Jan Schruers
February 25th	The Late Pre-Cambrian Fara Formation , Wadi Bani Awf	Carlos Fonseca & Jan Schruers

Lectures

November 24th	Western Europe Early Hydrocarbon Exploration (1850-1971)	Prof. Ken Glennie
December 12th	Petroleum Industry Sustainability	Prof. Patrick Corbett
December 19th	Oman GeoParks - Preserving Oman’s Geological & Natural Heritage	Prof. Mike Searle
February (TBA)	Alberta Oil Sands	Dr. Tariq Cheema
February (TBA)	The Late Pre-Cambrian Fara Formation , Wadi Bani Awf	Carlos Fonseca

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Geological Society of Oman
Post Box 993, Ruwi 112, Sultanate of Oman
E-Mail - Info@gso.org.om
www.gso.org.om