The Natih Petroleum System of North Oman

Katarina Borowski

Mining Academy Freiberg, geologic department, Bernhardt von Cotta Str.2, 09599 Freiberg, Germany

Abstract. The Natih petroleum system was deposited in the North Oman foreland basin in the middle to late Cretaceous (Terken 1999). Its present deformed habitat is due to continent ocean obduction in the north of the Arabian Plate and tranpressional movements of the Indian Plate along the Arabian Plate in the late Cretaceous (Loosveld et al. 1996). By having an extent of 20,000 km², it is one of the smaller petroleum systems in Oman but unless efficient. The generated petroleum has a volume of about 1.3x10⁹ m³ (STOIIP) and most is trapped in two giant structures called Natih and Fahud (Terken 1999). But there are some minor important oil shows as well that are seen as future reservoir targets.

Introduction

Oman is situated on the eastern margin of the Arabian Plate and is bounded by the Gulf of Aden spreading zone in the south, the Masirah Transform Fault in the east and the Oman Mountains (Semail Ophiolite) in the north (Loosveld et al. 1996). The Natih Formation is one of Omans Cretaceous Petroleum Systems and is located in the North Oman foreland basin in between the Oman Mountains and the peripheral bulge (see studied area, Figure 1).

Most of the generated oil can be found in the major fields Fahud and Natih that were discovered in the 1960s. Together, they hold an oil volume of about 2.45x10⁸ m³. But by now, only nine percent of the generated hydrocarbons were discovered in this area (Terken 1999).

There are some minor economic oil shows as well. In the 1970s and 1980s, truncation traps in the Maradi Fault Zone were targeted unsuccessfully and supposed stratigraphic traps (turbidites) along the gentle slope of the foreland basin remain uncertain because of the high exploration risk (Terken 1999).
Regional Geology

From the Early Jurassic to Late Cretaceous, Oman was situated in a regressive system tract due to the opening of the Neo-Tethys by the break-up of Gondwana (Hughes-Clark 1988; Le métour et al. 1995). Therefore, it was a site of carbonate deposition and the Natih Formation represents the youngest prograding sequence of this succession (van Buchem et al. 1996).

With the opening of the Atlantic Ocean 110 Ma ago caused by the first Alpine tectonic event, the Neo-Tethys between the Afro-Arabian and Eurasian Plates was closed again and ended the carbonate deposition (Dercourt et al. 1986). The uplift of the Natih Formation in the Early Turonian is noticed by local erosion and karstification of the top (Terken 1999).

The compressive setting led to the formation of a northeasterly dipping intra-oceanic subduction zone (Glennie 1995) which collided with the Oman continental crust 93 Ma ago (Lippard et al. 1986). The results were the obduction of oceanic crust (Semail Ophiolite) and the formation of the North Oman foreland basin (Terken 1999). It is bounded by a peripheral bulge that slipped in extensive erosion later (Terken 1999) and led to a hiatus of the Natih formation in this area (Fi-
Fig. 2. Tectonic evolution of the foreland basin in North Oman (after Terken 1999)
Figure 2). Due to the initial underfilled character of the foredeep (Boote et al. 1990; Warburton et al. 1990), large amounts of Fija Shale were deposited by gravity glide there (Glennie et al. 1974; Warburton et al. 1990). The huge sediment load within the foreland basin led to subsidence and local flexural extension of the continental crust (Bechennec et al. 1995; Loosveld et al. 1996).

The combination of the compressive collision setting and the sinistral transpression at the eastern margin caused by the northwards drift of India (84 Ma), led to the formation or reactivation of conjugate sets of strike slip faults in north Oman (Mountain and Prell 1990; Ries and Shackleton 1990; Peters et al. 1995; Loosveld et al. 1996).

In the late Cretaceous the deformation stopped abruptly when a new subduction zone developed offshore Iran (Le Métour et al. 1995). A global regressive event was initiated and formed the regional Base Tertiary unconformity (Skelton et al. 1990). During the Early Cenozoic the foreland basin sedimentation remained uninterrupted while producing uniform sequences of clastic and evaporitic deposits (Loosveld et al. 1996).

With the onset of the second Alpine tectonic event 34 Ma ago (Figure 2), the Oman Mountains were uplifted to their culmination collapse, forming large extensional structures (Mann et al. 1990). In addition, several normal faults like the main Natih fault were inverted (Loosveld et al. 1996).

Reservoir Properties

Stratigraphy

The 400-meter thick Natih Formation consists of carbonate deposits mainly. It is divided into seven litho-stratigraphic units: A-G, whereas the units A/B, C/D and E represent the major sedimentary sequences (Figure 3).

The A/B and E units are quiet similar in habit. They consist of bioclastic grainstones in the upper part and shaly limestones rich in organic matter in the lower part. Within the transgressive lower interval of these cyclic units, clayey marls can occur as well. These units show a notable facies variation (Terken, 1999).

The C/D unit is strongly clay-rich and uniform in facies (Terken 1999).

Source rocks

There are two main source rocks located within the Natih Formation (Figure 3). And although deposited in an intra-cratonic basin on the Arabian Plate, the source rocks have always been connected to the Neo-Tethys in the northwest (Murris 1980) and therefore consist of Kerogen types I and II (Figure 4b). These Types tend to generate oil mainly but Type II generates gas either. The extent of the
source rock is limited by a platform carbonate rim facies (Van Buchem et al. 1996) and the maximum burial depth is about 3000 meters in the foreland basin (Terken 1999).

Fig.3. Natih-3 well log showing the major sequences and litho-stratigraphic units (after Terken 1999).
The lower source rock is located in unit E and has mediocre quality due to the total organic carbon content of rarely 5% (Figure 4a). The 50 meter thick source rock within unit B is of excellent quality because of the total organic carbon content of at most 15% but in average of about 5% (Terken 1999).

The gas generation from Kerogen type II within the Natih source rock is limited. Only in the deepest areas of the foreland basin, the gas generation started in the Late Tertiary. It is not trapped but migrates within the Natih Formation to the surface in the Salakh Arch and flows out (Terken 1999).

**Maturity**

The present source rock conversion has reached 90% in the deeper parts of the foreland basin and 40% along the shallower Maradi Fault Zone (Terken 1999).

The Vitrinite Reflectance Estimation VRE (Figure 5) derived from biomarkers is about 0.73 for the Fahud Field and of about 0.88 for the Natih Field (Terken 1999). The obvious difference in oil maturity is because of the Fahud Field is filled up with hydrocarbons of the just-mature source rock of the Lower Tertiary and it lacks a connection to the still active oil kitchen in the present (Visser 1991). Whereas the Natih Field still is connected to the active oil kitchen and the now highly mature source rock that is generating more mature oil (Terken 1999).
Reservoir rocks

Most of the generated Natih Oil was trapped in the Natih Formation itself (Figure 3; Terken 1999). There are three major hydrocarbon reservoirs that are all similar in their porosity/permeability relationship (Whyte 1995). The porosity is primary as well as fracture-related. In the Fahud field, the porosity is up to 40% and in the Natih field 30% porosity was noticed (Terken 1999). The permeability is low but intersected by local dense fracture zones (Whyte 1995).

Due to an early formation of the Fahud Fault, Natih Oil is now absent from the southern areas. In the Middle Tertiary, the Natih Fault developed in the North and captured the oil to the Fahud Field (Terken 1999). Therefore Natih Oil in the Fahud Field is of Early Tertiary age and has migrated around 40 km but lacking a present connection to the active oil kitchen (Terken 1999). Otherwise, the Natih
Fault Field is still connected and has short migration paths around 20 km (Terken 1999).

**Caprock**

The seal of the Natih Petroleum System is a series of deep-marine shale of the Fiqa Formation. It overlies the Natih Formation in the most parts of North Oman and is an excellent caprock in thickness and permeability properties (Terken 1999).

**Conclusion**

The Natih Petroleum System of North Oman is the most efficient petroleum system in Oman although being of small extent.

Several factors lead to its extreme efficiency. The foreland basin went through a moderate structural deformation only during basin during Alpine tectonic events. The deformation was damped by a subsurface detachment which led the compressive stress along wrench faults without affecting the foreland basin but resulting in large structural closures. Therefore the migration of the generated hydrocarbons remained mostly lateral that is by fact more efficient due to better permeability properties along fault zones than in horizontal sections. The continuous connection to an active oil kitchen of high maturity within the Natih Formation is of importance as well as the excellent intra-formational source rock. The impermeable thick Fiqa Shale forms an excellent and efficient seal because it was deposited before the hydrocarbon migration started.

The further prospecting of hydrocarbon charge will involve the more uncertain reservoirs like the Fiqa turbidites. Despite being close to the mature oil kitchen, these turbidites are unknown in extent. Other underexplored potential hydrocarbon bearing structures are the faulted truncation traps along the northeast flank of the peripheral bulge (Terken 1999).

**Definition**

The term petroleum system was introduced by Demaison & Huizinga (1991) as “a dynamic petroleum generating and concentrating physico-chemical system functioning in geological space and time”. It can be subdivided into one or several plays.

The abbreviation STOOIP is the stock tank originally oil in place. It is calculated by the volume of the initial oil in place within the reservoir divided by the oil for-
mation volume factor, a conversion factor, to receive the amount of oil at surface conditions.

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