D-7 CONTINENTAL, SABKHA AND SHALLOW OPEN MARINE LIASSIC-TRIASSIC SEQUENCE OFFERS NEW EXPLORATION PLAYS IN MALTA

G. DEBONO¹, S. XERRI¹ and W.F. BISHOP²

¹Malta Government, Oil Exploration Department,
Auberge de Castille, Valletta CMR 02, Malta

²Consultant

Summary:

Early Jurassic and Triassic sedimentary rocks from a deep well on the island of Gozo, Malta, show a remarkable correlation with contemporaneous ones in North Africa. The prevailing depositional environment during the Middle to earliest Late Triassic in the Gozo area was transitional with deposition of anhydrite and shales equivalent to the evaporitic facies of the Currusc Formation of North Africa. An angular unconformity, interpreted from seismic data at the base of this formation, indicates a probable underlying Hercynian surface. Block-faulting in the Norian turned the area into a very shallow sea in which occurred transgressive deposition of biomicritic dark limestones equivalent to the Azizia Formation of North Africa. A major regional uplift at the end of the Triassic caused a westward regression and deposition of transitional and continental sediments equivalent to the Bu Scebba Formation of North Africa. Reworked quartzite in this formation suggests a nearby source of exposed Devonian sandstone while seismic profiles indicate to a likely paleohigh to the east. A transgression at the end of the Triassic and in the Early Jurassic led to a sabkha deposition of a transitional sequence of anhydrite and dolomites akin to the Bir El Ghnem Formation of North Africa. The sequence at Gozo underwent further structuring in the Cretaceous to form a faulted reverse anticline, and more regional tilting followed in the early Miocene.

The link to North Africa puts the area in the context of a well understood depositional model and opens exploration opportunities for new plays in the area. Geochemical analysis of drilling gas and well cutting samples shows migrant hydrocarbons derived from a mature Type II marine source rock within the main oil window- probably the biomicritic limestone or an undrilled Palaeozoic source.

Introduction:

A deep well onshore Gozo (Fig.1) was drilled in 1998 on a gravity high in search of the Upper Triassic-Liassic Gela dolomite play of SE-Sicily. The Gozo structure represents a combination architecture made of a reverse faulted anticlinal structure

Fig 1

of mid-Cretaceous age overlying a system of en-echelon, tilted fault-blocks of Late Triassic (Norian) age. The fault-blocks developed along an E-W trending wrench zone during a Tethyan transtensional phase whereas the reverse faulted anticline developed along an NE trending shear zone during the Austrian transpression. The combined structures were further tilted to the NE during the Alpine phase and the formation of the Malta graben and subduction of the Caltanissetta basin. Instead of the Gela play, the well encountered a sequence which is more reminiscent of the contemporaneous evaporitic sediments of North Africa. The sequence is made up of the following four formations:

(a) Gibbs Formation (4589-6048m) Lias-Rhaetian

This unit, here named Gibbs Formation, is made up of three members. The upper member is massive dolomite with traces of anhydrite. The middle member consists of intercalations of anhydrite and dolomite while the lower member consists of shales, anhydrites and rare dolomite. The Gibbs Formation was deposited in a tidal flat to sabkha environment and is laterally equivalent to the Upper Triassic evaporitic Bir El Ghnam Formation of NW Libya.

Fig.2

(b) Red Shale Formation (6048 – 6207 m) Rhaetian

This unit, here named Red Shale Formation, is composed of greenish-grey and red shales, occasionally laminated, partly silty with interbeds of fine dolomite, quartzose siltstone with dolomitized-argillaceous matrix or anhydrite cement, and anhydrite. This formation was deposited in a continental to sabkha environment and is laterally equivalent to the continental Bu Sceba Formation of the Tripolitania area. Reworked Palaeozoic microflora made up of well-preserved Devonian spores and acritarchs in this formation strongly suggests a North African sediment source or a nearby exposed Hercynian surface.

(c) Kercem Formation (6207 – 7788 m) Rhaetian - Norian

This unit, here named Kercem Formation, consists of two members. The upper one is a thick succession of oolitic-bioclastic packstone /grainstone dark limestone and grey-green shale with minor quartzose siltstone and very fine, well-sorted quartzose sandstone. The lower member is dolomitized, especially towards the base and has interbeds of silty shale and rare anhydrite. The unit was deposited on a shelf and is laterally equivalent to the Azizia Formation of North Africa. Reworked Palaeozoic microflora was also found in this formation.

(d) Green Shale Formation (7788 –8012 m) Middle Triassic ?

The formation at TD, here named the Green Shale Formation, is composed of greenish-grey and red shale and anhydrite, with levels of siltstone and dolomite. The environment of deposition was continental to sabkha, similar to the Red Shale Formation and represents the sabkha, lateral equivalent of the continental Currusc Formation of North Africa. No paleontological element could be identified to indicate an age with certainty, but a tentative Middle Triassic age was assigned.

Depositional Model in the Middle Triassic - Early Jurassic:

The Middle/Upper Triassic to Liassic sedimentary rocks of Gozo fit within the general depositional model of North Africa, which is broadly represented by an extensive fluvio-deltaic system developed on a Hercynian surface, discharging northward onto the broad North African shelf bordering the southwestern shores of the Paleotethys. During this period, deposition of sediments included eolian, cross-stratified, red sands and coarse-grained fluvial sands and conglomerates in the source areas of drainage; fluvial channel sands, levees, and sheet sands in the more mature parts of the drainage; silts and redbeds in the flood plains; deltaic sands and shales further down the discharge; transitional anhydrites and dolomites in the sabkhas; and open-marine carbonate sediments farther out on the shelf. A widespread transgressive phase flooded the area and deposited a thick interval of shallow-water carbonates between the continental and transitional facies. Beyond the shelf area, deposition of thick shales also occurred in newly formed pull-apart basins fringing the southwestern Paleotethys shoreline. Data from the Gozo well indicate a transitional location within this depositional model that shifted in time from continental to sabkha to open marine environments.

Hydrocarbons:

Dead bitumen was encountered in the well, almost uninterruptedly from about 2,000 m to TD at 8012 m. In the deeper section, significant shows of gas and traces of migrant hydrocarbons were also encountered. Drill cutting samples from the Triassic-Jurassic interval were analysed for migrant hydrocarbons and source rock potential.

(a) Migrant Hydrocarbons:

The significant decrease in S_2 values observed in samples washed by organic solvent suggests the presence of migrated hydrocarbons within this interval, particularly where the electric logs show separation of curves and the FMS log shows open fractures. The gasoline range

C_4 to C_7 hydrocarbon analyses of samples correspond to major increases in the abundance of drilling fluid gas and show a mature, oil-like distribution with relative abundances of the C_5 , C_6 and C_7 normal hydrocarbon.

(b) Source Potential:

Source-rock evaluation of drill-cutting samples from the Red Shale Formation show low TOC in the range 0.26% to 0.34%. It is unlikely that this shale would have had sufficient source potential, and it probably has not generated significant amounts of hydrocarbons in attaining the present level of maturity. Increased TOC values are noted in the Kercem Formation, with values ranging between 0.2 and 1%. The S_2 for the same interval varies between 0.10mg/g and 3.14 mg/g. Although these ranges, especially the TOC, represent only poor to fair source potential, the great thickness of the interval makes the generation of large volumes of hydrocarbons possible. An alternative source to the Kercem Formation is an undrilled deeper section of probable Palaeozoic age.

Geothermal History:

The deep portion of the well (4500 m to TD) is middle- to late-mature for oil generation and mature for gas generation as indicated by vitrine reflectance values in the range 1.11% to 1.27% and spore colour indices in the range 8.0 – 8.5. Basin-history studies using present geothermal gradient indicate early oil expulsion in the Early Cretaceous from the Triassic interval, with peak expulsion in Late Cretaceous and Early Tertiary. The presence of dead bitumen in the pre-Tertiary section suggests that early expulsion and migration of pre-Cretaceous bituminous oil was dispersed, and the Austrian trap was charged later with mature hydrocarbons as maturity increased with further burial during later Cretaceous and Tertiary times. The ensuing large-displacement faulting encouraged vertical migration but also induced leakage of hydrocarbons from the Gozo structure.

Reservoirs and seals:

The dolomite facies of the Gibs Formation and parts of the Kercem Formation constitute fair reservoirs on account of fractures, as indicated by FMS image interpretation which identified a number of fracture and microfracture zones in these units. A good correlation of drilling fluid gas with fracture zones and zones of electric log separation also suggests that at least some of the fractures are petroliferous. The anhydrite beds of the Gibs Formation, the Red Shale Formation, and anhydrite beds within the top part of the Kercem Formation are potential seals. The highest concentration of migrant hydrocarbons was found below an anhydrite bed at about 6530 m (Fig.4). The sequence of very tight anhydrite and shale of the Green Shale Formation is also a good seal and could overlie an undrilled reservoir.

Fig. 4

Conclusions:

New Triassic - Liassic petroleum plays are recognized in the Maltese Islands. Four formations in this interval are represented by continental, sabkha and open marine sedimentary rocks similar to the contemporaneous ones of North Africa. In Gozo, a combination structure composed of an Austrian tranpressive reverse faulted anticline overprinted on Tethyan transtensional en-echelon fault-block architecture has shows of migrant hydrocarbons in fractured carbonates derived from a mature Type II marine source within the main oil window. The fair TOC values and great thickness of the Kercem Formation makes it a likely source with peak expulsion in the Late Cretaceous and Early Tertiary. Several other structural highs onshore the Maltese Islands and in the offshore area offer similar play concepts which constitute future viable exploration objectives.