

# Hydrocarbon Maturation History of the Ghadames Basin, North Africa: The Influence of Exhumation and Erosion

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The Ghadames Basin is a prolific hydrocarbon province, with recoverable oil discovered to date in excess of 3.5 billion bbl. Constraining its burial history is crucial for accurate prediction of hydrocarbon generation and migration, and of particular importance for future exploration in the relatively undeveloped eastern Libyan part of the basin.

The geological history of the Ghadames Basin includes several periods of uplift and erosion, with resultant unconformities in the stratigraphic section. The correct estimation of the amount of eroded overburden at these unconformities is essential for the accurate constraint of burial histories and the precise prediction of timing of hydrocarbon maturation of the main source rock intervals (the Lower Silurian and Middle-Upper Devonian radioactive shales). Data from a number of wells distributed across the basin have been analysed and calibrated with observed temperature and vitrinite reflectance data. Typically within basin modelling it is difficult to constrain a unique burial history model as calibration can be achieved using a range of parameters and erosion scenarios.

Sonic velocity, apatite fission track (FT) and vitrinite reflectance analysis offer three complimentary methods to determine burial history and provide independent analytical techniques to evaluate the amount of exhumation and associated erosion that have occurred across the Ghadames Basin. Results suggest that much of the basin has experienced widespread apparent exhumation, increasing regionally towards the south and east. Two main phases of tectonic activity have been identified: the Hercynian (Late Carboniferous-Triassic) and Alpine (Late Mesozoic/Cenozoic) tectonic events. Denudation during the Hercynian increases towards the northwest, with relatively minor erosion evident to the south and east, where an almost complete Palaeozoic section is preserved. The significant regional exhumation recorded along the southern and eastern margins of the basin must therefore record a period of younger Alpine exhumation. This has significant implications for the timing of hydrocarbon maturation and expulsion within the basin, particularly of the Silurian source rock interval. Incorporating elevated Alpine exhumation values into the burial history models for wells over the eastern (Libyan) part of the basin allows calibration with available vitrinite reflectance data using more moderate values of Hercynian erosion than otherwise required. The result is a significant increase in the potential hydrocarbon generation from the Silurian (Tanezzuft) source rock during the Mesozoic/Cenozoic, and hence the implication of an improved chance for preservation of hydrocarbon accumulations following entrapment.

The integration of these different burial history analysis techniques with a comprehensive 1D and 2D basin modelling study suggests that the far western margin of the basin underwent pre-Hercynian maximum burial, but the central basin area and southern margins experienced their maximum burial depths only recently, during the Eocene. In Libya, on the eastern, northeastern and southern flanks of the basin, burial history analysis indicates Cenozoic maximum burial, with up to 2000 metres of Alpine exhumation and associated erosion occurring over the Dahar-Nafusah, Qarqaf and Tihemboka arches. The resultant generative models predict that the Lower Silurian (Tanezzuft) source rock underwent two distinct generative phases over the central basin area and its southern margin: (1) a period of pre-Hercynian (Carboniferous) generation; and (2) a period of post-Hercynian (Late Jurassic-Tertiary) generation, as Mesozoic reburial exceeded pre-Hercynian burial depths. A similar two-stage generation history is observed when using a Cenozoic maximum burial model over the eastern and northeastern flanks of the basin. By contrast, over the far western margin of the basin only one period of hydrocarbon generation from the Lower Silurian source rock is observed: a pre-Hercynian phase where around 95% of hydrocarbon generation potential was realised prior to the period of Hercynian exhumation. The Middle-Upper Devonian (Frasnian) source rock did not generate significant volumes of hydrocarbons over the central (Berkiné) basin area and its southern flank (towards the Qarqaf Arch) until the Cretaceous, and is currently within the peak oil generation zone. Over the western, northern and eastern flanks of the basin the Middle-Upper Devonian source is currently immature/marginally mature, and has not generated sufficient volumes of hydrocarbons for significant expulsion to occur.