AAPG HEDBERG CONFERENCE
"Paleozoic and Triassic Petroleum Systems in North Africa"
February 18-20, 2003, Algiers, Algeria

Petroleum Geology Overview of the North Africa Sahara Platform

Lorenzo Casati – Agip Algeria Production BV
Jonathan Craig – Eni/Lasmo plc

The Palaeozoic and Triassic successions of the Sahara Platform contain some 43% of the known oil and 84% of the known gas reserves of the entire North African region. To date, more than 46 billion barrels of oil equivalent of recoverable reserves have been discovered in approximately 350 separate accumulations across this vast region. These Palaeozoic-sourced petroleum systems reflect the complex interaction and spatial variability of the depositional systems and tectonic events which have affected the region from Precambrian times to the present day. The tectonic events ('Taconic', Caledonian', Hercynian, Austrian and 'Alpine') are particularly key controls.

The collisional amalgamation of African, South American, Indian, Australian and Antarctic basement terrains during the late Precambrian, and the subsequent delamination of the underlying mantle, resulted in the uplift and peneplanation of basement rocks across the new Gondwana supercontinent and the development of a wide, stable continental shelf around its margins. The peneplanation was well advanced by early Cambrian times and resulted in the development of an extensive, and essentially flat surface across much of the North Africa. This surface was gradually buried under sediment eroded and transported northwards from the remains of the Pan-African mountains to the south and was periodically flooded from the north to form a broad shallow marine continental shelf, throughout the Palaeozoic.

Reactivation of Pan-African structures during the Early Palaeozoic triggered the development of broad intra-cratonic sag basins that remained active depocentres throughout the Palaeozoic. Thick successions of Palaeozoic strata accumulated in many of these sag basins, but the shelf was sufficiently stable that similar and correlatable sequences were deposited across the whole margin from western Egypt to Morocco. The Silurian, Devonian and Early Carboniferous sequences all contain belts of marginal shallow marine sandstones that migrated laterally with changing sea-level and passed offshore into deep marine shales. The Cambro-Ordovician and Siluro-Devonian sequences are predominantly lowstand systems, consisting of coarse clastic sediments deposited in a variety of continental fluvial and shallow marine environments. The Cambro-Ordovician sandstones and the Lower Devonian F6 sandstones are important hydrocarbon reservoirs which together contain nearly half of the recoverable reserves discovered to date in the Palaeozoic-sourced petroleum systems of North Africa. Major transgressions during the Rhuddanian (earliest Silurian) and the Frasnian (late Devonian) Stages flooded large parts of the continental shelf with variably anoxic waters. The associated transgressive and highstand systems contain organic-rich 'hot' shales which form primary hydrocarbon source rocks and leaner shales which, together with the organic-rich shales, act as regionally extensive seals.

In the case of the earliest Silurian transgression, the organic-rich graptolitic 'hot' shales in the in-board parts of the shelf were deposited in isolated or restricted topographic depressions in a denuded sand-dominated Late Ordovician glacial landscape. Although the distribution of these earliest Llandovery source rocks is 'patchy', they still constitute the ultimate source of at least 80% of the Palaeozoic-derived hydrocarbons discovered on the Sahara Platform to date.

The Upper Devonian 'Frasnian' organic-rich 'hot shales' are more continuous but have a more restricted distribution as a result of 'Caledonian', Hercynian and later erosion. They are the ultimate source of around another 10% of the Palaeozoic-derived hydrocarbons discovered on the Sahara Platform.

The lateral continuity of major stratigraphic sequences remained a characteristic of Palaeozoic deposition on the North African continental margin until Late Carboniferous times when more isolated and restricted continental basins developed as a result of tectonic movements marking the initial pulses of Hercynian deformation.

The Hercynian collision produced widespread compressional deformation in northern and western Morocco and in northern Algeria. Uplift and profound erosion occurred in intra-plate areas such as southern Algeria and western Libya. Petroleum systems established on the Sahara Platform as a result of burial and maturation of Palaeozoic source rocks prior to the Hercynian orogeny were largely 'frozen' or destroyed by the deformation, uplift and erosion that accompanied the development of Hercynian unconformity. The subcrop pattern and the topography of the Hercynian Unconformity surface are key elements in the present-day petroleum systems of North Africa. They control the gross distribution of Palaeozoic reservoirs, source rocks and seals, the localised preservation of Palaeozoic hydrocarbons, the communication pathways between the Palaeozoic source rocks and stratigraphically younger reservoirs and the pattern of long distance migration into post-Hercynian reservoirs.

Early post-Hercynian sedimentation in the Oued Mya, Berkine and Ghadames basins of Eastern Algeria and Western Libya was characterised by the deposition of a complex systems of Triassic fluvial, aeolian and sabkha sediments across the subtle erosional topography of the Hercynian Unconformity surface. Sedimentation and associated volcanism during the Late Triassic and early Jurassic was increasingly influenced by NE-SW trending extension faults. The Triassic fluvial and aeolian sandstones in these areas constitute the most important hydrocarbon reservoirs in North Africa, hosting just over 50% of the Palaeozoic-sourced reserves in traps that are ultimately sealed by thick Liassic evaporites and locally by lateral equivalent lavas.

Apatite and Zircon fluid Fission Track studies from parts of central, and western Algeria indicate a period of regional heating associated with Late Triassic – Early Jurassic volcanic activity, which affected the entire Palaeozoic section. This localised 'heat-spike'caused renewed generation of significant quantities of gas in parts of central Algeria, most noteably in the Ahnet and Reggane basins.

Additional Mesozoic burial during Jurassic and Early Cretaceous times, eventually re-juvenated the hydrocarbon generating capacity of the two main Palaeozoic source horizons on the Sahara

Platform and resulted in the further migration of both oil and gas into intra-Palaeozoic and basal Triassic reservoirs between the Late Cretaceous and the present-day. Deformation and uplift during the Early Cretaceous 'Austrian' and mid-Tertiary 'Alpine' events modified existing and created new structural, stratigraphic and complex combination traps in many areas of the Sahara Platform. Locally, a final phase of tilting, re-migration of hydrocarbons and freshwater flushing of reservoirs occurred associated with the massive mid and late Tertiary uplift of the Hoggar Massif.

The ultimate intensity of deformation and the degree of thermal maturity of the main Palaeozoic hydrocarbon source rocks in North Africa decreases eastward away from the Hercynian and Alpine collision zones. The present day concentration of large oil and gas fields in eastern Algeria and SW Libya is a direct result of the favourable timing of maturation, trap formation and, crucially, preservation in these areas on the margins of the main orogenic belts.