GEOLOGY AND PETROLEUM POTENTIAL OF THE SEDIMENTARY BASINS, AFGHANISTAN

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ABSTRACT

In Afghanistan, the petroleum exploration began in 1936 which increased in 1957 with the technical and financial support of the former Soviet Union. Sheberghan gas fields' production not only supplied for the operations of Power Plant and Northern Fertilizer but also it was exported to Soviet Union until their withdrawal in 1989. It was until February 2011 when only 34 natural gas wells at three sites in Sheberghan produced in limited capacity. Afghanistan has six oil and gas basins which are Amu Darya, Afghan-Tajik, Helmand, Tirpul, Khushka and Katawaz. Amu Darya, one of the major areas in the north, which has been discovered and has been extracted for now. Over the years research has not been conducted with modern technology. Petroleum system modeling has been carried out for precise estimation reserves in this area are of particular importance.

Keywords: Afghanistan, Geology, Petroleum, Sedimentary Basins, Tectonic

Introduction

Afghanistan sits astride the collision zone of the Indo-Pakistan and Asian crustal plates which has given rise to the Himalayas, and as a result has some of the most complex and varied geology in the world. The oldest rocks are Archaean which are succeeded by rocks from the Proterozoic and every Phanerozoic system up to the present day. The country has a long and complicated tectonic history, partly related to its position at the western end of the Himalayas. The tectonic history of the area appears to be the result of successive accretion of fragments of Gondwana to the active margin of Laurasia since the end of the Palaeozoic. Hence, Afghanistan is an assemblage of crustal blocks separated by fault zones, each with a different geological history and mineral perspectivity. This diverse geological foundation has resulted in significant potential

for a variety of styles of copper mineralization, in particular, sediment-hosted, skarn, porphyry and vein-hosted deposits. Two major structures that influenced crude oil and natural gas occurrence developed in northern Afghanistan during Mesozoic and Cenozoic time; the Parapamiz-Bande Turkestan Range (a mountainous foldbelt), located in the southern and central parts of the northern Afghanistan; and the Murgab depression of the Amu Darya Basin, located in the northern part of the area. The Parapamiz-Bande Turkestan may have been a rift basin formed on the Eurasian plate behind a magmatic arc of the Hindu Kush and Parapamiz.

Geology of Afghanistan

Afghanistan geology is one of the most complex and diverse geology in the area. Archean are the oldest rocks and they do well by rocks from the Proterozoic and Phanerozoic systems until the present day. Afghanistan also has complicated and a long tectonic history, pretty related to its location at the western end of the Himalaya.

There are three major areas of sedimentary rocks in Afghanistan which are situated in the north, southwest and southeast. The center part of Afghanistan has magmatic and metamorphic rocks.

According to the research that has been done in the mentioned areas, high fold and fault were accrued to the second and third of this area, and there is negligible fuel latent. Thus, there are less interested further. Only the North of Afghanistan has considerable forecasts for gasoline (Schindler, 2002).

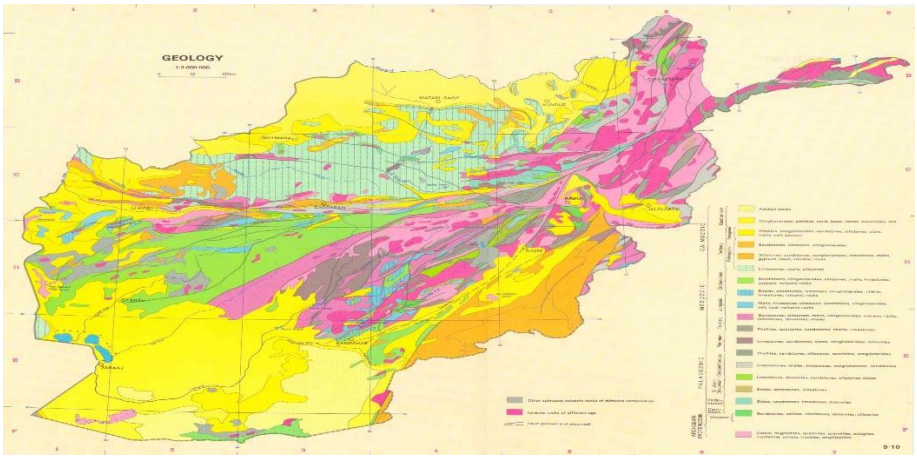

Figure 1. Geology of Afghanistan (Kingston and Clarke, 1995)

Structure and Tectonic

The North Afghan platform forms the Parapamisus and western Hindu Kush mountains and high plains of the Amu Darya basin, lying in northern Afghanistan and the southern parts of

Turkmenistan, Uzbekistan and Tajikistan. On this platform, relatively undeformed mostly clastic Jurassic to Recent sediments overlying deformed Triassic and older rocks. On the south and east, the platform is sharply defined by the Harirud strike–slip and related faults marked by the line of the Harirud and Pansjer rivers. On the north and north–west, geophysics and borehole records show a gradual passage into the Murghab and Tadjik basins, filled with dominantly clastic Mesozoic–Quaternary sediments. This platform cover consists of Mid-Mesozoic to Neogene sediments covering Palaeozoic–Triassic rocks and structures. The platform has four main areas separated by major faults: the Herat Trough, the Qualai Naw, Maimana and Sherbergnan blocks. However, the dominantly right-lateral Neogene faults do not significantly offset any structures in the pre-Jurassic basement and have little effect on Mesozoic–Recent facies belts. To the north, the platform is faulted against the Tajik basin, while to the northwest, it passes gradually into the Murghab basin.

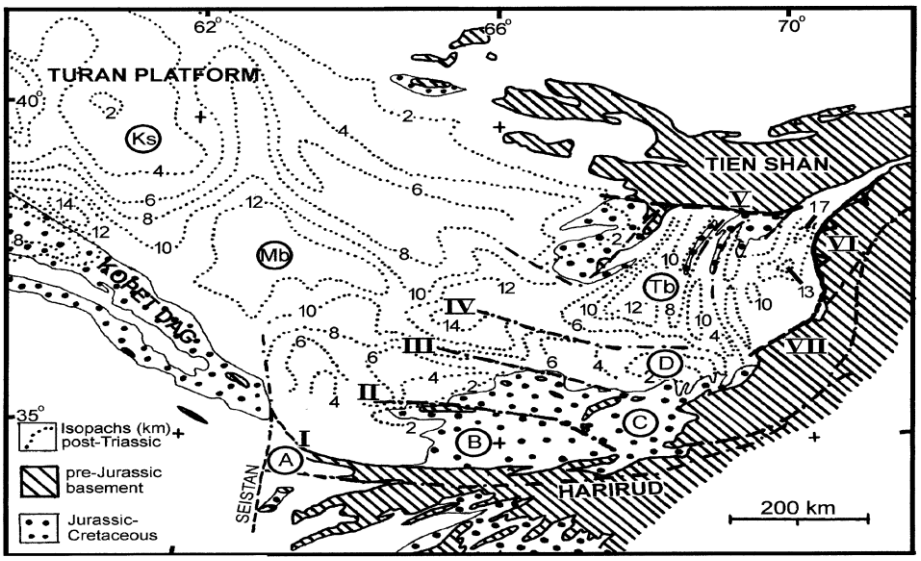

Fig. 2. General geology, tectonic units and features (Abdullah et al., 1980)

The pre-Jurassic basement is exposed mostly along the southern and eastern margins of the platform in the Parapamisus and Hindu Kush ranges. Northwards and westwards, it outcrops only in a few tectonic inliers, like the Bande Turkestan uplift. Along the southern edge and eastern edge of the platform, the basement is cut by an Early Mesozoic magmatic arc, which extends northwestwards (mostly obscured by the younger sediments) along the southern edge of the Amu Darya basin (Inanch.S, 2018).

Sedimentary Basins in Afghanistan

Afghanistan has six sedimentary basins, which located different part of the country. Almost all of the petroleum exploration and development activities were confined to northern

Afghanistan within the Amu Darya and Afghan-Tajik basins. During the Soviet era (1957-1989), a total of seven (7) oil and eight (8) gas fields were discovered. Over 20 potential structures were identified; 3 were subjected to further deep exploration drilling. In Ahmadabad area, presence of oil in Palaeogene sediments was intersected at 840 meters and 1,190 meters; oil flowed at 6.7 cubic meters per day. With the application of 3-D Seismic and further exploration this area has potential to uncover large deposits in the area. Katawaz and Helmand Basins negligible exploration has been undertaken in these basins and hence remains untested, despite favorable geological settings (Inanch. S, 2018)

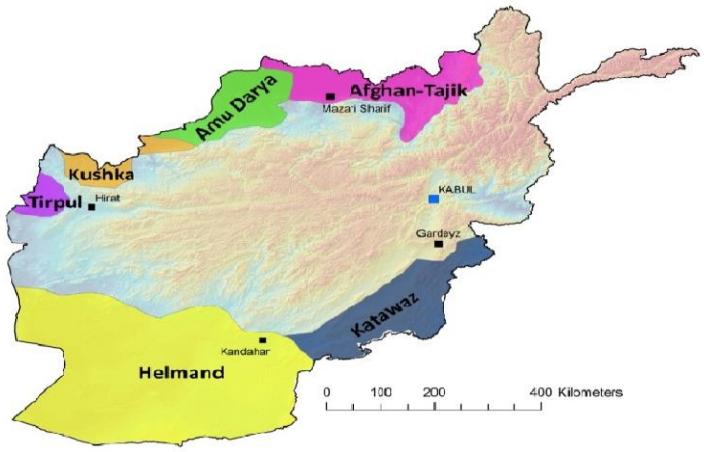

Figure 3. Shows general location of the 6 sedimentary basins in Afghanistan (MMP,2013)

Table 1: Sedimentary Basin and their name, location and status (Ishaq & Farooqai, 2013)

No	Basin	Location	Status
1	Amu Darya	North of Afghanistan	Underexplored
2	Afghan Tajik	Northern and Northeastern of Afghanistan	Underexplored
3	Tirpul	Western of Afghanistan	Underexplored
4	Kushka	Northwestern of Afghanistan	Underexplored
5	Katawaz	Southern of Afghanistan	Negligibly explored
6	Helmand	Southwestern of Afghanistan	Negligibly explored

Amu Darya Basin: The sedimentary crude oil zone and natural gas of Amu Darya is situated in the north and northwest of the country bordering Turkmenistan and Tajikistan. The crude oil zone is stretched over 75,000 square kilometer's. Officially, its survey started with the collaboration of former Soviet Union in 1958 following an agreement between the two counties. Sources said around 500 digging spots had been identified. So far 67 spots have been explored in which eight had natural gas and six contained crude oil. It is estimated that these reserves hold 962 million barrels of crude oil

and 52 trillion cubic feet of natural gas. The original reserves had 120 billion cubic feet of natural gas of which 57.5 billion cubic feet gas had been utilised. In terms of reserves, the Amu crude oil and gas zone is considered to be 15 in the rank out of total 152 oil and gas zones in the world.

Afghan-Tajik Basin: This basin situated in the north and northeast of Afghanistan; the Afghan-Tajik crude oil zone is stretched over about 31,000 square kilometres area along the 360 kilometres border with Turkmenistan. The zone extends from Takhar to Jawzjan province, bordering the Hindukush Mountains in the east, Amu River in the north and west and Alburz Mountain in the south. The oil zone is also stretched to the border territory of Tajikistan. Geologists have discovered several sites of oil and gas reserves in the other side of the border. The Tajik-Afghan crude oil zone was discovered in 1958 with a reserve of around 946 million barrels of crude oil and 8 trillion cubic feet of natural gas. The worth of Afghan-Tajik oil and gas zone is estimated at $123 billion. The sedimentary Afghan-Tajik oil and gas zone is divided into 12 blocks.

Tirpul Basin: This area is located in the western part of Afghanistan in an area near the border between Iran and Islam Qala in Herat and it is 95 kilometers away from the border with Iran. The area of the mentioned area is (14) thousand square kilometers and in the Herat sedimentary area, seismic, gravimetric, and geological survey researches have been carried out, as a result of which a number of deep geological structures have been prepared for exploratory drilling. Above the structures of Ahmedabad, Tirpol and Goharshad Begum, it has been proved that its oil and gas productivity is the first point of exploration in Ahmedabad. Although there is no accurate information about the amount of oil stored and exploitable in this area, exploration work is going on in the mines of this area and several domestic and foreign companies have wanted to extract oil from this area. Tirpul sedimentary area is one of the interesting geological areas where all the conditions for the formation of hydrocarbons are favorable.

Kushka Basin: It is said that representatives of the Ministry of Mines have been sent to Gulran, Kashk-e-Kehne and Kashk-Rabat-Sangi districts in northern Herat province, bordering with Turkmenistan, to investigate oil and gas reserves. Recent geological studies in the districts of Kashk-e-Kehne, Kashk-Rabat-Sangi district, Golran district and even areas in the west of Badghis province show that there are gas resources in these areas. Research is currently underway in this area. Let's see what results are obtained.

Katawaz Basin: Katwaz oil and gas field is a joint area between Yahya Khel, Zarghoon Shahr, Jani Khel and

Khoshamand districts in the southern part of Sharna. This area is located in the southeastern part of the country and it is related to the geocene clinal zone (the cause of the rise and depression) and the area of this area is about (40) thousand square kilometers, and the thickness of the rocks on it reaches (6) thousand meters. Sediment is pre-Cambrian sediments (crustal sediments). The oil and gas of the Ketwaz basin is related to the Paleogene (first formation period) Eocene (new formation period) sediments that have been fruitful in the part of Pakistan region. In this area, Cretaceous and Jurassic sediments are also expected to contain oil and gas. Geologists researching in the field of oil and gas believe that Ketvaz oil and gas is a sedimentary area that can make good predictions about its future. Also, good oil and gas reserves have been discovered in the common area of this area, which is located on the other side of the Durand Line in Pakistan.

Helmand Basin: This area is generally formed by Marko Plain and Rigestan, and its area reaches (131) thousand square kilometers, the thickness of the sedimentary rocks of the mentioned area is (5-6) km, which is favorable for the formation of hydrocarbons. Almost no geological studies have been carried out in this area, its prospects will be clarified after conducting a series of geological researches.

Petroleum Potential of Northern Afghanistan

The characteristics of the pre-Jurassic basement can be used to tentatively outline stages of development. Since the area is so complicated, a detailed tectonic history cannot yet be written. Ordovician to Lower Devonian stage consists of a passive margin developed on oceanic crust. The pre-Upper Devonian sections, though metamorphosed consist of mature shelf and passive margin sandstones, shales and limestones: thick, extensive Devonian limestones suggest a passive margin. There is not enough evidence preserved to determine the orientation of this passive margin (Brookfield & Hashmat, 2001). The Callovian–Oxfordian marine section provides 10% of the hydrocarbon yield of predominantly type-II kerogens. The mixed marine–continental Neocomian and Aptian–Albian provide a meagre 1% and about 14%, respectively. Presumably the hydrocarbons are mixed. The coal bearing clastic source rocks decrease very markedly in thickness onto the North Afghan platform (Brookfield and Hashmat, 2001)

Geology and Structure of Northern Basins

As a result of previously conducted geological investigation in the north and northwest of Afghanistan, five hundred structures for the accumulation of oil and gas were identified. Deep drillings were carried out in 67 structures. Northern Afghanistan considered to have the highest potential for oil and gas reservoirs in Afghanistan. Amu Darya Basin located in

the northwest of Afghanistan contain large number of undiscovered prospective fields (Klett et al, 2006). It Can be observed in Fig.2.9 that the proven oil and gas basin of Amu Darya is stretched in the northern Afghanistan. The Amu-Darya Basin extends over an area of 57,000 km^2 are situated in particular northern Afghanistan.

The east boundary is the Hindu Kush and Badakhshan. Northern Afghanistan has pre-Jurassic basement unconformably overlain by Jurassic to Paleogene oil- and gas-bearing terrigenous and carbonate rocks, which in turn are unconformably overlain by Neogene orogenic continental clastics (Jameson et al. 2012).

The basement in both basins comprises peneplane fold structures composed of continental and oceanic blocks accreted during Late Paleozoic tectonism and consist of intensely deformed and partially metamorphosed sedimentary rocks at depths of 4 to 16 kilometers. A Permian to Triassic transitional complex, up to 2,500 meters thick, overlies the pre-Permian section. Undifferentiated Permian and Triassic marine carbonate and clastic rocks that pass into redbeds fill grabens in the basement (Kulakov, 1979; Orudzheva and Kornenko, 1991).

The Jurassic to Paleogene sedimentary cover is divided into four intervals:

(1) Lower to Middle Jurassic continental to paralic clastic rock.

(2) upper Middle to Upper Jurassic marine carbonate and evaporite rocks.

(3) continental Neocomian clastic rocks and redbeds.

(4) Aptian to Paleogene marine carbonate and clastic rocks.

Neogene to Holocene orogenic clastics were deposited as a result of tectonic deformation related to the collision of the Indian plate with the Eurasian plate, which began in latest Oligocene time.

Stratigraphy

The taphrogenic Triassic section is commonly deformed and partially metemorphosed in outcrops around the Amu Darya Basin. Although undeformed rocks of this age may be present beneath the Jurasic to Cenozoic sediments in the inner parts of the basins, the rocks are over mature with respect to petroleum generation and considered here as an economic basement for petroleum production. The Lower Triassic section in northern Afghanistan is approximately 1,000 meters thick and consists of conglomerate overlain by dolostone, siltstone, sandstone, volcanic rocks, and tuff. Near Doab, Lower Triassic rocks are over 400 meters thick and include thin limestone beds unconformably overlain by conglomerate, dark mudstone, siltstone, sandstone, volcanic rocks, and tuff. The Middle Triassic section in northern Afghanistan is approximately1,000 meters thick and consists of mudstone, limestone, and sandstone. Near the Hindu Kush range, Middle Triassic rocks are thicker (4,700 meters) and

include thick beds of intermediate and acidic volcanic rocks and tuff. The Upper Triassic section in northern Afghanistan consists of sandstone, conglomerate, mudstone, and siltstone, with some volcanic rocks. Kugitang suite (Callovian-Oxfordian) is represented by mainly carbonate deposits of an Upper Jurassic barrier-reef system, which extends west-to-east. The upper Oxfordian Khodzhaipak Formation of western and southern Uzbekistan was deposited as a basinal facies of the main reef complex, but overlaps some reefs.

To the south, the formation consists of pure gypsum 635 to 675 meters thick with andesite and tuffs 70 to 90 meters thick. To the north, the formation consists of mudstone with two gypsum beds 7 and 13 meters thick with salt lenses 1.5 to 17 meters thick and up to 17 meters long observed in outcrops. The total thickness of the formation ranges from 150 to 800 meters or more.

Three members are observed in a complete stratigraphic section. The lower two-thirds of the suite are made up of red-colored silty mudstone. An interlayer of dolostone with marine fauna of Hauterivian age is the middle member. The upper part is brownish-red mudstone interbedded with gypsum. In the Afghan-Tajik Basin, the Almurad suite consists of red mudstone, gypsum, dolostone, and siltstone up to 120 meters thick and thins northward. Sandstone in the middle unit (middle Albian) is a good reservoir rock. The sandstone is gas bearing at Etym Tag and Khuja Goger Dak Fields and oil bearing at Angut Field. Albian reservoir rocks pinch out and laterally grade into clays, argillaceous siltstone, and marl on the Akhchin step, Andkhoy uplift and Maimana step. (Klett et al., 2006).

Petroleum System of Northern Basins

Elements of the Amu Darya Jurassic-Cretaceous Total Petroleum System and the Jurassic Total Petroleum System include Lower to Middle Jurassic carbonaceous mudstone and coal and Upper Jurassic basinal marine mudstone source rocks; Upper Jurassic carbonate and Lower Cretaceous clastic reservoirs; Upper Jurassic evaporites and Lower Cretaceous mudstones seals; and Mesozoic and Cenozoic structures and reef-related traps. The third, Kalaimor-Kaisar Jurassic Total Petroleum System includes only Lower to Middle Jurassic carbonaceous mudstone and coal source rocks; Lower to Middle Jurassic and Lower Cretaceous clastic reservoirs and Upper Cretaceous carbonate reservoirs; intraformational Jurassic, Cretaceous, and Paleogene mudstones seals; and Mesozoic- and Cenozoic-age structures as traps. Lower to Middle Jurassic rocks are considered the most likely source for natural gas in the Northern Basins. Condensate in Lower Cretaceous reservoirs of Etym Tag Field is light (density of 0.846 grams per cubic centimeter or 36 degrees API gravity), low sulfur content

(0.53 percent), and paraffinic (5.09 percent). The condensate has a paraffinic to naphthenic (Brookfield & Hashmat, 2001).

The source rocks for crude oil in this basin have not been identified by previous studies. This system is composed of lower Eocene basinal marine mudstone source rocks; Upper Cretaceous to Paleogene reservoirs; lower Eocene and upper Paleogene mudstone seals; and Neogene compressional structures associated with Himalayan orogenesis as traps. Evaporite-evacuation sites (areas where evaporite is absent) might have allowed local mixing of Jurassic-sourced petroleum with Paleogene-sourced petroleum. Anticlinal structures in the eastern part of the basin are eroded and some are breached, resulting in biodegradation and leakage of petroleum (Schumacher,2002). Another unnamed total petroleum system includes Lower to Middle Jurassic carbonaceous mudstone and coal on the North Afghan High where coalbed gas accumulations may be present. The presence and extent of the Lower to Middle Jurassic (Klett et al., 2006).

Table 2. Specifications of source rocks for Northern Basins (Klett et al., 2006)

No	Formation	Depth (m)	Thickness (m)	TOC (%)	HI (mgHC/gTOC)	Kerogen
3	Suzak	1288-1333	45	0.5- 3.5	160- 875	Type II
2	Kugitang	3770-4170	400	0.22- 1.2	60- 530	Type II
1	Baysum	4170-4870	700	0.7- 4.3	80- 198	Type III

The structure of subsalt anticlinal traps and possibly stratigraphic traps are in the pinch-out section of Jurassic sedimentary rocks along the margin basin.The Upper Jurassic including evaporate sediments are delivered a regional seal for petroleum accumulations. Based on geological data, perhaps the regional seal existing only on the western (Klett et al., 2006).

Table 3. Petroleum system of Northern Basins (Klett et. al,. 2006)

Petroleum system	**Formations**	**Lithology**
Source rocks	Lower to Middle and Upper Jurassic	Coaly continental to marine clastic
Reservoir rocks	Upper Jurassic, Hauterinian and Middle Palegene	Carbonate, sandstone
Seal rocks	Upper Jurassic, Lower Cretaceous and Middle palegene	Salt, carbonate and madstone

Conclusion

Afghanistan has six Sedimentary Basnis, including Amu Darya And Afghan-Tajik, two of the major areas in the Afghanistan, which has been discovered and has been extracted for now. In Afghanistan petroleum exploration began in 1936 which increased in 1957 with the technical and financial support of the former Soviet Union. Petroleum system modeling has been carried out for precise estimation reserves in this area are of particular importance.

The North Afghan platform forms the Parapamisus and western Hindu Kush mountains and high plains of the Amu Darya and Afghan-Tajik basins, lying in northern Afghanistan and the southern parts of Turkmenistan, Uzbekistan and Tajikistan.

Elements of the Amu Darya and Afghan-Tajik are Jurassic-Cretaceous Total Petroleum System and the Jurassic Total Petroleum System include Lower to Middle Jurassic carbonaceous mudstone and coal and Upper Jurassic basinal marine mudstone source rocks; Upper Jurassic carbonate and Lower Cretaceous clastic reservoirs; Upper Jurassic evaporites and Lower Cretaceous mudstones seals; and Mesozoic and Cenozoic structures and reef-related traps.

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