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New Geological Concepts in the Evaluation of the Southern Basins of Libya, with Particular Reference to the Al Sharārah Trend of the Murzuq Basin

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ABSTRACT

The oil accumulations discovered in the Ordovician Mamuniyat and Hawaz clastic reservoirs on the Al Sharārah trend of the Murzuq Basin have opened up a new exploration play of great significance. These discoveries, the majority of which were made during the 1990s and since the year 2000, demonstrate the importance of new geological concepts and highly sophisticated technology in increasing the reserves base of Libya. Although the oil-bearing Ordovician reservoirs of the Murzuq Basin had been on production from fields in the Algerian Illizi Basin since the 1960s the potential of these remote and difficult discoveries was not immediately realised. Among the factors that made it feasible for development to go ahead in the 1990s were new thinking about the reservoir development of these glacial and pre-glacial deposits and about the details of their depositional facies. Once the early discoveries were properly understood and the seismic technology was available, discoveries were made in fast succession extending the Al Sharārah trend eastwards. It is anticipated that the technical successes in the Murzuq Basin will encourage greater exploration efforts in Al Kufrah Basin using analogues derived from the Murzuq Basin and using technologies developed in its exploration and development.

INTRODUCTION

The oil accumulations of the Al Sharārah trend of Murzuq Basin, which lie in Licences NC115, NC186 and NC190, (Fig. 1), are reservoired in Ordovician Mamuniyat and Hawaz clastic reservoirs and sourced from the Tanzuft hot shales (El Hawat *et al*., 2000; Sikander, 2003). They exemplify, therefore, the *Tanzuft-Ordovician Sandstone* petroleum systems of the Murzuq Basin, accounts of which have been given by Boote *et al*. (1998), Craik *et al*. (2001) and Luning *et al*. (2000). These petroleum systems are also present in the Illizī Basin of eastern Algeria where significant oil accumulations were discovered in the Ordovician in the late 1950s and brought on production in the early 1960s (Boote *et al*., 1998).

In Libya, exploration was undertaken on the same play by Gulf Oil Company with drilling in concessions 67 and 68 primarily in the period 1958 to 1960. The concession 67 wells, drilled just to the west of the present Al Sharārah trend, had no oil shows but some gas shows. The concession 68 wells had oil shows in exploration wells A1-68 and B1-68. The appraisal wells A2- and A3-68 had what were considered mixed results, the first well being dry and the A3-68 well having further oil shows. Gulf undertook no further drilling on the B1-68 prospect and considered the three wells on the A-68 structure to demonstrate that this possible accumulation was uneconomic.

The results from Gulf well A1-68 may be summarised as follows - there were oil shows both in Devonian sandstones and in what was then termed the ‘Gargaf Quartzites’. Perforations in the casing over a 1000 ft interval through the Devonian to Ordovician interval were swabbed at the rate of 2 to 3 gallons of fluid per hour, 70% of which was 39 degree API oil. A 30 ft interval was tested within the ‘quartzites’ (which are now interpreted as Hawaz sandstones) lying immediately beneath the Tanzuft Shale and a small quantity of 38 degree API oil was obtained from this drill stem test.

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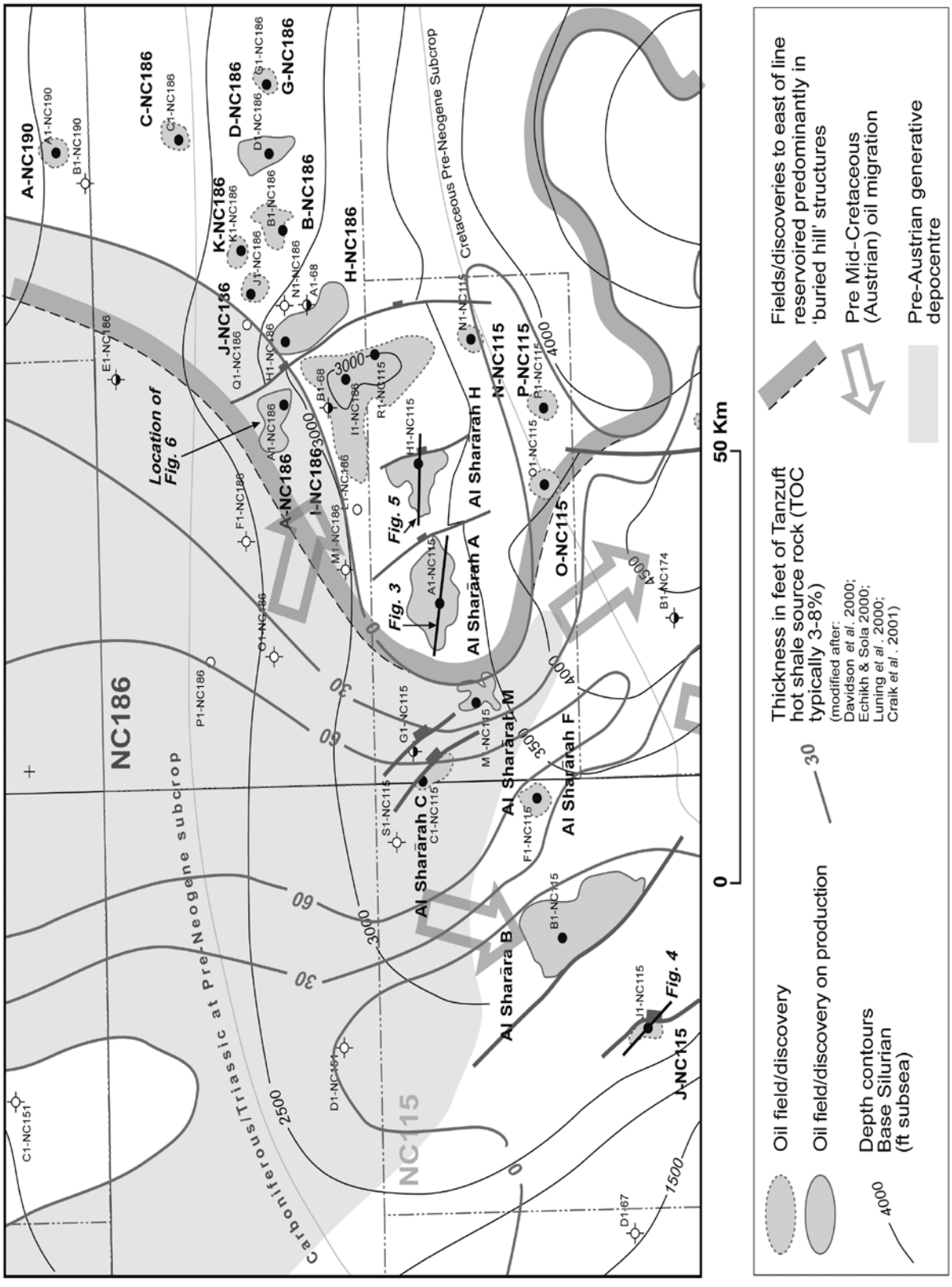

Fig. 1. Sketch map of the fields and discoveries of the Al Sharārah trend; these oil accumulations belong to the 'Northern Petroleum System' of the Murzuq Basin. Fields brought on production after 2006 may not be identified as such on the map.

AL SHARĀRAH TREND

No further drilling was undertaken on what was to become the Al Sharārah trend until the 1980s, although exploration had been conducted elsewhere in the Murzuq Basin by Braspetro and Occidental oil companies, mainly with disappointing results. The Romanian National Oil Company (Rompetrol) was awarded the NC115 concession in the Wādī al Ajāl in the 1980s and proceeded to drill in relatively easy terrain and in locations that were logistically relatively uncomplicated. Drilling commenced in 1984 and the first two prospects drilled (A1- and B1-NC115) discovered what are now recognised as the two giant oil fields (fields with greater than 500 million barrels of recoverable oil reserves) of the Al Sharārah trend. Seismic technology had improved greatly since the 1950s/60s when the concession 67 and 68 wells were drilled and large base-Silurian closures were readily identified. In 1985 and 1986 Rompetrol went on to discover three further significant oil accumulations at Al Sharārah C, J and H. Four and six appraisal wells were drilled at Al Sharārah A and B respectively.

Despite the promising results obtained by Rompetrol by the end of 1986 the nature of the complex reservoirs of these accumulations was still poorly understood and it was not until the 1990s following appraisal drilling by AGOCO oil company that the concession passed to Repsol to develop the field.

Repsol recognised the potential of the adjacent acreage lying to the northeast of NC115 and applied successfully for what is now NC186. In 2000 the first exploration well was drilled which discovered a significant accumulation at A-NC186, which is now on production. Exploration drilling on this trend followed rapidly and by 2005 nine discoveries had been made on the concession including the H-NC186 and the I-NC186 pools on which the old concession 68 wells had been drilled.

The H-NC186 oil field is located to the east of the A-NC186 field (Fig. 1). The structure, as defined by modern seismic data, is an elongate palaeotopographic hill aligned NW-SE, formed during the Ordovician glaciation and sealed by Tanzuft shales (Fig. 2). Oil was found in the Ordovician Hawaz Formation beneath the glacial unconformity. The location of Gulf well A1-68 is uncertain but it can be recognised now as having been drilled on the flanks of this structure as were the two appraisal wells A2 and A3-68. The A2-68 well, drilled 2 km to the north, was dry and the A3-68 well, drilled 1 km south of A1-68, reported oil shows updip of the A1-68 well. The position of these early wells is a reflection of the poor structural control available in the 1960s but it also illustrates that without modern seismic data differentiation of the stratigraphic units of the pre-Silurian section is very difficult. Since this is important in identifying the Hawaz Formation this is clearly of great significance. The results obtained from the Repsol discovery well H1-NC186 in 2004 contrast dramatically with those from the concession 68 wells. With a test result of 1300 bopd Repsol were in a position to recognise a significant oil accumulation. The three appraisal wells and 16 development wells drilled subsequently have demonstrated very great lateral variability in the reservoir however, the H3 appraisal well in the south having no reservoir.

The H-NC186 field has an average net pay of about 10 m and average porosity of about 12%. With recoveries typically of about 30%, this producing oil field has recoverable reserves of about 50 million barrels. Even if the A1-68 well had been better located and it had flowed oil, and even if the following two appraisal wells had been successful, it is probable that these reservoir properties would have been considered in the 1960s to have been unpromising and the structure would not have been further appraised. In the I-NC186 structure, on which B1-68 was drilled, the net pay is more like 4 m. In conclusion, therefore, the factors that made the H-NC186 structure a promising oil field development in 2005 and not in the 1960s are better seismic resolution, allowing well locations to be better judged, better understanding of the pre-Silurian sedimentary architecture and a recognition that the complex and heterogeneous reservoir can be developed.

NEW GEOLOGICAL CONCEPTS

The accumulations of the Al Sharārah trend lie on an ENE-WSW structural alignment, the traps of which are believed to have been charged mainly from the north prior to Mid-Cretaceous (Austrian) tectonics and inversion of the Al ʻAṭshān palaeobasin / depocentre (Boote *et al*., 1998). The pools have survived subsequent structural uplift and deformation. The trapping style comprises ‘buried hill’, fault bounded and anticlinal structures. The fault-bounded and anticlinal structures predominate in the west (Figs 3, 4) whilst the ‘buried hill’ style of trapping predominates in the east (Figs 5, 6).

The 1980s Rompetrol discoveries in NC115 were left undeveloped until the 1990s at least in part because of the difficulties associated with the heterogeneities of the Ordvocian reservoir. It was not until the 1990s under

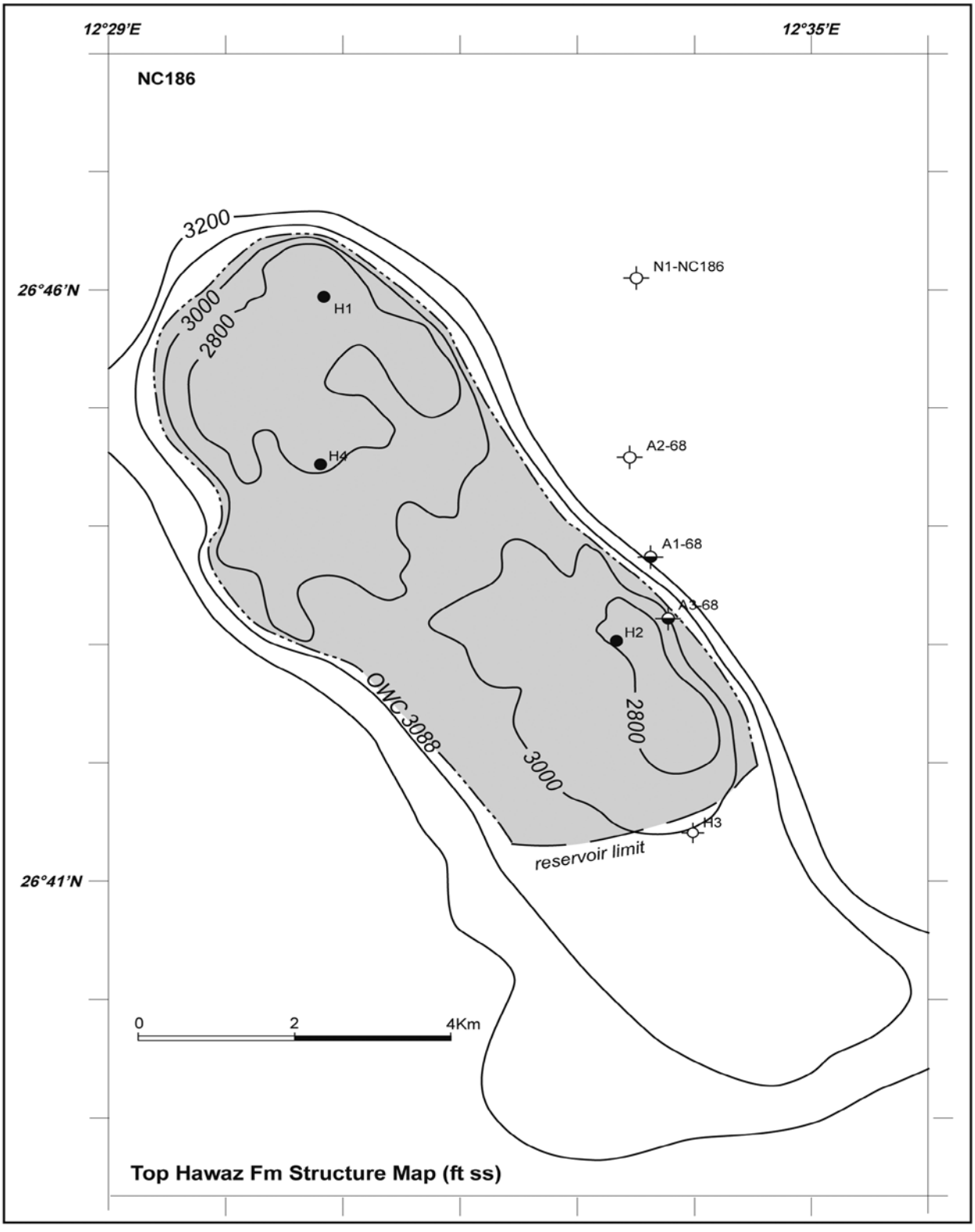

Fig. 2. Depth map on top Hawaz Formation of the oil-bearing H-NC186 'buried hill structure' showing approximate location of A1-, A2- and A3-68 wells. The correct location of these wells is uncertain. Wells H1- to H4-NC186 drilled by Repsol since 2003 established an oil accumulation with an area of over 10 000 acres, a crest at about 2720 ft below sea level and a gross oil column of at least 365 ft.

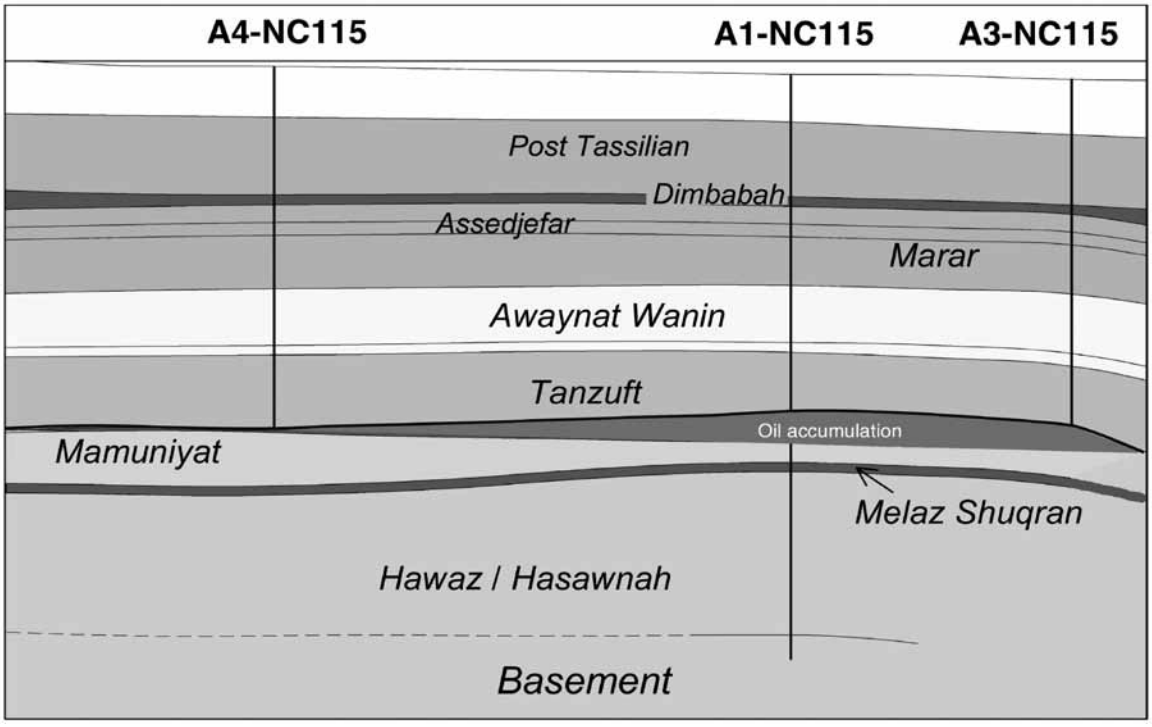

Fig. 3. Sketch cross-section through the Al Sharārah A oil field. For location see Fig. 1.

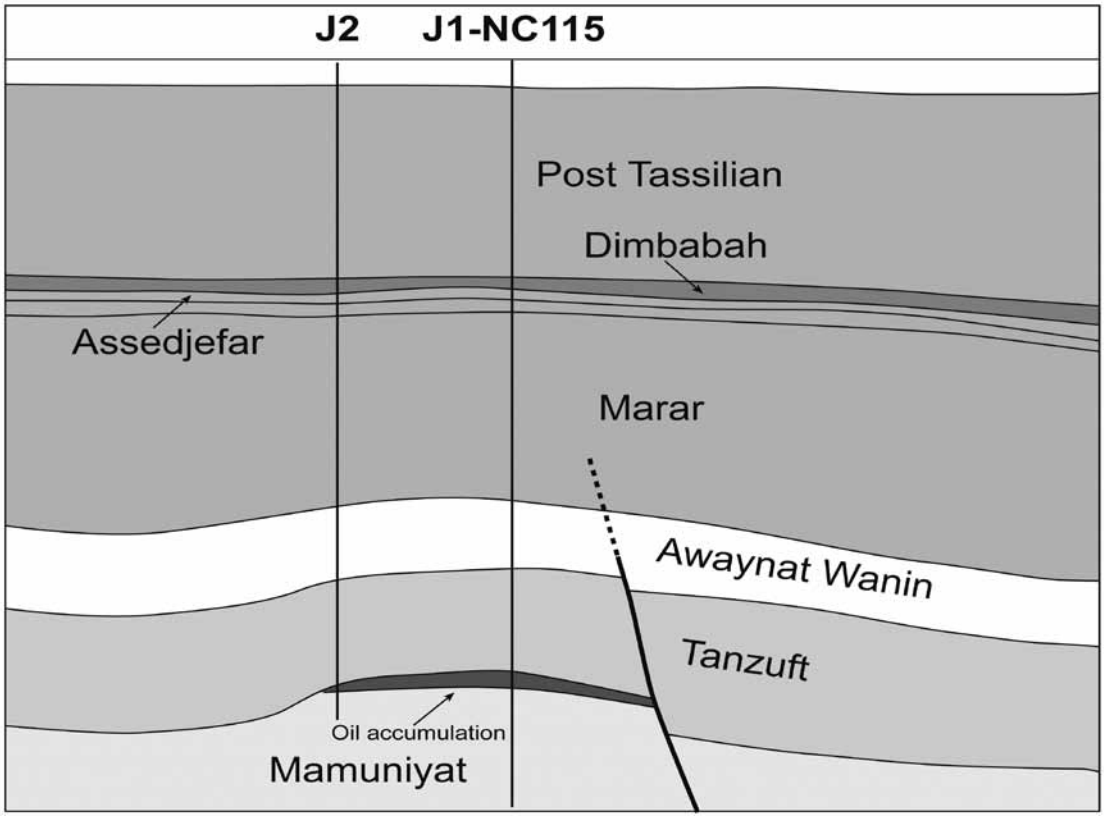

Fig. 4. Sketch cross-section through the oil-bearing J-NC115 structure. For location see Fig. 1.

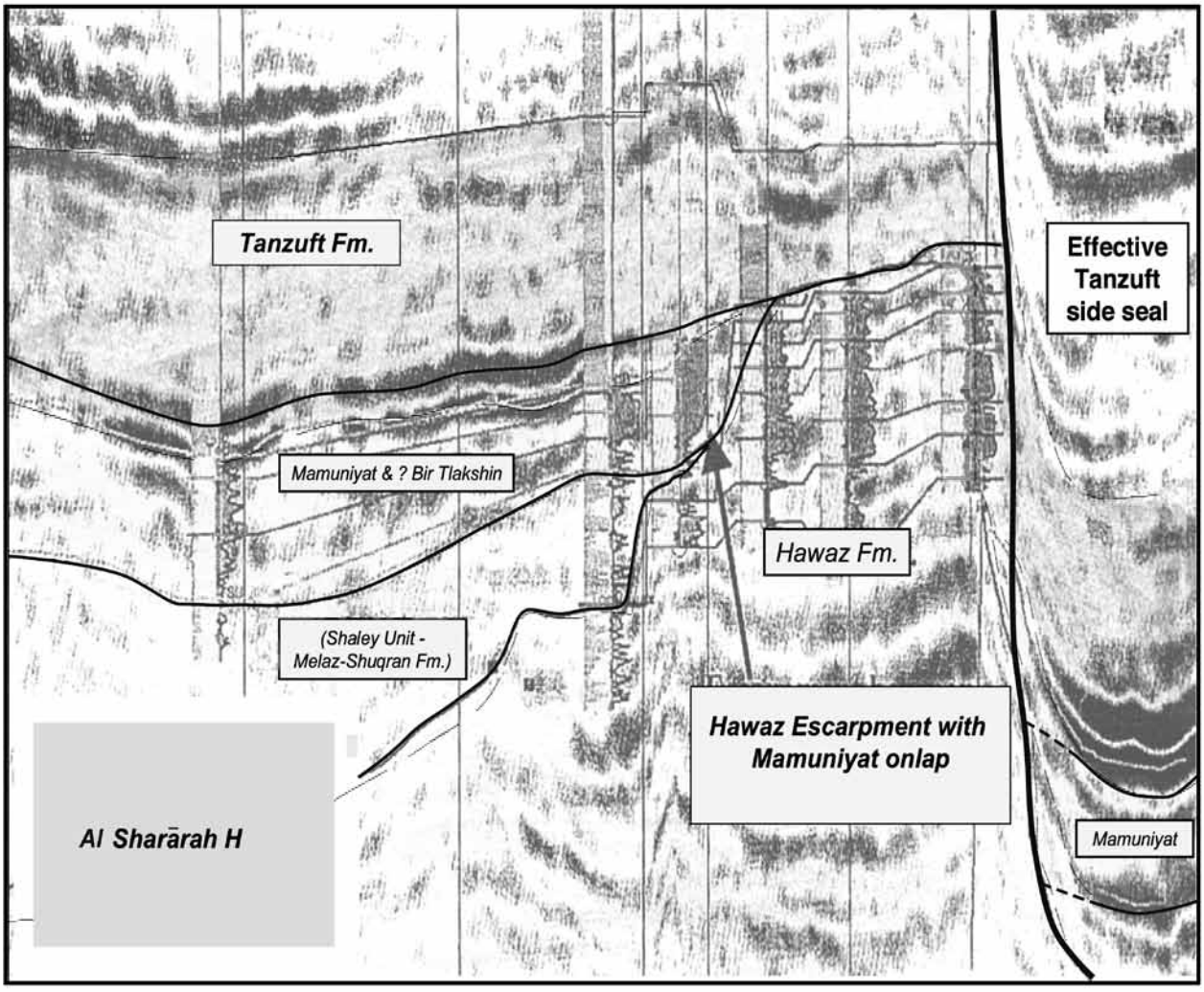

Fig. 5. Seismic character and well sections of Al Sharārah H field showing Mamuniyat beds onlapping a Hawaz 'buried hill structure'. Modified after Aziz (2000). For location see Fig. 1.

the operatorship of Repsol that development took place. What was not realised until that point was that the Gargaf 'quartzites' comprised a variety of facies of different ages including glacial clastic facies, some with permeabilities locally above 1 Darcy and that their distribution within structurally defined traps was extremely complex, the more porous facies commonly lying down flank (Fig. 5).

During the 1980s and 1990s these glacial deposits were studied in detail in industry-sponsored research projects and a diverse variety of glacial depositional facies were defined by reference to recent understanding of present-day glacial processes. These facies are described in Clark-Lowes (2008) in which the importance of glacial palaeovalleys is emphasised. In the western part of the Al Sharārah trend the facies are characteristic of central-palaeovalley positions (where hot shale development generally also occurs in the Tanzuft Formation –Luning *et al*., 2000) whilst to the east, the facies are characteristic of areas marginal to the palaeovalley (Clark-Lowes, 2005). In addition, improved seismic techniques allowed the complex palaeogeomorphology of the Late Ordovician glacial landscape to be imaged (Smart, 2000) (Figs 5, 6).

CONCLUSIONS

An attempt has been made to show how new geological concepts and sophisticated technology allow commercial discoveries to be made in areas previously dismissed and this has been done by reference to the history of discovery and development of the Al Sharārah trend and the NC186 H and I structures in particular. In these structures the wells drilled in the 1960s were not understood at the time;

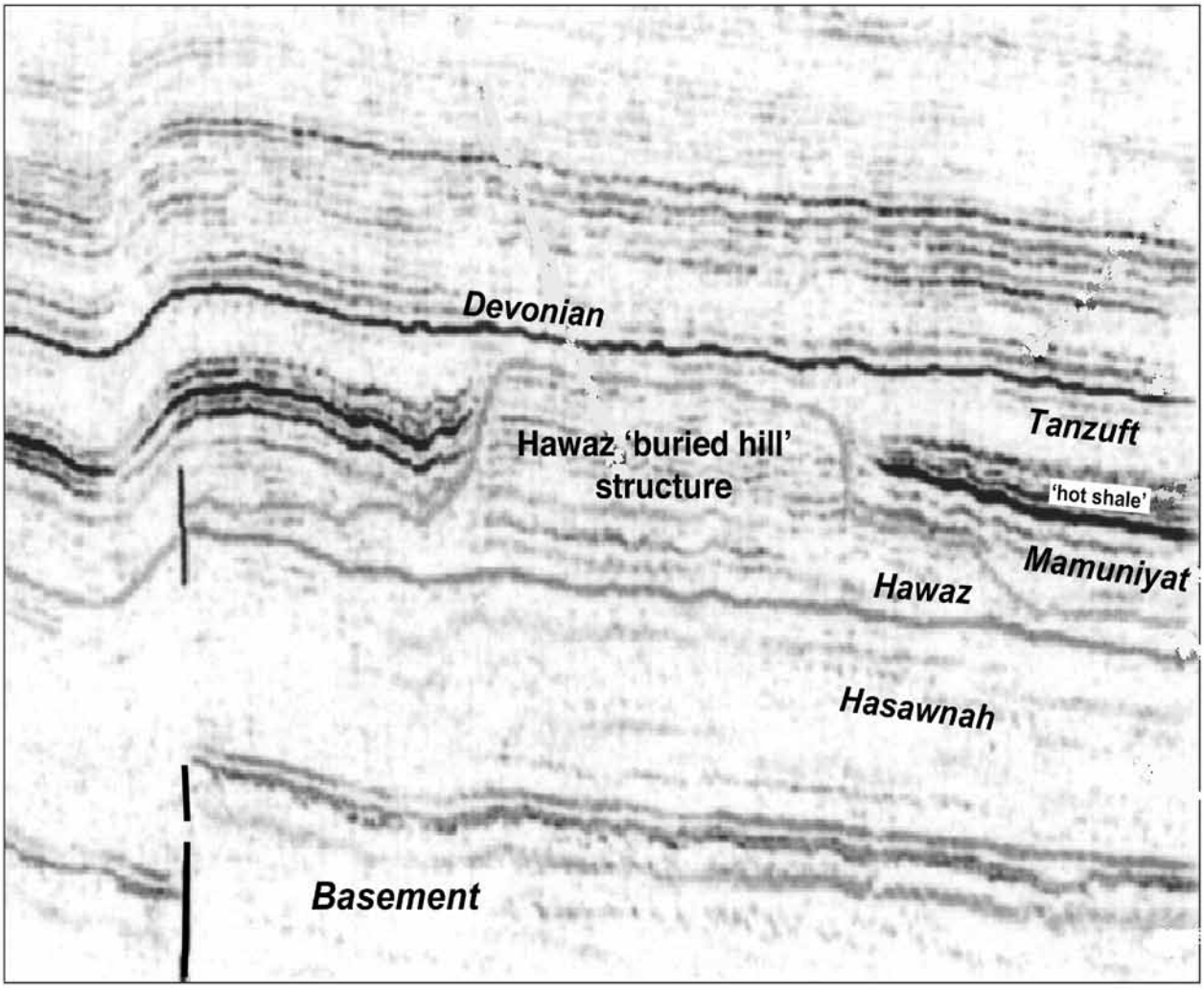

Fig. 6. Seismic section through the A-NC186 field showing Hawaz 'buried hill structure'. Modified after Craik *et al*. (2001). For location see Fig. 1.

analysis of subsequent exploration history reveals what changes occurred that allowed the area to be recognised as containing commercially attractive oil accumulations.

The basic factors that made the H-NC186 structure a promising oil field development in 2005 and not in the 1960s are better seismic resolution and better understanding of the pre-Silurian sedimentary architecture. However, perhaps the most important change was the development of economic and infrastructure conditions where multiple oil pools with relatively poor and or difficult reservoir properties and small reserves can be jointly developed to give a commercial result. The key factor here was the discovery of the Al Sharārah giant oil fields without which no pipeline infrastructure would have been provided to the Murzuq Basin.

Twenty oil pools have been discovered on the Al Sharārah trend, seven of which are currently on production. The Al Sharārah fields were brought on production from 1999 onwards and by 2005 production from the Al Sharārah trend was well over 200 000 bopd. The two fields of particular interest where 1960s wells were drilled are H-NC186 and I-NC186. The H–NC186 field was tied into the pipeline from D-NC186 to Al Sharārah A and came on stream in December 2006. It is claimed peak production of 40 000 bopd is achievable. The I-NC186 field was the subject of a development plan in 2006 and it is thought production of well over 20 000 bopd is achievable.

Based on a recent analysis of the proven oil-bearing petroleum provinces of Libya, the Murzuq Basin, with more than 3 billion barrels of recoverable oil, comes fourth. This is calculated in terms of originally recoverable reserves, the figures used being the most

likely case, or P50 case. Unsurprisingly the Eastern Embayment or Nubian province is larger, as are the Zalṭan and Āmāl platforms. However, the significance of the oil endowment of the Murzuq Basin is demonstrated by its position ahead of all the other petroleum provinces of the Sirt Basin and also those of the North West Offshore and the Ghadāmis Basin.

The oil exploration successes in the Al Sharārah trend of the southern Murzuq Basin will encourage greater exploration efforts in the other main southern basin of Libya, Al Kufrah Basin, using analogues derived from the Murzuq Basin and using seismic technologies developed in its exploration and development.

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