Tasour Field, Republic of Yemen Block 32: Case History of a Decade of Learning*

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Introduction

The Block 32 development area is located in the Hadramaut region, south-central Yemen, adjacent to the prolific Nexen/Occidental Masila fields which contain total reserves of more than one billion barrels (Figure 1). Block 32 was awarded to Clyde Petroleum in 1992 and had a succession of partners over the next 10 years. The Tasour-1 discovery was made in late 1997, following over 1500 km of 2D seismic and 5 dry holes. The area is characterized by a highly dissected dendritic drainage pattern of jebels (plateaus) and intervening wadis (valleys) superimposed upon gently dipping block-faulted Jurassic/Cretaceous/Tertiary sediments of the Say'un-Masila basin. The area presents unique operational challenges typified by 300-m vertical limestone cliffs and temperatures of up to 60°C. Lower Cretaceous Qishn sandstones form the principal reservoir with porosities up to 23 % and permeabilities up to 2-3 darcies. The oil (29° API) is sourced principally from the underlying Jurassic Madbi shales and collected in a simple faulted trap, characterized by isopach/isochron thinning which is indicative of early structuring. Sealing thickness of approx. 135 m requires a bounding fault displacement of less than 60 msec. to avoid breaching the trap. This paper illustrates the unique problems encountered in understanding the Tasour field (primarily structural) and the solutions achieved after a decade of trial-and-error learning.

Regional Setting and Geology

There are three major NW-SE trending sedimentary basins in central Yemen, two of which are very prolific petroleum provinces (Figure 1). The westernmost Marib/Shabwa basin, principally filled by pre/syn/post-rift Jurassic - Lower Cretaceous carbonates, clastics, and evaporitic sequences, is characterized by complex salt tectonics and listric faulting. The central Say'un-Masila basin, principally filled by Middle-Upper Cretaceous open-marine carbonate/clastic sequences, is characterized by flat-lying (post-rift thermal sag) strata and simple extensional block faulting. The younger Jeza basin is dominated by Upper Cretaceous-Tertiary sediments with no commercial hydrocarbons discovered yet.

These basins are separated by the Mukulla and Fartaq highs, respectively, and are bounded to the north by the Hadramaut arch.

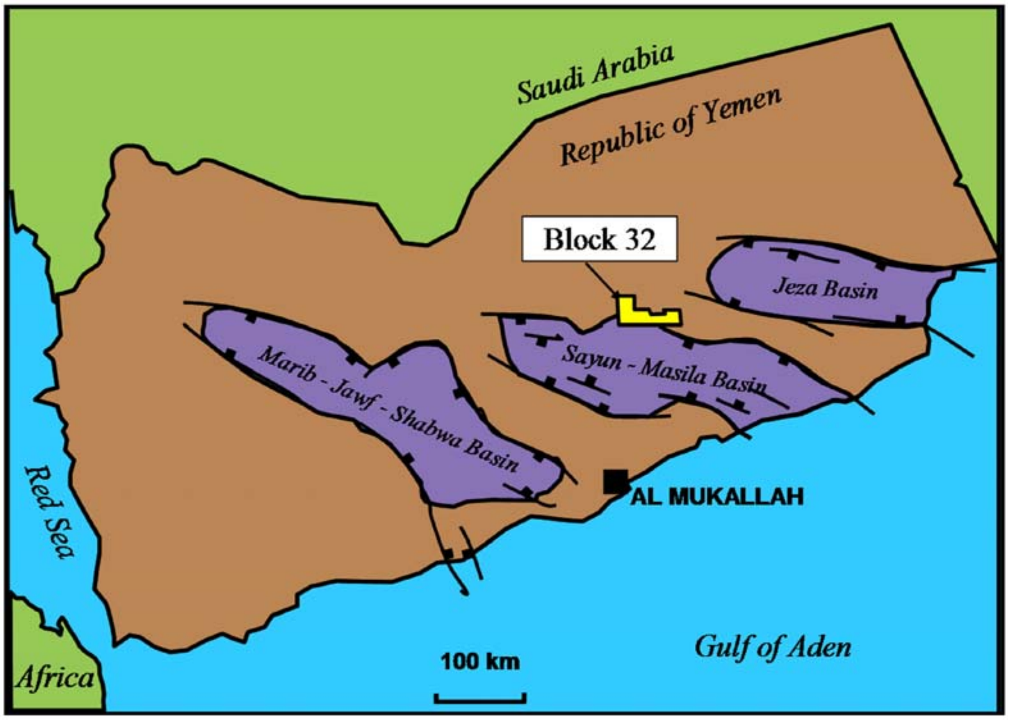


Figure 1. Location map of Block 32 on the north side of the Sayun-Masila basin, Hadramaut region. The Sayun- Masila basin contains fields totaling over one billion barrels. The Marib-Jawf-Shabwa basin contains fields totaling over 900 million barrels and 16 trillion cubic feet of gas.

Block 32 sits on the northern edge of the Say'un-Masila basin to the south of the Hadramaut arch. Upper Jurassic/Lower Cretaceous pre- and syn-rift sequences include basal Kohlan clastics, shed from surrounding crystalline basement highlands, followed by massive carbonate/shale/carbonate (Shuqra/Madbi/Naifa/Saar) sequences acting as both source and reservoirs. Lower Cretaceous fluvial/estuarine deposits of the Qishn Formation (Putnam et.al., 1997) form the principal reservoirs. These are overlain by thick Middle Cretaceous clastics/carbonates composing the Harshiyat, Fartaq, and Mukalla formations. These are unconformably overlain by the massive Lower Tertiary carbonates of the Umm Er Radhuma (UER) and Jeza formations, which are exposed in spectacular 300-m vertical cliffs in the wadis.

Although the Qishn Formation accounts for the majority of the oil reservoirs found to date, important sub-Saar prospects are found in the Sayun-Masila Basin, including debris/turbidite fans, grainstone shoals, basal sandstones/syn-rift breccias and fractured basement (Oil & Gas Journal, 2001). Although no hydrocarbons have been found to date in these reservoirs in Block 32, they are still prospective.

It was also found in the early 1990's that surface UER Formation structures usually mirror the underlying productive Qishn Formation structures (Glazebrook, personal communication). At first glance, this would seem somewhat contrary to the isopach thinning prerequisite as structures without thinning are recent (post-migration) and always wet. Accurate regional UER structural mapping was not possible until very high resolution satellite images became available. The 2002 SPOT5 satellite images, with a resolution of better than 2.5 m, permit construction of an accurate Digital Elevation Model (DEM) and seismic elevation/static model; also, they are useful for development assessment. The SPOT5-derived UER surface structure map for Block 32 was constructed by combining the DEM with spectral analysis of the satellite images (Harris, et. al., 2003; Thompson, 2002). The Tasour field is one of several in the area without a definitive surface closure.

Seismic Acquisition/Processing Problems and Solutions

The rugged topography presents an extreme challenge to seismic acquisition and processing. Otherwise, seismic interpretation is quite straightforward with only five reflectors of significance corresponding to Fartaq carbonate, Qishn carbonate, Qishn Red Shale, near S1 sand and Saar carbonate. Heli-portable dynamite crews are utilized in seismic acquisition in the majority of the area. Data quality is severely compromised by the topography and typically 100 fold is required to surpass noise. The exception is in the wadis where excellent data quality is the norm. Seismic acquisition methodology has evolved in a circular manner. The late 1980's to early 1990's saw straight lines, regardless of surface difficulties. These were typically poor quality and noisy due to low fold at wadi-jebel crossings and limitations of the elevation static models (refraction statics do not work). Acquisition in the mid-late 1990's attempted to stay either on top of the jebels or down in the wadis, or minimized the crossings by circuitously following the topography. This was intended to minimize the elevation/static corrections but often resulted in highly crooked lines. Crooked line bin-scatter resulted in arbitrary line positioning which made fault location inaccurate and generated misties at depth. Differently binned versions of the same seismic line could be up to 500 m apart. It was also found (Mills, 1992) that geophone placement on certain formations, notably the upper Jeza and UER limestones, produced very noisy records due to geophone coupling and/or absorption problems, whereas the Jeza shales produce better records. The Jeza, however, is often represented by steeper slopes, which hamper the layout of complex receiver patterns.

Early acquisition parameters were also quite simple, relying on short shot-and-receiver group intervals to build fold. Some areas defied acquisition of good data even with few jebel-wadi crossings. The nature of this acquisition noise was eventually identified and successfully addressed. Complex shot-receiver patterns were developed specifically to attenuate high-amplitude reverberation from the vertical jebel walls (Nickoloff and Manatt, 1997). These patterns, although challenging to administer in the field, are reliable and still provide the best data quality attainable.

Early on, it was found that refraction static corrections could not be made because only lines in the wadis had any identifiable first breaks. Without refraction statics, the DEM derived elevation/static model is central to the ultimate usefulness of the seismic data. Static models with up to five layers have been attempted, but two layers are now found to be adequate. Incorporation of the 2002 SPOT5 satellite-derived UER/DEM structure model has added significantly to proper elevation static corrections, especially in older data where field-mapped geologic profiles were not acquired. The UER Formation has a uniform thickness and its base corresponds to the base of the elevation/static model. The DEM, coupled with the overall improvement in processing technology and innovative new techniques, has extended the upper frequency limit from 30 to 70 Hz. This is significant because the three principal reflectors (Qishn top, Red Shale and near S1 sand) are all very close together and exhibit tuning effects. A typical wavelet has a peak breadth of approx. 10 msec. The frequency differences between older and newly processed lines, while seemingly small, are quite significant because 5 msec. of 2-way time translates into approx. 16 m depth at Red Shale level. In practice, higher frequencies often degrade the 'mapability' of events by obscuring the principal (tuned) reflectors with excessive detail.

Initial mapping of the Tasour field indicated a fault-bounded anticlinal structure. It was not until the crooked line binning issues were re-examined that the concept of *fault-shadow* effects were considered. Fault shadows are typically manifested as anomalous time pull-down of seismic events below the fault plane. This effect can be removed to a large degree by prestack depth migration. Figure 2 illustrates a typical seismic dip line before and after prestack depth migration. The removal of the anomalous time pull-down effect has had a dramatic effect on the structural interpretation of the Tasour field and has thereby removed the greatest uncertainty in estimating ultimate recoverable reserves.

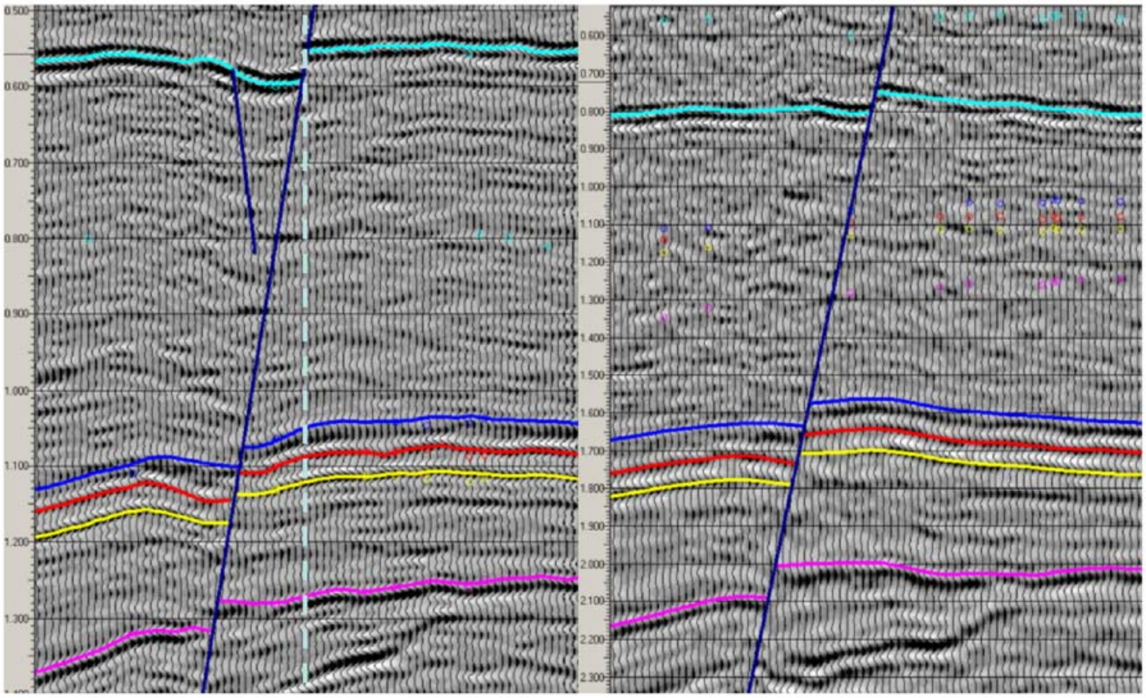


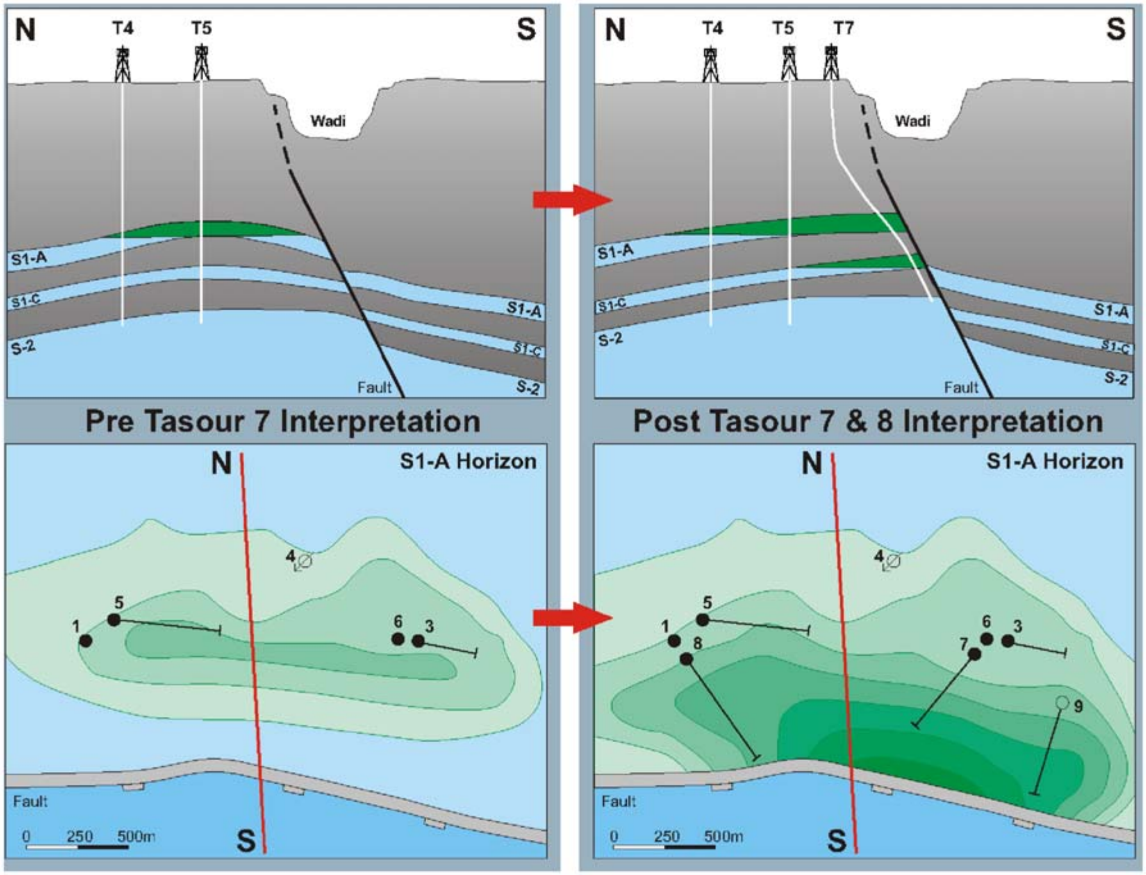
Figure 2. Seismic time section (left) showing typical pull-down of events in the fault-shadow (area to the left of the dashed line and below the fault plane) and the same line after pre-stack depth migration (right). Upper blue event corresponds to the Upper Cretaceous Fartaq carbonate marker; yellow event is approximately the Qishn S1 sand, and the lower magenta event is the Lower Cretaceous Saar carbonate.

Reservoir/Production Issues

The Qishn reservoirs throughout the area usually out-produce initial reserve estimates. Primary recoveries can exceed 50% due to exceptional reservoir properties and an active water drive. Porosity typically averages 22% and permeabilities range from 2-3 darcies, eliminating much of the risk usually associated with reservoirs. The very strong water drive (up to 1300 psi) provides a natural water flood resulting in the exceptional primary recovery factors. Produced water is re-injected into the Qishn Formation for additional pressure support. The production rates on the Tasour field to date are far better than expected. This is in part explained by conservative estimates for the recovery factors. The greatest impact was the resolution of the structural uncertainties leading to the drilling of several crestal wells. These wells are in a position to allow the natural water drive to push the oil to them and maximize recoveries. The Tasour field is located approximately 60 km from the Masila Central Processing Facility operated by Nexen. Tie-in of the 8-inch 25,000 Bbl/day pipeline was fast-tracked and on stream in only 11 months. As of mid 2003, Tasour had produced in excess of 10 MMBO, and production has continued to climb with successful field delineation.

Summary

The Tasour area presents unique exploration/development challenges that have been met over the past 10 years by successful trial and error. Seismic acquisition has now reached the point where very good quality 2D data can be expected with careful field procedures. The Tasour field continues to grow in size with each additional well and is now approximated at 21 MMBO recoverable (38 MMBO in place). Several new prospects have been delineated with the current evolved methodology. Resolution of the fault shadow issue has significantly enhanced the pool size. Earlier interpretation as a faulted anticlinal structure has been replaced with a more typical rotated fault-block interpretation without significant rollover into the fault, as shown in Figure 3.



Pre Tasour 7 Interpretation

Post Tasour 7 & 8 Interpretation

Figure 3. The Tasour field pre (left) and post (right) drilling of wells Tasour 7 and 8 which tested the fault shadow hypothesis after prestack depth migration of seismic data.

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