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Characterization of Organic Potential of Jhuran Shale Formation of Kutch Basin

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Abstract:

The organic hydrocarbon potential, maturity, evolution, and characterization of Shale have been investigated using range of samples Middle Jurassic (Shales from Nirona section) and the Mesozoic Jhuran formation including Jara, Ratia and Kodki Shales. A range of Shale samples from upper Triassic to middle Jurassic have been analyzed by a combination of pyrolysis, organic and inorganic techniques. Experimental methodologies have been investigated, developed and modified wherever necessary, to enable both the pyrolysis parameters and thermal maturity of organic matters in shales to be determined.

In the following paper we discuss studies carried on outcrop sample of Jhuran shale of the Kutch basin. To understand the availability, maturity and hydrocarbon potential of organic matter within the Shale sequence, a set of experiments including Rock Eval pyrolysis, XRD, SEM were conducted. The samples were collected from outcrop sequence of Middle Jhuran formation of Jara, Nirona, Ratia and Katrol hill. The TOC(total organic content) obtained from the pyrolysis was in the range of 1.5 to 9 % ,though a lower value of free hydrocarbon(S1) and thermally cracked hydrocarbon suggest an immature kerogen type, also the plot between HI(hydrogen index) and Tmax indicates same for majority of samples. A mineralogical classification through XRD analysis aimed at quantification of different minerals and to further characterize them in Clastic, Clay and Carbonate group and sub-classification to identify different clay suggested a higher presence of Illite and Kaolinite of detrital nature. To further validate these results FTIR spectroscopy was conducted which validated the previous developed understanding. SEM analysis coupled with EDS to visualize the general nature of shale and to identify presence of the different clay corroborated with the mineralogical study. The SEM analysis suggests a tight nature with lesser intergranular porosity. These images also revealed presence of Pyrite framboids in the specimen which suggest an anoxic depositional setting which indicates a better preserved organic matter.

Introduction:

Shale is a sedimentary rock that is formed from the compaction of fine grained silt and clay sized mineral particles. Shale is a type of mudstone which has distinguished property of being fissile and laminated with average total organic content ranging from 0.8% to 2.2% (Chinn et al. 1991).

Exploration and production of unconventional natural gas have moved to the center stage of current debate on energy, safety, and environment (Rao et. al., 2001). The evolutionary development in shale gas exploration and its production in the USA is the innovative technical movement of the decade and thus became a competitive exemplar. To keep the market competency further other big producing nations are about to jump in the market of natural gas exploration from shale.

Shale gas is a natural gas and found within the shale formations. Shale is the most abundant fine-grained sedimentary rock in the world which is formed by the compaction of silt and clay-sized mineral particles. In gas shales, the gas is generated from the transformation of organic material by bacterial (biogenic) and geochemical (thermogenic) processes. The gas is so generated gets stored by multiple mechanisms as free gas in micropores/microfractures and as adsorbed gas on internal surfaces of organic components (Boyer et al., 2006). Thus, shales act as both Source Rocks and Reservoir Rocks. The concept of exploiting shale gas reservoirs has been met by innovative technologies of hydrofracturing and multilateral horizontal drilling in the USA. For India, technically recoverable shale gas resource is estimated at 96 Tcf. (EIA 2013).

Shale resources in India are scarcely developed yet few workers The Jhuran Formation is well exposed in the Kutch Basin and sample locations (Nirona, Kodki, Jara and Ratia) are shown in the figure 1. The interpreted depositional environment of the formation varies from prodelta (Biswas, 1993), shallow marine (Rajnath, 1932; Krishna, 1998).

Geographical Location:

Shale samples of Jhuran Formation and Nirona Formation have been collected from four new localities (Jara hill, Kodki, Nirona, and Ratia. Samples from Jara A to Jara F4 were started to collect from 550 meters to 1330 meters in the south-west of Jara Village along with the river channel besides Lakhapar-Zara Rd. About 25m of gently dipping strata was exposed with a heavily weathered surface. Collection of other shale samples was done in a similar manner respective to their vicinity. Thus, organic carbon within these shales needs to be characterized in terms of quantity, quality, thermal maturity and hydrocarbon generation potentiality. The present research work deals with the geochemical (Rock-Eval pyrolysis) and Clay characterization and SEM study on total 45 samples collected from these locations. Figure 1 shows a simplified geological map locating the region.

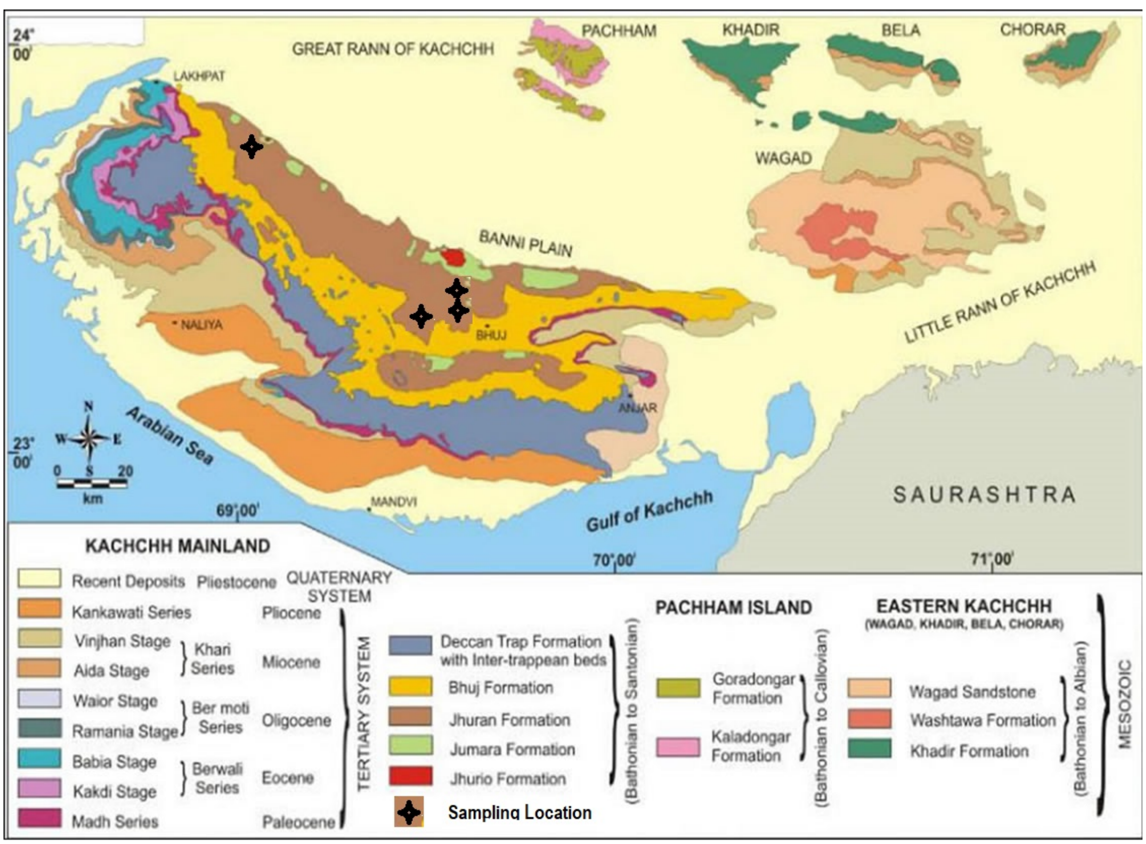

Fig. 1 Geological map of Kutch showing various outcrops of the Mesozoic Formations *(after Biswas). Figure modified after Desai (2016)*

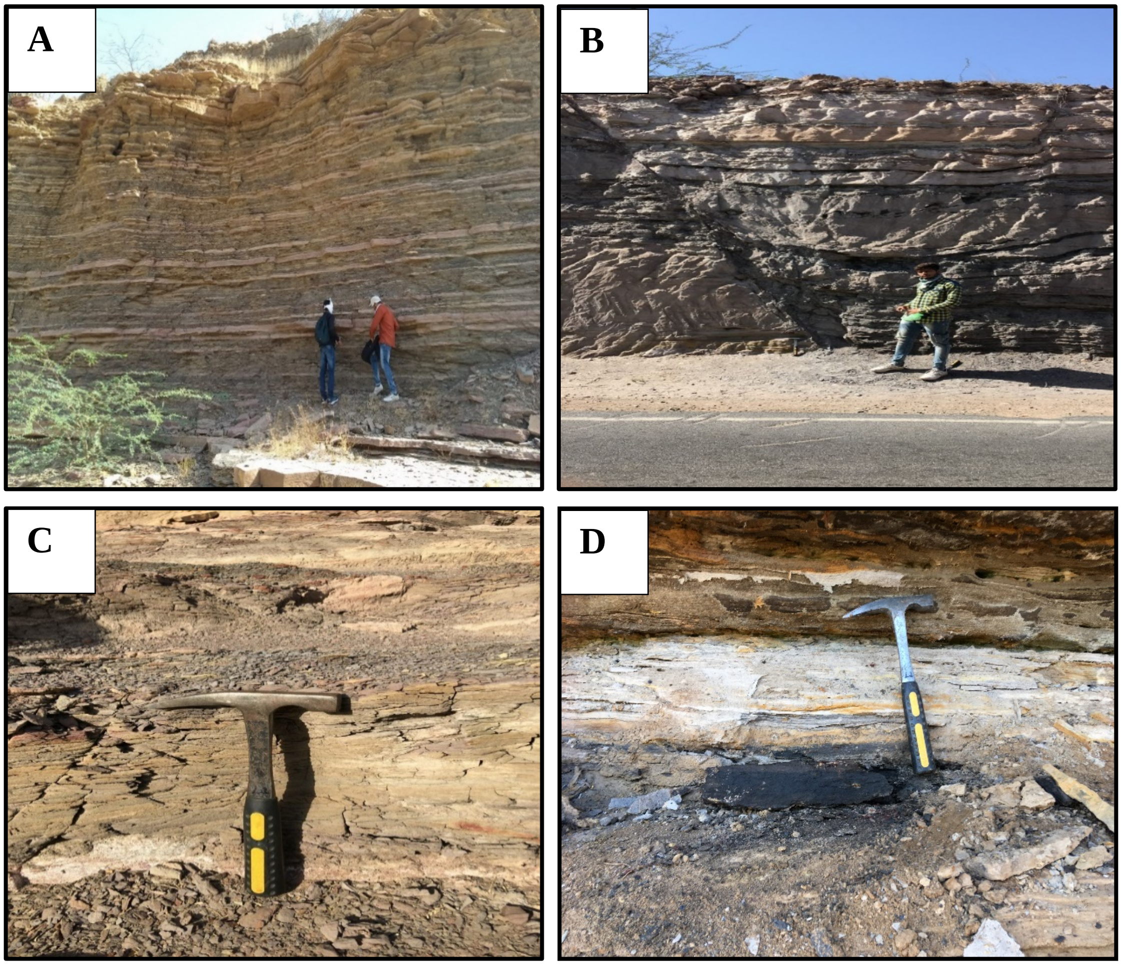

Fig. 2 (A) Collection of Jara shale samples along with the orientation of river channel; (B) Collection of Kodki shale samples near roadside; (C) Collection of Nirona shale samples with a geological hammer in the picture; (D) An exposed view of the site for the collection of Ratia shale samples.

Geological Setting:

The Jhuran and Bhuj Formations form the outer semicircular girdle of the Jara dome. Rudramata Shale Member and Upper Member of the Jhuran Formation are exposed around Jara Dome and Lakhapar (N 23°41'49.1" and E 068°56'55.9") village which, situated on the outer periphery of the Jhuran-Bhuj girdle, are of prime concern for this study.

The Jhuran Formation belongs to the Marine Mesozoic sequence of the Kachchh Basin. This sequence rests unconformably on the Jumara Formation and is succeeded by the deltaic Bhuj Formation (Biswas, 1993). The Jhuran Formation is well exposed in the Northern and Charwar Range of Mainland Kachchh. This Formation is divided into Lower, Middle (Rudramata Shale), Upper and Katesar Members (Biswas, 1977). Of these four members, the Middle, Rudramata Shale Member forms an important mappable unit of the Kachchh Basin (Biswas, 1993) and is exposed throughout the width of Kachchh, from Guneri dome in the west to Jhuran River section in the east.

Nirona Formation belongs to the non-marine Upper Triassic to Middle Jurassic (Aalenian) depositional environment. Nirona Formation consists of arkosic, coarse-grained sand and igneous wash at the bottom; calcareous sandstone, minor shale, limestone and mottled clay in the middle; sandstone, laminated shale and Kaolinitic clay at the top. It is overlain by Lodai.

The margin of the northern basin began to break up due to the second phase of basement extension. This gave rise to shale sedimentation in the area. Table 1 shows a generalized sedimentary for the Mesozoic stratigraphy in the area of Kachchh Mainland Basin.

Table 1 Mesozoic Stratigraphy of Kachchh *(after Biswas, 2016)*

Age	**Litho-unit Thickness**	**Lithology**	**Environment**
Early Cretaceous	Bhuj formation (400 to 900 m+)	**Upper Mbr.:** Coarse-grained, Felspathic sandstone **Ukra Member** **Lower Mbr.:** Brown and reddish felspathic sandstone, ironstone and kaolinitic shale	Fluviatile deltaic
Tithonian to Kimmeridhian	Jhuran Formation (375 - 850 m)	**Kateshar Member** **Upper Member:** Pink and yellow sandstone with minor shale **Middle Member:** Grey shale Rudramata shale member **Lower Member:** Shale and sandstone with calcareous bands	Infra-littoral Deltaic
Callovian to Oxfordian	Jumara Formation (300 m)	Dosa Oolite:Grey gypseous shale Middle Mbr. Lower Mbr.	Sub-littoral
Upper Bathonian to Callovian	Jhurio Formation (325 m +)	Bedded Lst. Goden Oolite Lst./Shale Lst./Sh	Sub-littoral

		interbedded	

Results and Conclusion:

A total of 45 fresh shale samples were analyzed from various localities and provide values TOC, HI, OI, S2 and Tmax. Vitrinite Reflectance was measured by Jarvie's correlation for all these samples. Results of Vitrinite Reflectance for some samples were correlated with standard reflectance microscope method. 18 samples were shortlisted for clay mineralogy by XRD and 4 samples for SEM-EDS. The major findings are as follows:

a) The total organic carbon (TOC) content in the shales ranging from lowest 0.42 (Kodki) to the highest 7.39% (Ratia).
b) Hydrogen Index (HI) values ranges from 21 to 190 mg HC/g of TOC while Oxygen Index (OI) values ranges from 22 to 165 mg HC/g of TOC, on a HI vs OI plot, majority of samples lie along the Type-III curve.
c) Tmax values for these shales ranges from 371 to 479ºC, on a HI vs Tmax plot indicate that majority of the samples are identified as thermally immature. An S2 vs TOC cross-plot confirms fair to good hydrocarbon potential of the analyzed samples.
d) Clay mineralogy by XRD method was adopted for the identification of clay minerals on the basis of their respective 2Ɵ and d-SPACING values. Major clay minerals viz. Chlorite, Illite, and Kaolinite were identified in the shale samples along with the Quartz. The quantity was observed to be ranging from 15.52 to 31.68% for Chlorite, 12.32 to 48.52% for Illite and 36.27 to 87.68% for Kaolinite. Cumulatively Quartz percentage was also observed ranging from 9.95 to 57.50% with average value 23.21%.
e) SEM analysis coupled with EDS to visualize the general nature of shale and to identify presence of the different detrital clays corroborated with the mineralogical study. The SEM analysis suggests a tight nature with lesser intergranular porosity. These images also revealed presence of Pyrite framboids and biotite in the specimen which suggest an anoxic depositional setting which indicates a better preserved organic matter.
f) Very low vitrinite reflectance values ranges from 0.218 to 0.378 %Ro for Nirona and 0.363 to 0.586 %Ro for Ratia by reflectance microscopy confirms the presence of thermally immature samples.

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