



Petroleum Geological Characteristics of Suzak Formation in the Afghan-Tajik Basin Part of Northern Afghanistan

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Abstract In this study, the source rock potential of the Organic-rich Eocene-age Suzak Formation was investigated. This formation is located in Afghan-Tajik basin in northern Afghanistan. To understand the capacity of this formation organic geochemical and organic petrographic analysis of the source rock was carried. During these analysis, in northern areas of Afghanistan bedrock, crude oil, and natural gas samples along with outcrops were collected from fields and wells to correlate with natural gas and crude oil to postulated source rocks. Suzak mudstone outcrop samples have low organic matter which is averaging about 0.4 %. Whereas the TOC contents of two outcrop samples is greater than 1 %, both approximately 1.3 %. The total organic matter contents of two Suzak core samples is about 13.9 and 19.7 %, indicating that these samples are able to generate petroleum. The Rock-Eval analysis demonstrated that Tmax is between 435-465 °C, in which organic matter takes place between immature-post mature zones. The Rock-Eval analysis also shows that most of the outcrop samples contain type III kerogen which is gas-prone. But core and a few outcrop samples have crude oil-prone type II kerogen. The vitrinite reflectance values of the most samples are changing from 0.9 % to 1.5 %, proving that the organic matter is thermally mature. The vitrinite reflectance values of tow samples are approximately 2 % which shows that the samples are able for natural gas generation. One aberrant sample probably includes vitrinite reprocessed with a reflectance value of 5.6 %.

Keywords Afghan-Tajik, organic matter, Rock-Eval, Suzak Formation, Total Organic Carbon, vitrinite reflectance

Introduction

Afghanistan has five large and one small sedimentary basin. Nearly all of the petroleum exploration and development activities are restricted to the North Afghanistan, where the two large basins, Afghan-Tajik and Amu Darya basins are located [1-2].

The Afghan-Tajik Basin takes place in Afghanistan, Tadjikistan, Uzbekistan, and Turkmenistan. Generally, the bulk of the basin is located in Tadjikistan and Afghanistan. A small part of the basin is located in the Uzbekistan and Turkmenistan. Inside the borders of Afghanistan, it takes place in northern and northeastern parts of the country and more than 10 km of Mesozoic and Cenozoic layers are covered by it [2]. Oil generation on marginal structural stages is from Upper Jurassic and Cretaceous reservoirs however in the basin center, it is from Paleogene reservoirs [3].

In the Afghan-Tajik Basin part of Tadjikistan, Petroleum has been discovered and is produced. Bu in Afghanistan no discoveries have been made until today, petroleum has been observed on structures of Gunj and



Kunduz (Kortau) in some wells. According to the researches which took place in part of northern Afghanistan, 21 wells have been drilled in the Afghan-Tajik Basin up to now. Due to some technical problems with overpressure, most of the wells have not penetrated targets or untested and incomplete [4].

The Paleogene Total Petroleum System of the basin is proved as crude oil-prone [5]. Cretaceous rocks of the Surkhan megasyncline have been opened by few wells. Although the best part of the wells end just below the Paleocene rocks [6]. Based on organic geochemical and organic petrographic analysis the Eosen age Suzak Formation has proved as the source rock of petroleum in this basin [7].

Regional Geology

Afghan-Tajik Basin is an interglacial basin surrounded with Gissar and Pamir mountain ranges and in general it has an area of approximately 12×10^4 km². The Afghan-Tajik Basin is located in the south-east of Tadjikistan, north and north-east of Afghanistan, desert and semi-desert regions of Turkmenistan and south-west of Uzbekistan [8] (Fig. 1).



Figure 1: Location of the Afghan-Tajik Basin [9]

The Afghan-Tajik Basin located within the borders of Afghanistan has an area of 31,000 km² and has a common border with Turkmenistan about 36 kilometers. The type of the basin is orogenic and Hercynian which has known as the basement of the basin and contains highly disturbed and metamorphosed rocks of Pre-Cambrian and Paleozoic. These rocks are visible in areas which are surrounded by Tien Shan and Pamir mountain ranges. The basement of the basin has 3 units, they are Back-arc Unit, Platform Unit, and Collisional Unit. The generation, migration, and accumulation of petroleum is nearly connected to the platform unit. For that reason, the platform unit is the emphasis [10].

Oil and gas production has not been done up to now in the Afghanistan part of the Afghan-Tajik Basin. However, production is carried out from parts of this basin in Uzbekistan and Tadjikistan [11].



Although the source rock of crude oil has not been detected, according to the geochemical analysis and researches carried out by USGS (United States Geological Survey) in 2006, it is explained that Suzak mudstones may be the petroleum source rock in this basin.

Structural Development of the Afghan-Tajik Basin

The structural development of the Afghan-Tajik Basin is connected to the southern Paleo-Tethys Ocean and its orogenic belt. The thrust faults and folds has been developed by the impact of these orogenic belts. These thrust faults have affected the structural framework of the basin and they have also play an important role in the accumulation of hydrocarbons [9].

This basin has faced 3 different structural transmutation phases:

(1) Late Permian-Triassic back-arc foreland phase, in this stage, the Paleo-Tethys Ocean is closed, compressed the basin, shaped thrust faults and folds, and along with these changes the unconformity between Jurassic and Triassic systems was created [9].

(2) Jurassic-Eocene Faulted-depression stage. In this phase, after the orogenic period, the basin has undergone a platform phase and formed a series of continental molas formation. During this stage, the Afghan-Tajik Basin faced 3 large-scale collisions, 3 transgressions from west to east, and created 3 continent-marine sedimentary cycles [9].

(3) The regeneration foreland basin stage of Oligocene to now. In the Neogene period, the Eurasian Plate and Indian Plate began to collide. During the Miocene period, the Afghan-Tajik Basin undergone to a strong compression and formed a series of thrust faults and related folds [9] (Fig 2).

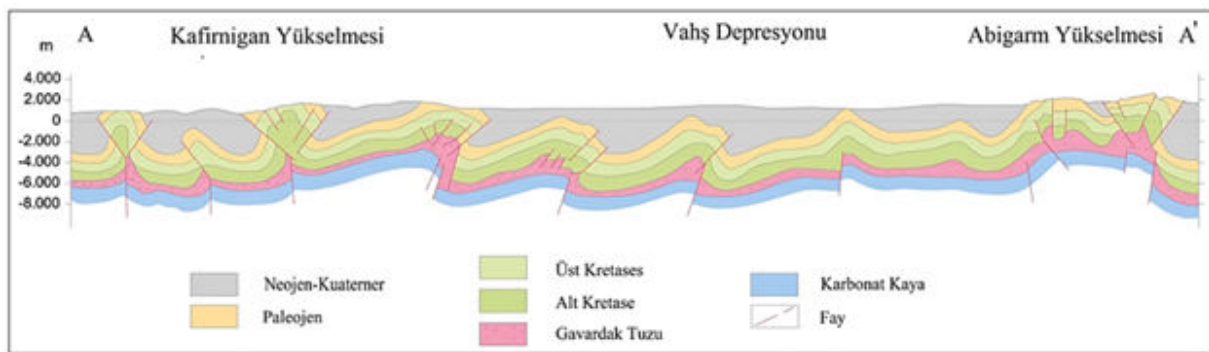


Figure 2: Cross section of The Afghan-Tajik Basin [9]

Structurally because of the movements of plates, in this basin, in the north-south direction, a series of depression and uplift zones were formed. From east to west they are: The Kulyab Depression, the Obigarm Uplift, the Vahsh Depression, the Kafirnigan Uplift, the Surhandarya Depression and the South-West Gissar Foothills. In the north of the basin the Dushanbe trough is an exception which has a generally west-eastern strike. The Kulyab Depression has been known as a deepest depression in the basin which represents a foreland basin to the Pamir Fold Belt [12] (Fig. 3).



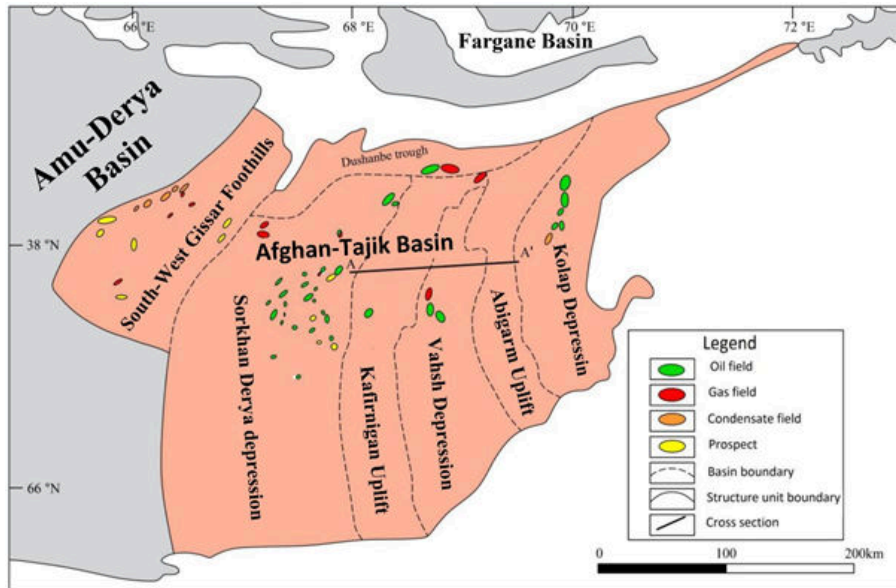


Figure 3: Structural units and petroleum distribution of The Afghan-Tajik Basin [9]

Petroleum Geological Characteristics

The Afghan-Tajik Basin has large hydrocarbon resources. Eocene age Suzak mudstones which are rich in organic matter proved as the source rock for oil in this basin. And in general, reservoirs of petroleum are found in Mesozoic and Cenozoic sediments [13].

This basin contains two petroleum systems;

- Jurassic petroleum system
- Paleogene petroleum system

Paleogene system covers the Jurassic system. These two petroleum systems are separated by each other with a thick Jurassic salt layer. In general, it has been determined that the Jurassic petroleum system is gas-prone and the Paleogene petroleum system is oil-prone (USGS and MoMP-Afghanistan 2006) (fig. 4).

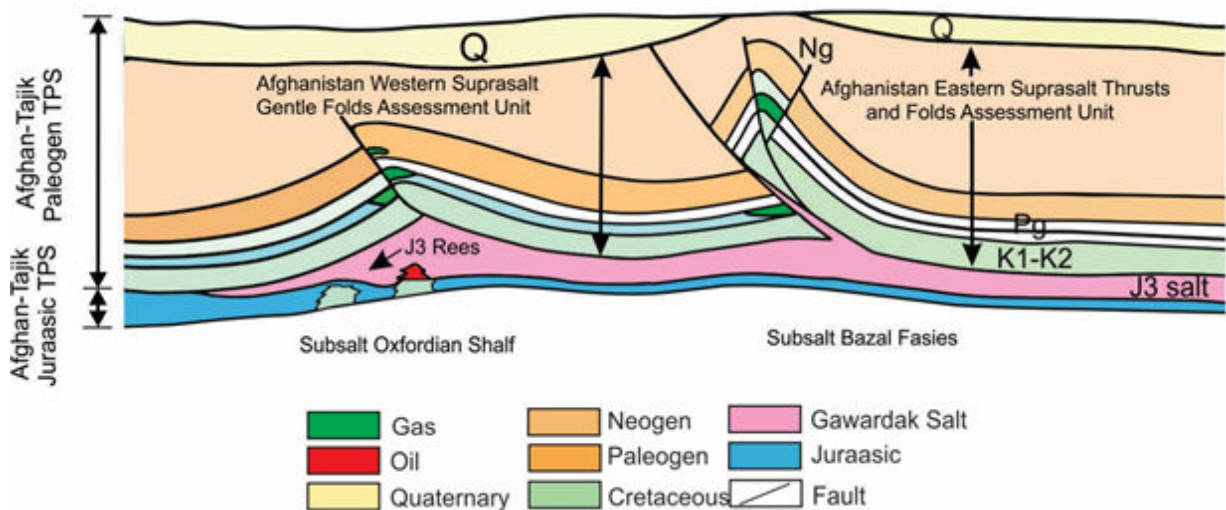


Figure 4: Accumulation model of Hydrocarbons in the Afghan-Tajik Basin [9]



In this study, all researches were made on Paleogene petroleum system. Lower and Middle Jurassic clastics are the sources rock for gas, while Eocene and possibly Lower Cretaceous rocks are the sources of oil [5]. In the Afghan-Tajik basin, northern areas of Afghanistan Petroleum has not been produced yet but it has been produced across the borders in neighboring countries, Uzbekistan and Tadjikistan [14]. The bedrock for crude oil has not been identified definitively. Organic-rich Eocene Suzak mudstones have been explained for many years by geologists. According to organic geochemical analysis of source rock extracts and petroleum carried by USGS, the Suzak mudstone maybe the source of petroleum in this basin. The USGS data shows the existence of a previously unrecognized Paleogene oil-prone total petroleum system [4].

Organic Geochemical and Organic Petrographic Analyses (TOC, Rock-Eval Pyrolysis and Vitrinite Reflection Analysis in Suzak Formation)



Figure 5: Images from Suzak Formation, Northern Afghanistan. Outcrop samples were oxidized extensively [4] In the Afghan-Tajik Basin, organic geochemical and organic petrographic analysis were carried out by the USGS and the Ministry of Mines and Petroleum of Afghanistan for determining the Suzak Formation petroleum potential. For this purpose, Suzak mudstone outcrop samples from northern parts of Afghanistan and southern parts Tadjikistan, as well as core samples from Kunduz well number 3 which are taken from northern areas of



Afghanistan, and in Tadzhikistan samples were collected from Kyzylsu well number 5, Khodzhasartis well number 18, and Tanapchi well number 5. To identify the source potential of crude oil all the samples were analyzed (fig. 5).

Sufficient results have not been obtained due to excessive oxidation of the outcrops (fig. 6). But from few Suzak outcrop and core samples which have enough organic matter, sufficient results have been obtained from them and also provided TOC, vitrinite reflectance, and Rock-Eval pyrolysis information (fig.6).

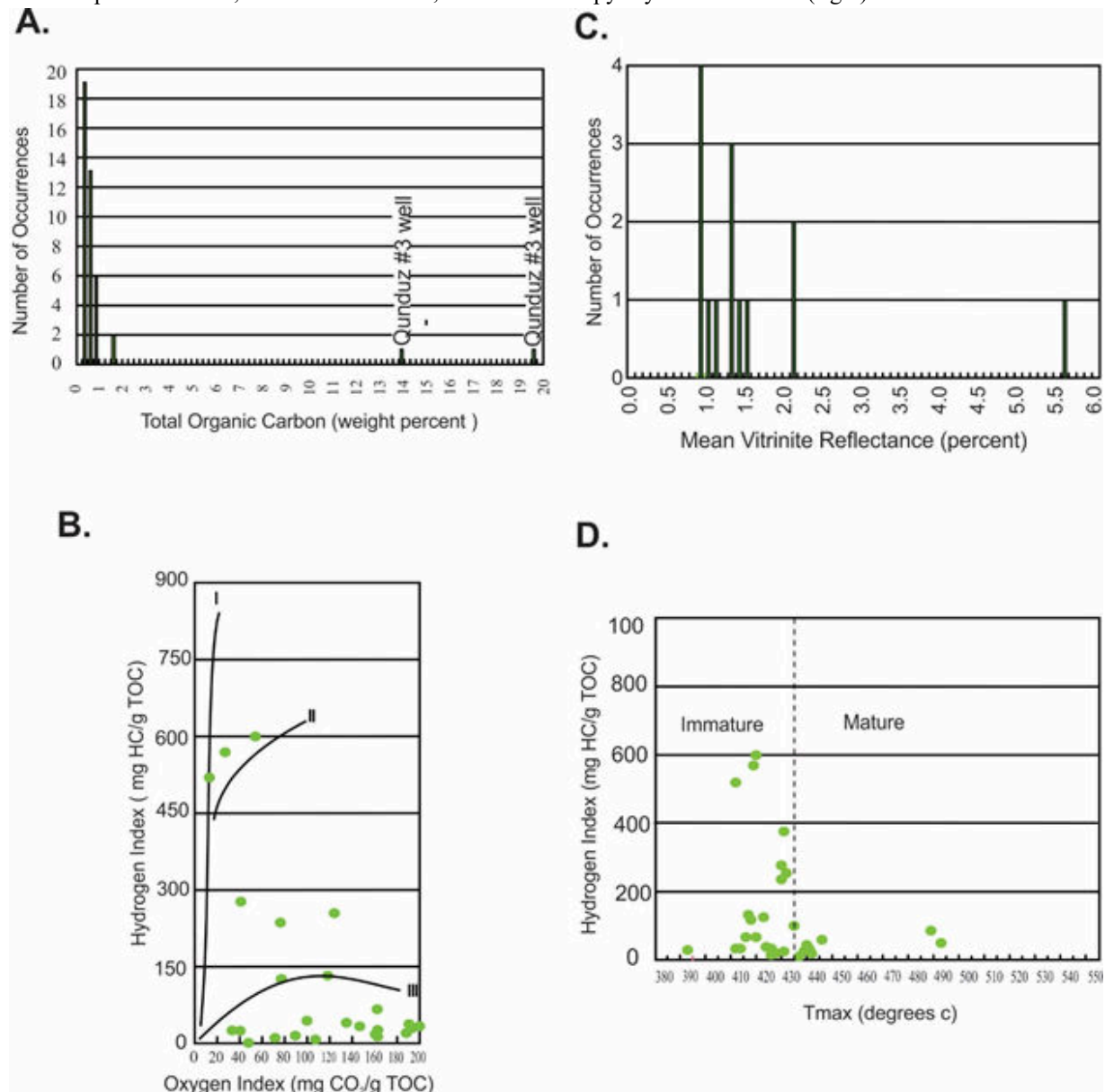


Figure 6: Graphs show organic geochemical analyzes of samples from Suzak Formation. A) Distribution of total organic matter content. B) Kerogen types according to Van Krevelen diagram. C) Distribution of mean vitrinite reflectance values. D) Hydrogen index-Tmax graph [4]

The overall TOC contents of the Suzak Formation outcrop samples are generally low, with an average of 0.4% achieved (Fig. 7). Only two outcrops have a total organic carbon content of more than 1%, and both contain about 1.3% total organic carbon. Two samples of the Suzak madestones which are taken from Kunduz well



number 3 of north Afghanistan have a TOC content of 13.9% and 19.7%. It shows that the Eocene-age Suzak mudstones have the capacity of the petroleum source rock.

In general, as it is shown in Tmax graph, the samples are not matured. However, there are 5 samples which are matured and 2 of them are in the extremely mature zone (Fig. 6).

According to the pyrolysis analyzes of the Suzak Formation samples, the majority of the outcrop samples were inclined to gas-prone and have type III kerogen (terrestrial) (Fig. 6). Kunduz well number 3 samples and several outcrop samples determined as oil-prone and have type II kerogen (marine).

In most of the samples, the vitrinite reflectance value is seen around 0.89% and 1.49%, it means the organic matter is in mature zone and able for generating oil. Two samples have vitrinite reflection values about 2%, which indicates that they have the ability to produce gas. One sample vitrinite reflectance value is about 5.6% (Fig. 6).

Discussion and Conclusion

The Afghan-Tajik Basin has great potential for undiscovered petroleum deposits and potentially these deposits take place in Jura to Paleogene carbonate reservoir related to thrust faulting and folding. In this basin, the source rock has not been determined precisely. But Eocene age organic matter rich Suzak mudstone has been investigated with various methods for the source rock for years.

Organic geochemical and organic petrographic analysis (TOC, Rock-Eval Pyrolysis, Vitrinite Reflection) were carried out on outcrop and core samples taken from the study area with the aim of revealing the source rock potential of Suzak mudstone. The assessment is based on the geological elements of a total petroleum system, which contains source-rock presence and maturation, During the analysis, bedrock, crude oil, and natural gas samples along with outcrops were collected from wells and fields in northern Afghanistan and Tadjikistan to correlate with crude oil and natural gas to postulated source rocks.

The TOC content of Suzak mudstone outcrops samples is mostly low, with an average of % 1.3. The TOC content of the samples taken from the Kunduz well was % 13.9 and % 19.7. Based on the results of the total organic carbon analysis, Suzak mudstones in this basin are found to contain enough organic matter to produce petroleum. As a result of the pyrolysis analysis, the samples generally are not matured. However, there are some samples that take place in mature-extremely mature zones.

According to the pyrolysis analyzes of the Suzak Formation samples, the majority of the outcrop samples were inclined to gas-prone and type III kerogen (terrestrial). Kunduz well number 3 samples and several outcrop samples are proven as oil-prone; have type II kerogen (marine).

In most of the samples, vitrinite reflection values are seen to be around 0.89 % and 1.49 % indicates that the organic matter is in matured zone thermally and it is in the field of oil production. The two examples show that the vitrinite reflection values are about % 2, which indicates that they have the ability to produce gas. One sample has vitrinite reflection value about % 5.6.

The Afghan-Tajik Basin is mainly a gas-bearing basin, but the part of the basin that takes place in Afghanistan has been identified as an oil-bearing basin. According to the organic geochemical studies carried out in the part of this basin located in Afghanistan and also in the neighboring countries, it is explained that the Eocene age Suzak Formation contains a considerable amount of organic matter and has the capability of becoming source rock. Samples are generally outcrops, and these samples have proven that they contain enough organic matter and they are in the mature zone. As a result, the part of this basin located in Afghanistan is known as a petroleum-bearing basin and the Eocene aged Suzak Formation possesses the potential of the main source rock of petroleum.



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