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NORTHERN TUNISIA THRUST BELT:
Deformation Model & Hydrocarbon Systems

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Introduction

Geologically, Northern Tunisia (both onshore & offshore) corresponds to a fold thrust belt linking the North Africa Atlas and the Sicily – Apennine chains, all belonging to the peri- Mediterranean orogenic arc that took place during Cenozoic following the collision between Africa and Europe plates. This NE/SW trending thrust belt is made of two major domains:

- The KABYLIAN domain

It is situated within the Tunisian offshore, northwards the " La Galite" island and represents the eastern part of the North African (particularly the Kabylian) crystalline units which were detached and transported during the Late Cretaceous – Oligocene Pyrenean thrusting as deep napes and later deformed during the Miocene Alpine shortening.

- The NUMIDIAN –TELLIAN domain

It corresponds to a vertical and lateral successive allochtonous units made of Oligocene –Miocene Numdian flysch and Cretaceous-Eocene shales and limestones. These thrusted sheets were mainly displaced during the Langhian –Tortonian compression and folded again during the Late Miocene – Pliocene shortening. Detachment levels are represented by the "allochtonous" Triassic salt, the Cretaceous and Tertiary shales.

These two domains are separated by the "KDF" fault (Kabylian Domain Front), which is identified in seismic as a major thrust.

For the hydrocarbon exploration, it is undoubtedly that the second domain (Numidian-Tellian) is more attractive and consequently, this paper will focus especially on this area.

DEFORMATION MODEL

The integrated use of the geological, geochemical, & geophysical data led to an inversion approach based on the similarities between the trending of the Tethyan margin structures and the Pyrenean –Alpine thrust fold belt and also on the well defined reactivation of the regional tectonic features related to the Tethyan rifting and margin growth during the Tertiary compressional events. These early-formed structures had controlled both the late deformations and the basin's geometries. Hence, Northern Tunisia area was submitted to two major tectonic cycles:

a. The Tethyan rifting and margin growth

Starting during Middle-Late Triassic with NE/SW to N/S opening direction, it led to the formation of rifts, tilted blocks, horsts and grabens. These basins had been filled with syn-rift deposits represented, particularly, by the Triassic sequences. The active margin development took place during Jurassic and continued through the Cretaceous, which are in general composed of shallow water to open marine sequences. However, the Early Albian is characterized by an active E/W shortening associated to a wrenching and doming assimilated to the "Austrian compression".

b. The Pyrenean –Alpine Orogeny

The earliest pulse of this major Mediterranean event is Late Cretaceous. The first paroxysm is dated uppermost Eocene-Oligocene and commonly known as the "Pyrenean compression". It resulted in the convergent plate boundary between Africa and Europe and characterized by a NW verging stress field, which induced a regional detachment and thrusting of the crystalline units and the Mesozoic overburden series. Thrusts, high angle reverse faults; wrench faults, ramps, overturned anticlines, pop-up anticlines, «en echelon» folds, fore deep and piggy back basins are the associated structures. Several Tethyan structures such as wrench and normal faults were reactivated during this phase. This remobilization led to a spectacular inversion well defined by the superposition of the thrust belt fronts the "Mesozoic Tunisian trough". Surface structural data, seismic interpretation and magnetic modeling support this inversion. The merging of these data highlights the regional deformation model (Figure 1B) consisting of a NW verging thrust fold belt composed of so far displaced faulted folds and ramps separated by fore deeps and ended to the SE by a fore bulge (platform) affected by the subsequent normal faults where Oligocene-Langhian deposits correspond to shallow water to fluvial detritus sediments.

The fore deeps were filled by thick turbidities up to 3000 meters. These sequences correspond to a syn-tectonic flysch commonly known in North Africa and Sicily as the Numidian turbidities.

During the Serravallian-Tortonian, the Alpine (s.s.) compression induced the detachment at different levels and southwards displacement of the Numidian sequences and locally Late Cretaceous-Eocene units. The Numidian sequence is duplicated at least on two superposed sheets. Allochtonous Triassic salt, Numidian, Cretaceous and Eocene shales acted as a detachment horizons.
This thrusting – folding had produced a high amplitude faulted anticlines and ramps associated to a piggyback basins accumulating unconformably over the Numidian flysch a conglomeratic and clastic Tortonian- Messinian. In the front of the thrusted complex, fore deeps are also common.

Later, the Pliocene –Pleistocene N/S shortening induced the deformation of older series. This deformation is characterized by high angle reverse faults, "en echelon" folds associated to strike slip faults and pull-apart basins.

HYDROCARBON SYSTEMS

Three potential petroleum systems are defined in this area:

- The **Albian/Cenomanian- Maastrichtian system** is composed of two source rocks (Fahdene & Bahloul Formations) and fractured carbonate reservoir (Abiod Formation). The sealing is well

assumed by the Paleocene shales. Some surface oil seeps are detected in these limestones within the allochtonous and imbricated units. In the foreland domain, this petroleum system is proven productive (e.g. Sidi Kilani Field).

- The **Ypresian/Ypresian system** is composed of open marine limestones (Bou Dabbous Formation), which is both source rock and reservoir. It is proven as a fractured reservoir sealed by the late Eocene shales in Belli and El Menzah fields (foreland fold). In Northern Tunisia, several oil seeps are observed in the Ypresian black limestones along the thrust fronts and the high angle reverse faults. In addition, the nummulitic banks are an excellent reservoir producing oil and gas in the eastern offshore and Sfax area.

- **The "stand alone" Numidian system** is a new and promising target in Tunisia and proven play in Sicily especially gas prone. The source rock corresponds to the shaly matrix of the sand bars, which represent the reservoir horizons. Sealing is assumed by the "interbedded " Cretaceous-Eocene allochtonous units and also by the Late Miocene-Pliocene shales, marls and evaporates.

As the expulsion-migration timing of the three source rocks is mainly Miocene –Pliocene (basin modeling: genex software) and regarding to the deformation timing table, different structures such as ramps, thrusted anticlines, triangle zones, pop-ups and undergone well conserved faulted blocks should be an attractive traps for significant oil & gas accumulations. Hence, this thrust fold belt is allowed to be one of the highest prospective areas in Northern Tunisia despite its early stage of exploration that could be considered as an encouraging factor.

Figure.1A- Structural Domains in Northern Tunisia

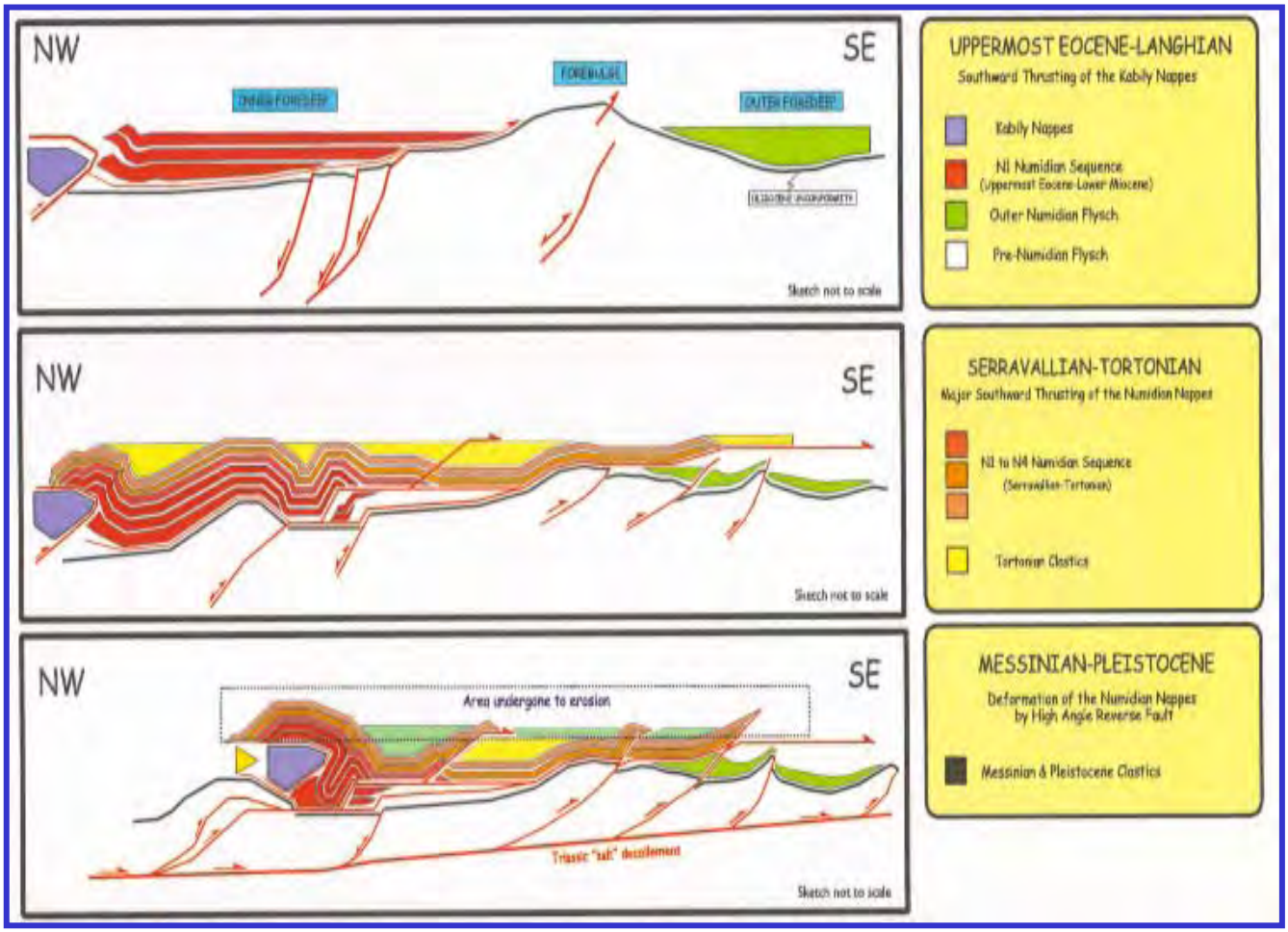

Figure1.B – Thrust belt deformation in Northern Tunisia