[PS]Modelling of Source Rock Maturation and Hydrocarbon Formation in Northern Iraq*

Mohammad Al-Gailani[1] and Nahidh Marouf[2]

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[1]Geodesign Ltd., Kingston upon Thames, United Kingdom (geodesignuk@googlemail.com)
[2]Geodesign Ltd., London, United Kingdom

Abstract

Detailed structural analysis carried out recently on the Zagros folded belt and surrounding areas allowed construction of a detailed structural history with complete facies and burial history for all of northern Iraq. Source rock maturation and hydrocarbon formation was modelled on more than 100 locations, including synthetic sites, using the Fobos Pro Modelling software. The resulting models from all the sites were compared with geochemical data obtained from the area to verify results.

The source rocks of Northern Iraq were subdivided into two main types based on previous geochemical analysis results obtained using conventional methods. The first category of source rocks are those of Middle-Late Jurassic - Early Cretaceous rocks bearing kerogen type II, while the second category of source rocks belong to the pre-Middle Jurassic characterised by kerogen type III rocks. Each modelled site produced the transformation ratio of all possible source rocks encountered, and the total amounts of oil and gas produced and expelled from each site were calculated. Comparison of modelling results from all of the sites with previous geochemical data showed very good matching and reliability. The resulting data from all the studied sites are compiled in an ArcGIS system with two regional maps showing the total oil and total gas for the entire studied area of Northern Iraq.

The total amounts of oil and gas generated and expelled over the last 10 million years (time of formation of the anticlinal structures) are in good correlation with the present amounts of discovered and proven oil reserves in the Kirkuk and the surrounding areas of northern Iraq. This makes the present modelling highly dependable for identifying future hydrocarbon potential in all the unexplored areas of Northern Iraq.

Study Parameters

The aim of this study is to evaluate the structural and tectonic evolution of the sedimentary basin in northern Iraq and the Kurdistan region with special emphasis on the geohistory simulation modelling and maturation of all the potential source rocks encountered in the basin and evaluate the hydrocarbon expulsion history in the Kurdistan region and all the surrounding areas. The study first addresses the main aspects of the structural and tectonic evolution of the sedimentary basin in northern Iraq and identifies all the sedimentary cycles in detail from the Late Triassic period to Pliocene.

The second part tackles the geohistory modelling of all the encountered source rocks in the basin and evaluates their maturation history and expulsion of hydrocarbons. The final part, would includes evaluation of the structural integrity of all the encountered hydrocarbon prospects in the region and identifies their potential hydrocarbon trapping mechanism as well as recognise all the potential source rocks for that particular structure and simulate their maturation and expulsion history. The study will provide details for all the possible hydrocarbon prospects in the region, identifying their structural trapping mechanism, describing all the available reservoir facies within the confines of their trappings and detailing the integrity of their cover seal capping rocks.

The study of the structural and tectonic history of northern Iraq and the Kurdistan region describes in detail the evolution of the sedimentary basin and involved constructing a series of isopach and facies maps accompanied by numerous schematic sedimentary cross sections covering the entire encountered sedimentary cycles from the Late Triassic to the Pliocene time.

The sedimentary sequence was subdivided into cycles defined by major unconformities with their corresponding conformity surfaces. Isopach and facies maps were constructed for each sedimentary cycle followed by detailed construction of lateral and vertical schematic sections identifying the various facies within each cycle and describing the transgression and regression episodes influencing the development of the various facies. The subsidence history during the development of each cycle was analysed and studied using a series of tectonic models and constructing several schematic cross sections showing the various tectonic and structural events affecting the development of each cycle.

The tectonic and structural evolution of the sediments were studied by constructing the thermal and subsidence history from 101 sites involving analysing 50 wells and 19 stratigraphic measured sections and 32 Simulated Seismic Based (Pseudo-Wells) Sites from the Kurdistan region and northern Iraq. Source maturation and expulsion history was achieved using a one dimension Fobos Pro (V3.2) software modelling programme with the results presented in a series of source rock transformation ratio (TR) maps constructed for each source rock sequence. The total amounts of expelled hydrocarbons are also presented in two regional maps covering the entire studied area showing the total expelled oil and the total expelled gas respectively.

Finally, all the constructed maps presented and displayed in the study are displayed in geographic information system (GIS) using ESRI ArcGIS (V. 9.2) software programme.

Geologic and Source Rock History

The Permo-Triassic Period was characterised by more than one phase of rifting, with the rift axis located east of the present Iraqi border. The Triassic sedimentary sequence was deposited on the western flank of the main rift. Extensional faults controlled the sedimentation and subsidence during this time interval. Shallow marine to tidal sequences were deposited with organic matter composed mainly of Kerogen type III bearing rocks.

During the Early Jurassic, the Neo-Tethys opened with passive margin conditions prevailing over the entire studied area. The basement subsided as a single mechanical plate derived by thermal subsidence where the influence of the former extensional faults (grabens) disappeared. The former transfer faults kept controlling the configuration of the sedimentary basin. Tidal to shallow marine as well as restricted lagoon environment prevailed during this period with the resulting sedimentary sequence rather poor in organic contents, composed mainly of Kerogen type III bearing rocks.

The Middle Jurassic-Albian period showed the passive margin conditions continued controlling the sedimentary basin configuration. The influence of the pre-existing grabens was rather to a minimum where thermal subsidence prevailed most of the time. However, during two sub periods, the Middle Jurassic and during the Late Tithonian-Berriasian, the development of sub-crustal dense phase resulted in abnormal subsidence history and generally reduced the surface heat flow and the geothermal gradient around a considerable part of the basin.

The Middle Jurassic to Albian time was also characterised by the evolution of deep bathyal and basinal sedimentary conditions in addition to the shallower marine ones. These sedimentary conditions, in addition to prevalence of an euxinic environment, developed deep sedimentary facies with relatively high TOC content mainly consisting of Kerogen type II-S bearing rocks. The Middle Jurassic-Early Cretaceous euxinic conditions provided excellent preservation for the deposited organic matter enriched with high sulfur content.

During the Cretaceous period, two northeast dipping subduction zones were developing. The most eastern one resulted in the formation of the Shalair-Kata Rush sequence while the nearer one developed the back-arc Qandil sequence. Both of these subduction zones have negligible influence on the development of the miogeosyncline basin.

The Late Cretaceous was also characterised by the development of the northeast dipping A-type (Continental) subduction zone beneath the present Qulqula-Khwakurk ridge. The subduction process started in the Late Albian and kept influencing the miogeosyncline basin until the Oligocene. The periodic thrusting and build-up of structural relief resulted in the prevalence of the foreland basin environment over the earlier passive margin one, which led to the development of the foreland basin sequence. During this period, the basin subsidence was mainly derived from the evolution of the foreland basin subsidence.

The foreland basin environment was interrupted during the Maestrichtian period by the development of a rift basin in the un-elevated folded zone. The rifting process caused the main subsidence in this area and resulted in the development of fault-controlled relatively thick sequences deposited during the Maestrichtian.

At the end of the Cretaceous Period, the Shalair-Kata Rush subduction ended and the Shalair sheet started to thrust over the Qandil sheet. At the same time, the Qandil back-arc basin was closed and the Walash volcanic arc started to develop over the still active oceanic subduction zone.

During the Palaeogene the continuous activation of the former A-Subduction zone beneath the Qulqula-Khwakurk ridge resulted in the development of the Ora-Balambo elevated folded subzone. The foreland basin conditions prevailed again over the entire miogeosynclinal belt. At the same time, the Walash volcanic arc grew which led to the development of the Naopurdan Foreland basin in front. The A-Subduction was possibly ended in the Late Palaeogene time.

During the Neogene, the continental Arabian-Iranian Plate collision took place which resulted in the development of thick molasse basins over the entire miogeosyncline. The continental collision also resulted in the development of the Zakho-Pila Spi elevated folded subzone and the un-elevated folded zone in the Miocene-Pliocene.

The development of the relatively thick and cool foreland basin sequence resulted in an excellent burial environment for the source rock materials which later matured and expelled considerable amounts of very good quality hydrocarbons at the right time of structural evolution, thus trapping huge of amounts of hydrocarbon reserves (already discovered) and with the potential of finding considerable amounts of yet undiscovered prospects. The development of many shallow marine reservoir sequences in conjunction with the formation of inverted folded structures provides an excellent combination of hydrocarbon trapping conditions.

Summary

The present study describes the structure and tectonic history of northern Iraq and the Kurdistan region and includes the evolution of the sedimentary basin from the Mesozoic-Cenozoic as well as the maturation and expulsion geohistory of hydrocarbons from all the potential source rocks encountered in the basin. The source rock maturation and the hydrocarbon formation and expulsion history throughout the entire studied area were both evaluated and presented qualitatively and quantitatively in a series of Geographic Information System (GIS) maps using ESRI ArcGIS (V 9.2) software programme which would enable the researcher to evaluate the hydrocarbon potential of any area and predict the petroleum system within the confines of the study.