Tectonic Evolution of the Northern Margin of the Indian Plate vis-a-vis Hydrocarbon Potential

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Abstract

The continental lithosphere of the northern Indian Gondwanan margin has witnessed an array of tectonic episodes since Permo-Carboniferous to Jurassic. The lithosphere broke as a result of the episodes of continental rifting and subsequent opening of the Neo-Tethys Ocean. The occurrence of pre-syn- and post rift sediments in the Tethyan realm of the NW Himalaya testifies their evolution in an extensional regime. Between Jurassic and Cretaceous the northern Indian margin already became an evolved passive continental margin with deposition of prolific shelf carbonates and associated argillaceous sediments of different bathymetric regimes. The process of rifting and evolution of passive continental margin continued until the Neo-Tethyan ocean floor started converging beneath the Asian continent during Cretaceous. Finally the northern Indian margin collided with the Asian plate at about 50-60 Ma. The collision between the Indian and the Asian plates gave rise birth to the gigantic folded and thrusted mountain belt known as the Himalaya. Keeping in mind the pre-collisional evolution of the Tethyan realm of the NW Himalaya during Permo-Carboniferous to Cretaceous/Early Eocene, it is quite likely that several petroleum systems might have evolved in areas of distinct plate tectonic regimes i.e. rift-passive margin-syncollision and post collision etc. One such petroleum system along with hydrocarbon show could be discernible in the Middle-Late Cretaceous-Eocene shelf sequence of the Zanskar Tethys Himalaya. The present paper highlights the observation made during an exploratory field investigation in Zanskar Mountains in 2014.

Introduction

The Himalaya mountain chain is a classical example of continental collision tectonics (Molnar and Tapponnier, 1975, Gansser, 1977). It is an archive of the geodynamic response of the Indian and the Asian plates to collision since the Palaeogene (Patriat and Achache, 1984, Klootwijk et al., 1992, Rowley, 1996). The collision is responsible for uplift of the Himalaya, Tibetan Plateau and rejuvenating the tectonic architecture of the Karakoram and the Kun Lun regions (Searle, 1991, Matte et al., 1996, Upadhyay, 2002, Van Buer et al. 2015 and references therein). The collision of the Indian and Asian plates occurred sometime during ~ 60-50 Ma, led to the demise of the Neo-Tethys Ocean that existed between the Indian and the Asian plates since Permo-Carboniferous to Eocene. This collision zone could be documented as the major crustal lineament covering a lateral stretch of ~2500 km and referred to as the Indus Tsango Suture Zone (ITSZ) or the Indus Suture Zone (ISZ) (Molnar and Tapponnier, 1975, Gansser, 1977, Thakur, 1990, Sinha 1989, Upadhyay et al., 2008, Singh et.al. 2015 and references therein).

The Indus Suture Zone contains a variety of rock associations ranging in age from the Cretaceous to Miocene, or the younger ones formed under varied conditions, namely forearc, island arc and ocean basin setting. They occur in a complex structural juxtaposition, namely continental slope deposits, ophiolitic mélanges with MORB and OIB basalts, forearc sediments, calc-alkaline volcanics, and post-collision terrigenous clastic sedimentary deposits. To the south, the Indus Suture is tectonically juxtaposed against Shelf-slope to deep-marine sedimentary rocks of the Zanskar Shelf-Lamayuru-Karamba Complex, interpreted to be the representatives of the shelf-slope-deep marine passive margin of the Indian plate (Frank et al., 1977, Fuchs, 1982, Searle et al., 1987, Thakur, 1981, Sinha and Upadhyay, 1994, Robertson and Degnan, 1993; Robertson, 2000, Upadhyay, 2002, Upadhyay et al., 2004). There are also remnants of a carbonate platform in this zone.

Present Study

The geological documentation over a period of more than four decades in NW Himalaya suggests that a thick and complete marine geological record, as deep as Neo-Proterozoic to Eocene/Oligocene, constitutes the northern margin of the Indian Plate. This widely distributed marine sedimentary record of Tethyan affinity is very well preserved within the Tethys Himalayan domain of the NW Himalaya. To the north, the Tethys Himalayan domain is tectonically abutted by the Indus Suture Zone (ISZ) and to the south it is delimited by the rocks of the Higher Himalayan Crystallines (HHC) along a low angle normal fault known as the South Tibetan Detachment (STD). Based on tectono-sedimentary evolution the sediments and the metasediments of the Tethys Himalayan domain of the NW Himalaya could be classified (Yin, 2006 and references cited therein) as follows:

(1). Proterozoic to Devonian pre-rift sequence characterized by laterally persistent lithologic units deposited in an epicratonal setting.

(2). Carboniferous–Lower Jurassic rift and post-rift sequence that show sudden northward changes in thickness and lithofacies.

(3). Jurassic–Cretaceous passive continental margin sequence.

(4). Uppermost Cretaceous–Eocene syn-collision sequence (Liu and Einsele, 1994, Garzanti, 1999).

(5). Oligocene-Miocene onwards post collision sequence (Singh et al., 2015).

Thus, it is evident that the northern margin of the Indian Plate evolved through a complex interplay of successive episodes of lithospheric extension, compression and strike-slip movements in space and time. The culmination of these forces led to the formation and evolution of pre-syn-post rift sedimentary basin between Carboniferous and Lower Jurassic, evolution of a passive continental margin at the leading edge of the northern Indian margin during Jurassic and Cretaceous, initiation of syn-and post-collisional compressional and transform regimes and subsequent basin evolution during Palaeocene to Mio-Pliocene time. The preserved rock record of the Tethys Himalaya thus suggests that the tectono-sedimentary processes, that reshaped the region, prevailed over a time span of at least about 500 Ma.

According to Bois et al (1982), the pre-Tertiary Tethys Ocean is believed to have an important influence on the accumulation and distribution of petroleum in the world. Major oil fields of the world are found close to subduction zones (Fig. 1) and from this point of view, the northern margin of the Indian plate, bordering with Indus Suture/subduction zone, becomes crucial sector as far as hydrocarbon potential is concerned. Similarly, Klemme and Ulmishek (1991) identified six stratigraphic intervals representing one-third of the Phanerozoic time, contain, petroleum source rocks that have provided more than 90% of the world's discovered original reserves of oil and gas. From this the Mesozoic interval contributes 54 % (Upper Jurassic ~25% and Middle Cretaceous ~29%) of the reserves (Fig. 2). Similar Mesozoic intervals are very well distributed within the Tethys Himalayan domain of the NW Himalaya. Thus, it is quite likely that the Tethys Himalayan domain is an ideal candidate for a number of petroleum systems vis-a-vis hydrocarbon potential.

Awasthi et al (2010) carried out the organic matter and its thermal degradation for generation of petroleum hydrocarbons in three argillaceous sedimentary formations of the Ladakh area of the Indus Suture Zone. According to them all the three formations have sufficient organic matter of right quality (mainly the kerogen type III with little type II) and have undergone sufficient thermal maturation to generate petroleum hydrocarbons, mainly gas with little oil.

Likewise, based on his exploratory geological investigation (September-October, 2014) in the Zanskar Mountains of northwestern Tethys Himalaya, India, the present author struck upon the presence of a most likely petroleum system of Middle Cretaceous to Early Eocene age. The salient observations are as follows:

1. At Shinge La (~5000 m) the outcrops of Mid-Late Cretaceous dark black shale have been named as Kangi La Formation/Lamayuru Formation or Goma Shale (Fuchs and Willems, 1990, Gaetani et al., 1983, 1986) smells heavily like petroliferous substance/gas. The average structural thickness of these sediments is 400-500 m (Fig. 3). The Kangi La/Lamayuru Formation is overlain by ~45 m thick nodular to planar, dark burrowed medium-fine grained sandstone and mudstones to bioclastic limestone and dark marly clays of Maestrichtian Marpo Formation. The dark colour of the sandy facies of the Marpo Formation may be due to oil staining. The entire sequence is tectonically overlain by the rocks of the Spongtang Klippe.

2. The early Palaeocene Stumpata Quartzarenite (13 m to 59 m thick (Fuchs and Willems, 1990, Gaetani et al., 1983, 1986) shows likely oil stained outcrops (Fig. 4).

3. About 2-3 km from the above mentioned location the Palaeocene-early Eocene Dibling Limestone (200 m thick (Fuchs and Willems, 1990, Gaetani et al., 1983, 1986) and associated grey, green and pinkish shale, silt, marls layers again smelled heavily like petroliferous substance/gas (Fig. 4).

4. The spring waters near the village of Kangi (2-3 km below the above mentioned outcrop) show very prominently the persistent flow of likely sheen of oily substance beside intermittent gas bubbles pouring out from the stream bed (Fig. 5).

These rock formations have been laterally mapped for a distance of about 55 to 60 km from around Shinge La in Photoskar Valley to Kangi via Sirsir La, Shillakong and Dumbur and beyond as well.

Conclusion

Thus, based on the first hand field data it could be envisaged that in the Zanskar Tethys Himalaya a prominent petroliferous system must have had evolved between Middle-Late Cretaceous to Early Eocene. Therefore, the need of the hour is to carry out detailed geological studies to locate the entire petroleum system and to evaluate its economic potential, if any, in the Tethyan Himalayan domain of the Zanskar Mountains and its extension in adjoining areas.

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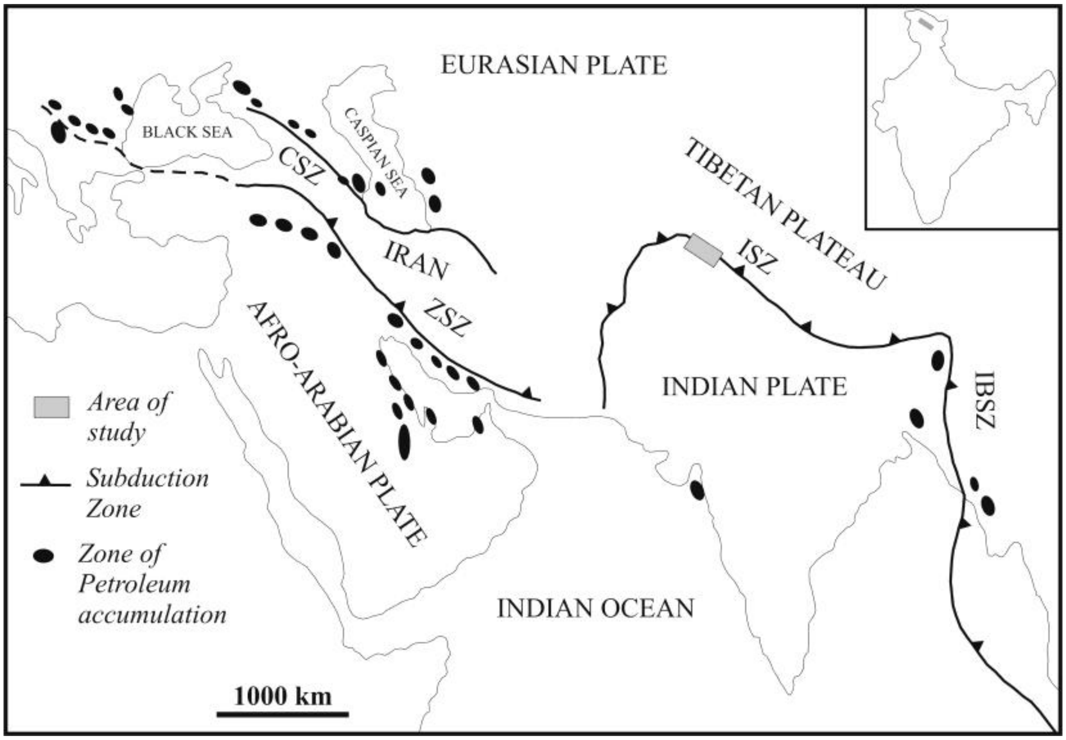

Fig. 1. Major oil fields with the subduction zone along Alpine-Himalayan tectonic belt (after Bois et al., 1982, Awasthi et al., 2010). ZSZ- Zagros Subduction Zone, ISZ- Indus Subduction Zone, IBSZ- Indo-Burma Subduction Zone, CSZ- Caucasus Subduction Zone.

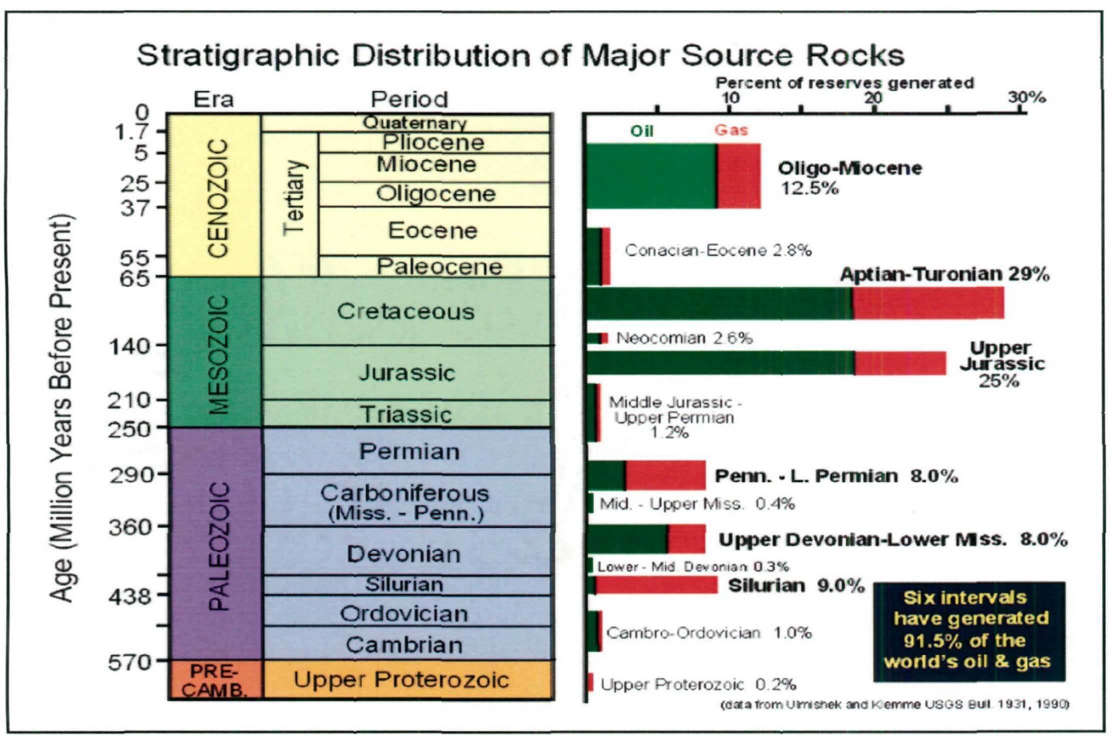

Fig. 2. Stratigraphic distribution of source rocks through deep time (after Ulmishek and Klemme, 1990)

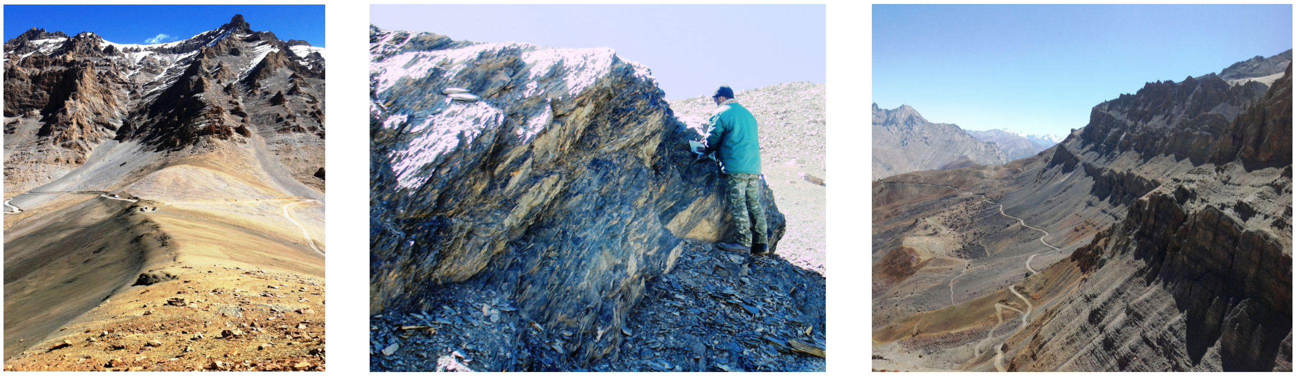

Fig. 3. Mid-Late Cretaceous black shale (smell like petroleum substance) and associated sequences at Shinge La (Photo: RU)

Fig. 4. Oil stained outcrops of Palaeocene Stumpata Formation and petroleum substance smelling outcrops of Kangi area (Photo: RU)

Fig. 5. The spring water near the Kangi village shows likely oil sheen in water (Photo: RU)