

Paleogeography and Sedimentation History of the Western Libya Offshore, Central Mediterranean*

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Abstract

The Gabes-Tripoli Basin (G-T Basin) is a Mesozoic-Cenozoic basin which was initiated as a result of widespread, late Triassic-Middle Jurassic extensional movements that developed over a broad zone of strain between the African and European plates. The subsurface analysis of the whole succession within the G-T Basin was carried out to unravel the subsurface aspects of the different depositional sequences and to interpret the overall basin evolution history. The method simply involves the subdivision of the whole sedimentary succession into tectonostratigraphic megasequences, all of which are linked in one way or another to regional tectonic episodes that can be correlated with the Mediterranean basin tectonic history.

The sedimentary succession in the G-T Basin ranges in age from Triassic-Recent. It comprises a 10 km-thick succession of pre-rift Early-Middle Triassic, nonmarine and marine clastics, syn-rift Late Triassic-Middle Jurassic, predominantly shallow marine carbonates and evaporites and Middle Jurassic-Recent post-rift marine carbonates and clastics. The tectono-stratigraphic units comprise 7 main sequences on the time scale of second order sequences. For most sequences and sequence boundaries, either a eustatic or tectonically enhanced origin can be established. The analysis of the basin-fill history of the G-T Basin from the Triassic until the Holocene reveals that the basin underwent development from a continental sedimentary basin located on Gondwana to an epicratonic rift basin. When extensional movement ceased (Middle Jurassic), the basin subsided thermally and developed as part of a passive continental margin on the North African plate margin. Correlation with the out cropping sequences at Jabel Nafusa reveal the HC potential of the Triassic Aziziyah and Abushaybah play and lead to the identification of a new lithostratigraphic unit, the Late Albian-Cenomanian Jennawen Formation.

Introduction

The G-T Basin occupies a part of the western Libyan offshore ([Figure 1](#)), which is situated on the extreme northern flank of the stable African cratonic crust. [Figure 2](#) shows the location of the study area and the drilled exploration wells used in correlations, facies analysis, and paleogeographic reconstruction of depositional sequences. The subsurface analysis of the whole succession within the G-T Basin was carried out to unravel the subsurface aspects of the different depositional sequences and to interpret the overall basin evolution history. After well to

well correlation, the whole sedimentary succession was subdivided into tectonostratigraphic megasequences, all of which are linked in one way or another to regional tectonic episodes that can be correlated with the Mediterranean basin tectonic history ([Figure 3](#)). The Post–Paleozoic stratigraphy, regional tectonic events and petroleum plays in the G–T Basin are presented in [Figure 3](#). Correlation of the interpreted offshore sedimentary facies within their possible analogue in the onshore area was considered. [Figures 4](#) and [Figure 5](#) show examples from onshore exposed Cretaceous sequences and the recently recognized Jennawen Formation (Mriheel, 2013). In this study, three sedimentary megasequences are recognized in the G–T Basin: pre-rift, syn-rift, and post rift. The total thickness of the whole succession rarely exceeds 10000 meters. It is worth mentioning that the post-rift phase is entirely marine and comprises about 75 % of the bulk volume of the basin fill sediments. The other pre-rift and syn-rift megasequences comprise, sub-equally, the remaining stratigraphic phases.

Sedimentation History

The sedimentary succession in the G-T Basin ranges in age from Triassic-Recent ([Figure 3](#)). In this study, the basin stratigraphy and evolution have been discussed based on global tectonic events linked with the break-up of the Gondwanaland, opening of the Atlantic Ocean, and motion of the African plate. The sedimentation history and basin evolution are explained in pre-rift, syn-rift, and post-rift stages ([Figure 3](#)).

The first stage of basin evolution involved uplifting and faulting during the Paleozoic, which caused erosion of the pre-Triassic sediments and development of a broad arch during the Hercynian orogeny. This phase preceded the break-up of Gondwana and the opening of the Neo-Tethys Ocean, which began in the early Jurassic (Guiraud, 1998).

During the Early Triassic, the pre-rift phase sequence was formed in initially faulted basement blocks and contains continental siliciclastics of the Al Guidr Formation. Subsequent rise in sea level, combined with mild tectonism during Middle Triassic, led to widespread deposition of shallow shelf siliciclastics of the Kurrush Formation.

During the syn-rift phase, the major faults and structural elements of the G-T Basin were either initiated or rejuvenated and significant subsidence of the basin allowed major sedimentation of carbonate, siliciclastics, and evaporites of the Al Aziziah, Abu Shybah, and Bir Al Ganam Formations respectively ([Figure 3](#)). This Late Triassic-Middle Jurassic tectonic activity laid the foundation of the extensional G-T Basin on the northern margin of the African craton. This phase was concomitant with the break-up of Gondwanaland and the opening of the Atlantic Ocean (Guiraud, 1998).

The post-rift megasequence comprises the Middle Jurassic–Recent marine depositional sequences. The start of Middle Jurassic time witnessed uplifting of the Jifarah Plain which acted as a source of the clastic influx and thus siliciclastic deposition was resumed toward the offshore area (Mriheel, 2000). At the western Libyan offshore area, Middle Jurassic–Early Cretaceous is represented by the Tigi Group, Cabao, and Kiklah Formations and is comprised of shallow shelf sandstone, siltstone and shale, dolomites and limestones.

Early Cretaceous sedimentation continued over the Jifarah Plain with fluvial deposits of the later part of the Kiklah Formation. On the offshore shallow shelf environments are ubiquitous. At the end of the Lower Cretaceous (Aptian–Albian), Kiklah, Turghat, and Masid Formations were deposited and are comprised of marginal marine siliciclastic and carbonate, shallow carbonate shelf, and deep shelf to basinal settings

respectively. This stage occurred contemporaneously with Sirt Basin rifting. Differential block movements toward the offshore that followed the Kiklah deposition continued as the area was invaded by the Late Cretaceous Sea. Initial transgression was first started during Late Albian-Early Cenomanian as the marginal marine sediments of the Jennawen Formation would suggest (Mriheel, 2013).

Cenomanian regional basin uplift was accompanied by widespread lowering of sea level resulting in development of a broad evaporitic and restricted carbonate shelf and deposition of the Alalgah sediments (Mriheel, 2000).

The advent of the Turonian marks initially the start of a long period of sea level rise in the basin that continued until the end of the Maastrichtian. A combination of sea level rise during the Late Cretaceous, corresponding to the Haq et al. (1987) eustatic sea level curve, and tectonism lead to deposition of pelagic shale, marl, and carbonates in deep shelf-basinal environmental setting. The pelagic facies of the deepening sequence correspond to the Makbaz, Jamil, Bu Isa, and Lower Al Jurf Formations ([Figure 3](#)).

During the late Coniacian, the western Libyan coastal fault system and structural elements of the basin were rejuvenated. As a result, the Jefarah Plain emerged as a landmass, and significant sedimentation onshore is thought to have ceased since then. This continuous rise in sea level and rejuvenation of the western Libyan coastal fault system appears to have slightly exceeded the uplift of the peripheral palaeohigh around the G-T Basin. Consequently, a long period of non-deposition and erosion persisted over the emergent area of the Jifarah Plain (Mriheel, 2000).

During the Palaeocene, the offshore area was subjected to severe regressive episodes concomitant with tectonic uplifting induced by volcanism along the southern margin of the G-T Basin. This was accompanied by exposure of the Late Cretaceous sequence toward the southern margin of the basin and deposition of a narrow belt of Ehdruz shallow shelf carbonates and its equivalent pelagic facies of Upper Al Jurf Formation ([Figure 3](#)).

The latest Palaeocene-Early Eocene time witnessed a relatively quiescent tectonic phase, during which the carbonates of the Farwah Group were developed. To the north of the offshore region, the Farwah Group passes into pelagic facies of the Hallab Formation.

After a short period of erosion or non-deposition of the early Eocene sediments, sedimentation resumed with the rise of sea level in the Middle Eocene.

The Middle-Late Eocene shallow shelf intercalations of carbonates and shales of the Tellil Group and its deeper water equivalent Ghalil Formation were developed.

Again after erosion or a non-depositional event, the shallowing-upward Oligocene-Miocene depositional sequence was established ([Figure 3](#)). The Oligocene-Miocene sequence is bounded by obvious hiatuses and consists of the Ras Abd Jalil, Dirbal, Al Mayah, Tubtah, and Marsa Zouaghah Formations (Mriheel, 2000).

The sedimentary sequence of the G-T Basin ends with siliciclastics of Pliocene-Recent age. The sequence is represented by the Sbabil and Assabria Formations ([Figure 3](#)).

Petroleum Accumulation in the G-T Basin

Significant hydrocarbon accumulations in the G-T Basin have been discovered in Eocene carbonate reservoirs. Bouri, Bahr Essalam, and Al Jurf are important fields sourced in principle from Eocene carbonates and shales. Additional hydrocarbon charge may have been supplied by Late Cretaceous source rocks. Up to now, all of the hydrocarbon plays have been found in positive structural traps, either in faulted anticlines or in anticline formed by salt domes.

After, detailed paleogeography reconstruction of the basin and establishment of new depositional models, it is proposed that there are other unexplored exploration plays in the Triassic and Cretaceous sequences ([Figure 3](#)). These could develop economically important hydrocarbon accumulations within the basin, which as yet remained to be explored. Both geological and seismic data in the G-T Basin support the existence of hypothetical petroleum systems within the Late Triassic and Early Cretaceous sequences. The hydrocarbons may have been trapped in the Abu Shaybah and Cabao-Kiklah reservoirs ([Figure 4](#)) and sourced from the Late Triassic Aziziyah and Albian Fahdene equivalent shales respectively. Furthermore, the newly proposed depositional model of the Late Albian-Cenomanian Jennawen Formation (Mriheel, 2013) reveals the existence of interesting siliciclastic reservoir ([Figure 5](#)). Compared with its onshore analogue, the Bahi Formation at Sirt Basin acts as an important reservoir, it is recommended that future exploration must not neglect the Jennawen marginal marine siliciclastics. Although drilling in the G-T Basin has been less intensive than in other major basins of Libya, the hydrocarbon discoveries made thus far have confirmed that abundant hydrocarbons have been generated and trapped within the basin. It is therefore safe to suggest that future discoveries will be forthcoming.

Conclusions

A detailed facies and sequence analysis carried out in the G-T Basin has resulted in a stratigraphic correlation scheme and construction of depositional models for the entire Mesozoic-Cenozoic succession. The sedimentary sequences forming the bulk stratigraphy of the G-T Basin comprises of pre-rift Early-Middle Triassic, nonmarine and marine clastics, syn-rift Late Triassic-Middle Jurassic, predominantly shallow marine carbonates and evaporites and Middle Jurassic-Recent post-rift marine carbonates and clastics. Seven 2nd order depositional sequences were identified throughout the main rifting stages. For most sequences and sequence boundaries, either a eustatic or tectonically enhanced origin can be established.

Correlation with the out cropping sequences at Jabel Nafusah reveal the hydrocarbon potential of the Triassic Aziziyah, Abushaybah, and Cabao-Kiklah hydrocarbon plays and lead to the identification of new lithostratigraphic unit, the Late Albian-Cenomanian Jennawen Formation.

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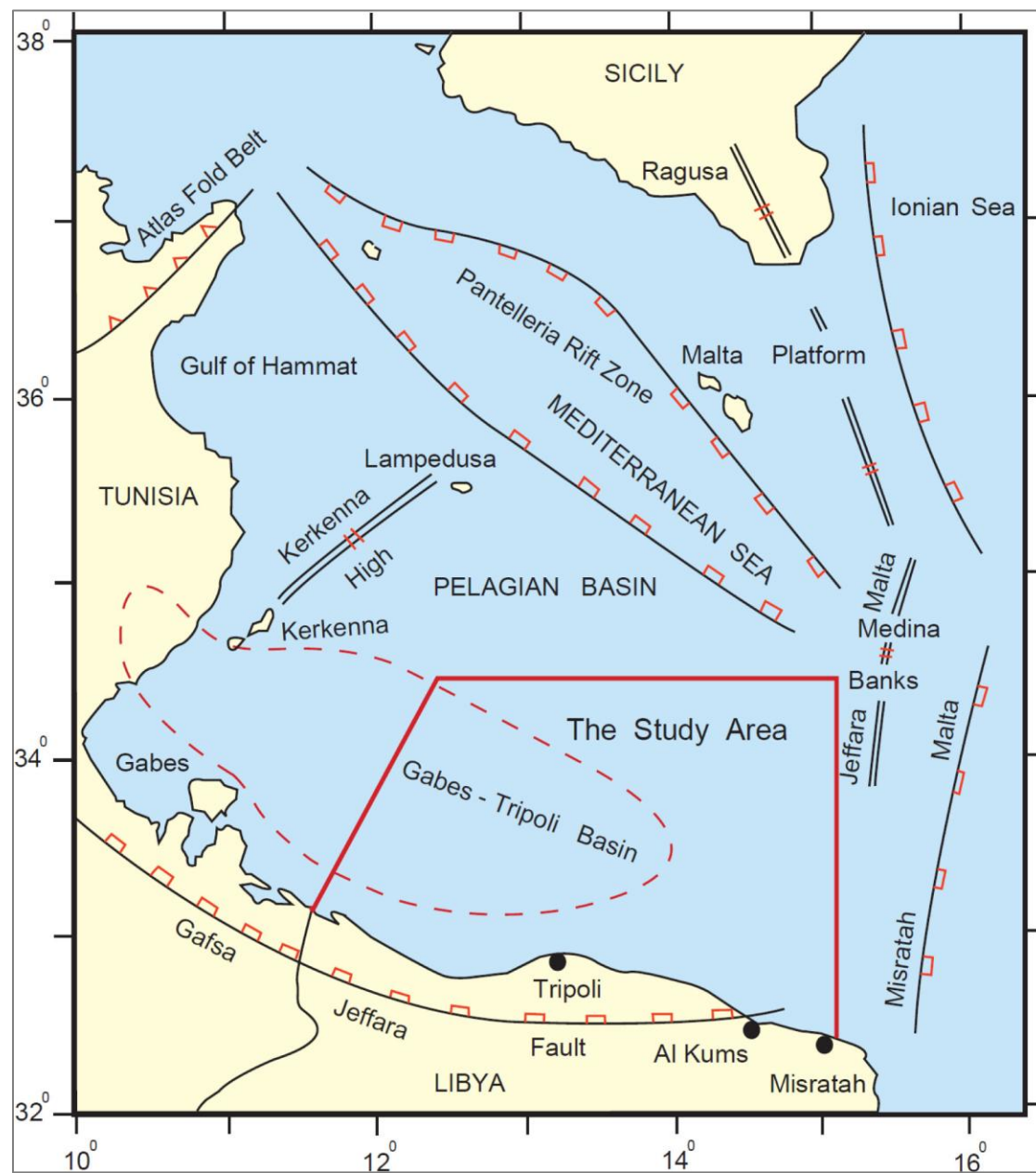


Figure 1. Map showing the study area relative to the Pelagian Basin.

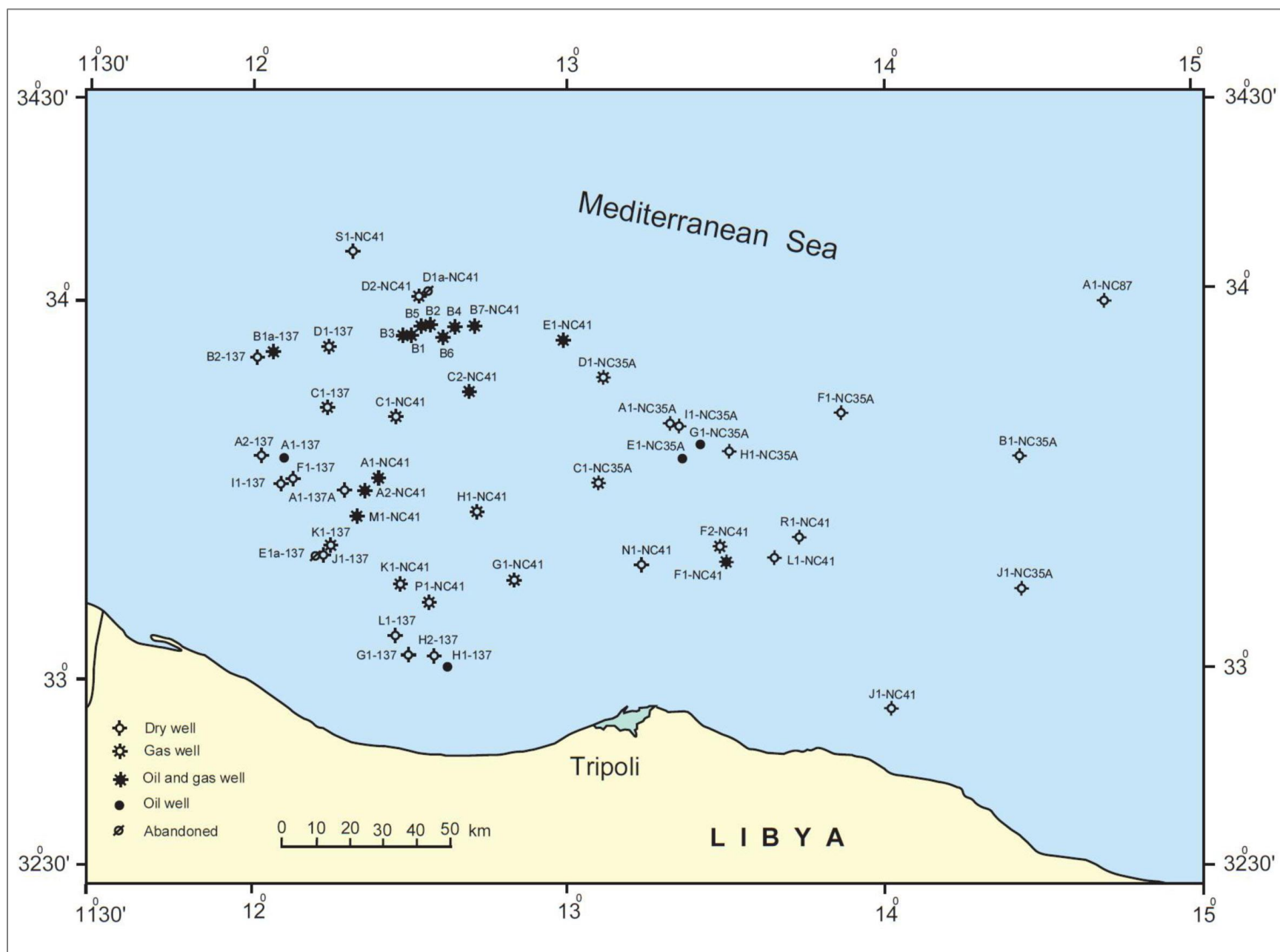


Figure 2. Location map showing the distribution of the studied wells.

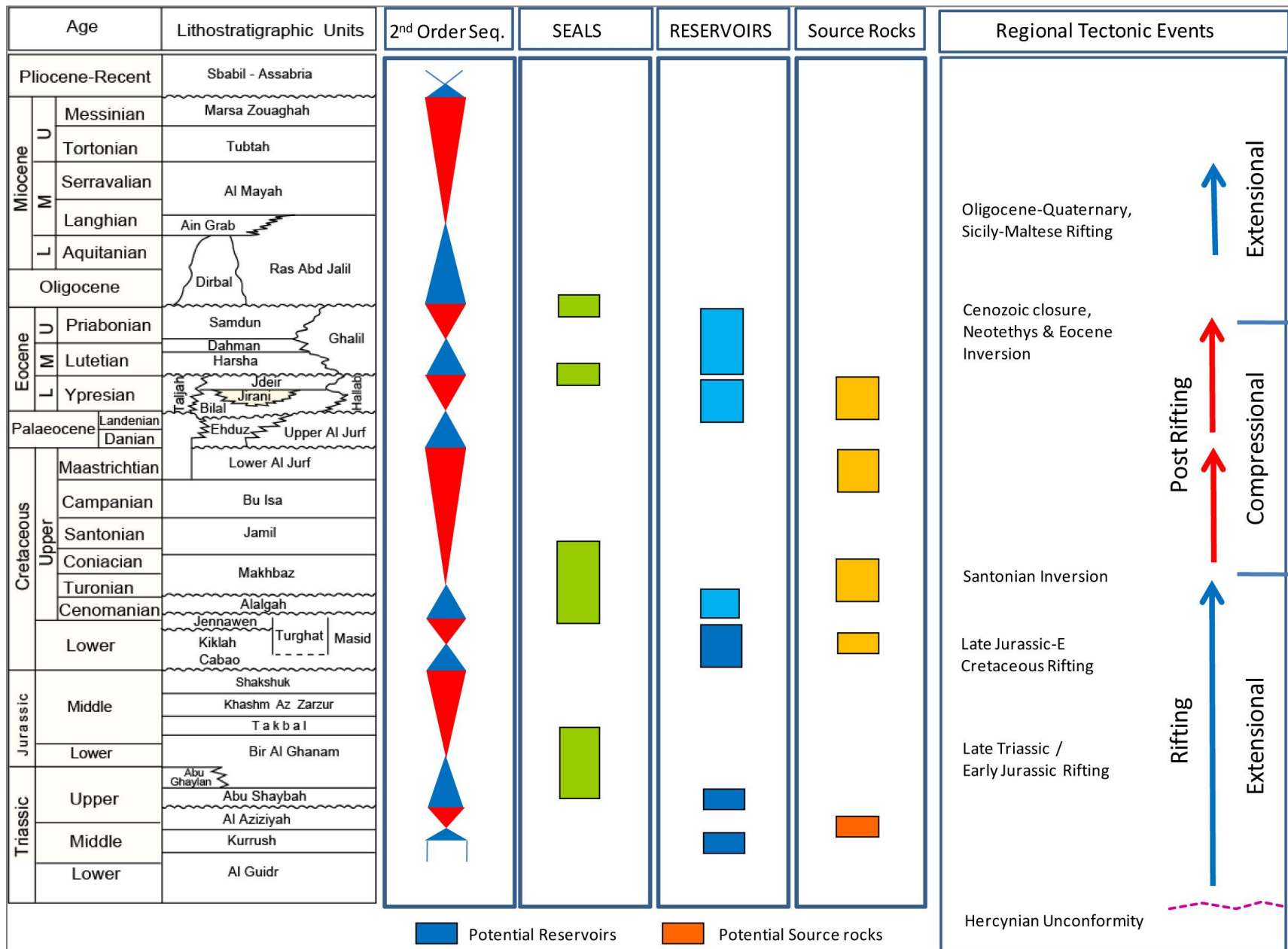


Figure 3. Showing the G-T Basin stratigraphy, regional tectonic events, and petroleum plays.

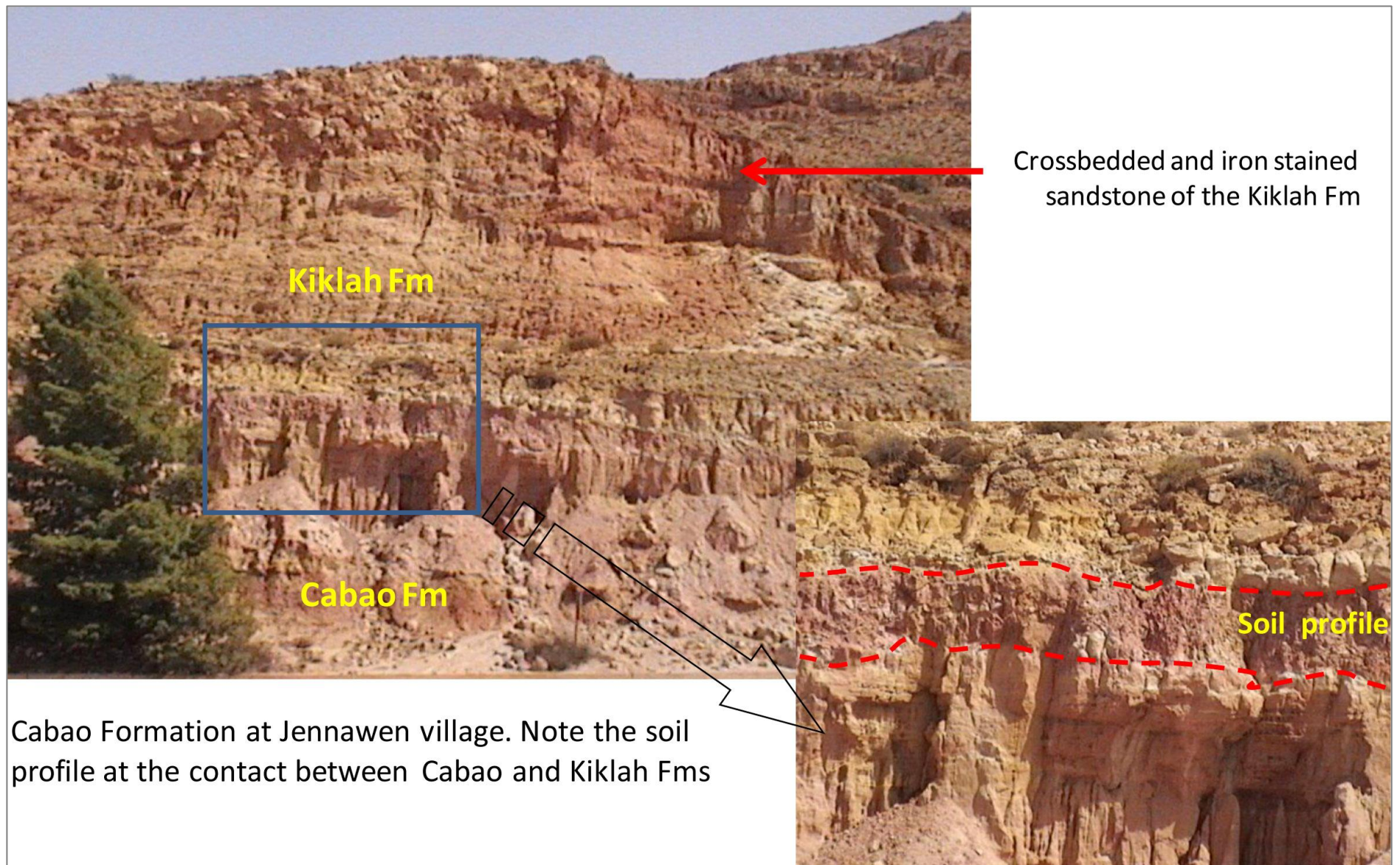


Figure 4. Thick sandstone section of Lower Cretaceous Cabao and Kiklah Formations. These units are considered as potential reservoirs at the G-T Basin, Western Libya offshore. At the Sirt Basin, onshore Libya, important hydrocarbon accumulations have been discovered in the Nubian Sandstone which is considered as equivalent to the Kiklah and Cabao Formations.

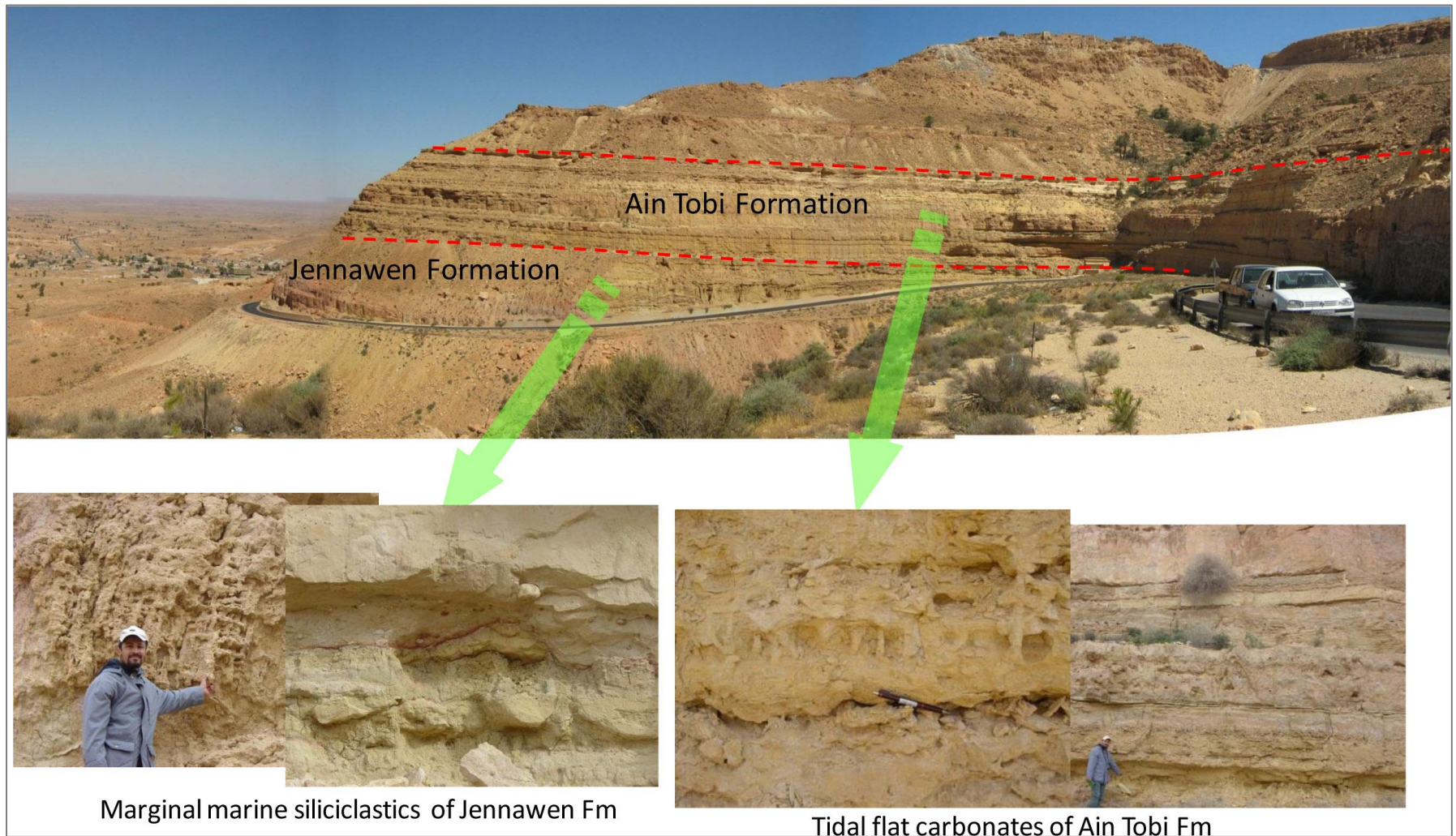


Figure 5. Showing the newly interpreted transgressive rock unit, the Late Albian-Cenomanian Jennawen Formation overlain by the tidally influenced carbonate of the Cenomanian Ain Tobi Formation. Seaward the marginal marine sediments of the Jennawen Formation is considered as a potential reservoir. At Sirt Basin, onshore Libya, important hydrocarbon accumulations have been discovered in the Bahi Sandstone which is considered as equivalent to the Jennawen Formation.