Petroleum Systems of the Berkine Basin, Grand Erg Oriental, Algeria

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ABSTRACT

The Ghadames Basin covers an area of approximately 250,000 km2 in Algeria, Tunisia and Libya. Maximum thickness of sedimentary section in the basin is reached in Algeria where as much as 7000m of mixed clastic and carbonate sedimentary rocks are preserved locally. The Algerian portion of the Ghadames Basin has recently been renamed the Berkine Basin and has been the focus area for exploration activities and major new hydrocarbon discoveries in the past decade. Earliest hydrocarbon exploration in the basin occurred in the early 1960's and up until the mid 1980's the basin was thought to have little potential for significant future discoveries. Opinions quickly changed following the discovery in 1992 by Cepsa of the Rhourde El Krouf field which tested oil at rates in excess of 2500 bopd from stacked Carboniferous sandstone reservoirs. Continued success followed with the discoveries by Anadarko and partners of the El Merk, and Hassi Berkine fields and Cepsa and partners of the giant Oughroud field, all of which tested high quality oils from Triassic sandstone reservoirs. Burlington Resources and Talisman Energy began exploration within the Berkine Basin Block 405 in 1995 with the drilling of the MLE –1 well which flowed oil from the Triassic and Strunian reservoirs. In 1996 the MLN –1 well was drilled and tested 15,850 bopd from the Triassic. A follow-up well drilled in 1997, MLN-4 tested a total of 22, 700 bopd and represented the first significant Strunian reservoir test. Success has continued through to present with wells such as MLSE-3 testing at a rate of 21,857 bopd from the Triassic, Carboniferous and Strunian reservoirs. Sonatrach notes recent successes in the Berkine Basin have accounted for as much as 84% of the reserve additions for Algeria on a yearly basis.

The stratigraphic succession in the Berkine Basin is comprised of a Paleozoic package which sits on Pan-African basement, beginning with the fluvial-glacial deposits of the Cambro-Ordovician. A widespread transgression in Silurian times resulted in the deposition of the Tannezuft shales which represent one of the main source rocks in North Africa. Several transgression/regression cycles resulted in continental deposition over much of the area during the Late Silurian and Lower Devonian which was followed by marine deposition through to Carboniferous times. Widespread uplift in the Hercynian resulted in a regional angular unconformity upon which the Triassic Argillo-greseux (TAG)continental sandstones were deposited. Transgression throughout Jurassic and Cretaceous times resulted in deposition of a relatively thick evaporitic and carbonate sequence that forms the ultimate top-seal in the Berkine basin. The entire sequence is capped by Miocene to Pleistocene clastics.

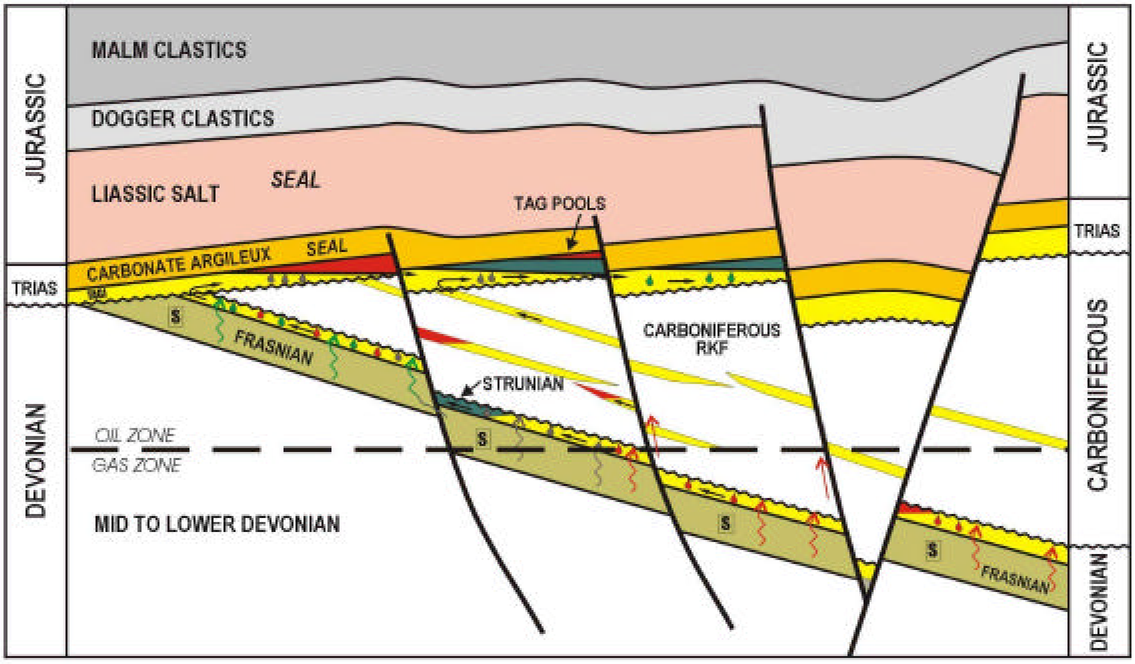
Within the Berkine Basin the petroleum system is thought to be characterized by two source rocks, the Silurian Tannezuft shale and the Devonian (Frasnian) F4 or Meden Yaha shales. In Block 405 the main source thought to be active is the F4. This source is dominated by a

mixed Type I/II kerogen and has up to 100 m of “hot shale” with TOC ranging from 10% to 15%. Within Block 405, the F4 source interval is at depths consistent with a range in maturity from onset of oil generation to early gas generation.

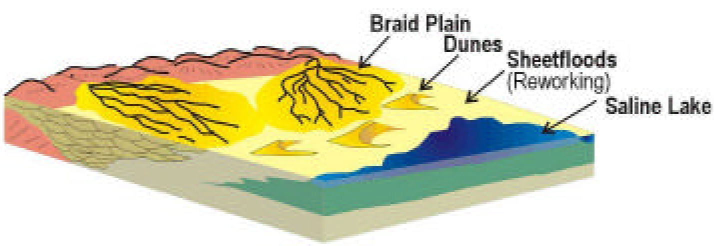
Finite strains within the Berkine Basin are a product of a number of tectonic phases beginning with the amalgamation of the Pan-African continent and concluding with the Austrian tectonic phase. Early sutures and faults acted as planes of weakness during subsequent tectonic events and were reactivated in a host of fashions, ranging from pure extension, through transtension to pure compressional inversion, dependant primarily on the original orientation of the planar anisotropies. In the southwestern Berkine Basin the main trapping mechanism for the Triassic reservoirs is extensional faults with offsets which range from tens to hundreds of metres. These faults appear to have originated from a Late Triassic to Jurassic reactivation of earlier formed structures and are often subtle and nearly unidentifiable on seismic data which was acquired prior to the mid-1990’s. As a consequence 3D acquisition has become the norm and the area is now host to what is thought to be the largest continuous on-land 3D survey in the world, covering well in excess of 2000 square kilometers. The trapping mechanism for Strunian reservoirs appears to be a result of a combination of structural and stratigraphic elements.

To date, the primary reservoir has proven to be the Triassic Argillo-greseux Inferieur (TAGI) which has been described throughout the area as being mainly fluvial to alluvial and locally, aeolian in origin. TAGI sandstones typically have porosities ranging from 13% to 18% and permeabilities from 40 to 90 millidarcies, with thickness varying from 50 m to in excess of 100 m. Proven secondary reservoirs exist in the Strunian F1 and F2 transitional marine and Carboniferous Rhourde El Krouf (RKF) fluvial-deltaic sandstones. The F1 and F2 reservoir sandstones are typically relatively thin (10m) but highly productive, with porosities ranging from 18% to 25% and calculated permeabilities in excess of 200 millidarcies. Reservoir sandstones of the RKF unit are an important oil bearing reservoir in the Rhourde El Krouf field, which has approximately 500 MMB of oil in place. Locally the RKF sandstones have excellent porosities ranging from 20% to 25% with permeabilities of several hundred millidarcies. Hydrocarbon migration for the Strunian reservoirs is believed to be initially vertical from the F4 into the Strunian carrier beds and then laterally between fault compartments towards the western up-dip pinch-out and/or truncation of the reservoirs. The area where the TAGI reservoir unconformably overlies the Strunian carrier beds and the F4 source rock provides a focus for hydrocarbon charge. Gentle tilt of the Triassic reservoirs down to the northwest determines that the migration pathway is reversed for the Mesozoic units with traps being gradually filled from west to east. Continued burial during hydrocarbon generation determines that, through time, progressively more gas will be added at the TAGI charge point, resulting in a general trend towards higher GOR in more westerly pools. The migration picture is perhaps complicated somewhat locally by transmission along fault planes.

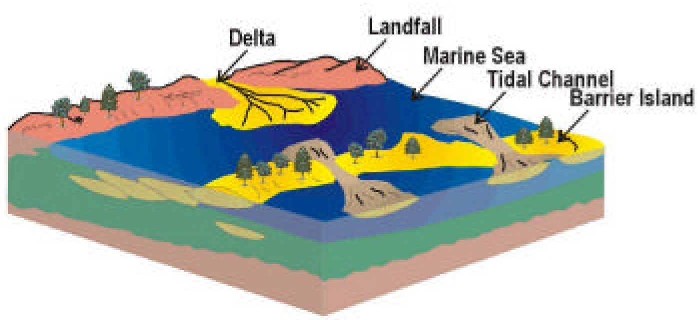
In 2000 Algeria’s total crude oil production was in the order of 800,000 bopd of which approximately one eighth came from fields within the Berkine Basin. By 2003, if all the anticipated production from the Berkine Basin comes on stream the contribution to Algeria’s OEPC quota could technically be as much as one half of the total. In addition to the large discovered volumes of oil the Berkine Basin is also host to several TCF of gas reserves which are present in Triassic, Carboniferous, Devonian and Silurian clastic reservoirs. It is anticipated that these reserves will also be monitized in the near future.



Petroleum System Schematic for the Southwestern Berkine Basin



Depositional Model TAG-I



Depositional Model Strunian F_2