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Total organic carbon content and total porosity estimation in unconventional resource play using integrated approach through seismic inversion and well logs analysis within the Talhar Shale, Pakistan

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ABSTRACT

Around the globe, the organic rich shale has become an increasingly important hydrocarbon resource due to the rapid depletion of conventional hydrocarbon reservoirs. The successful exploration and production schemes for organic rich shale are based on reliable identification of major organic components and total porosity. Therefore it is mandatory to identify the organic content in terms of total organic carbon (TOC) content and total porosity in promising shale formations through indirect seismic data, which is usually the only available source of information in most exploration phases. This research paper is focused on quantifying the Talhar Shale (member of Lower Goru Formation) as an unconventional reservoir using model based inversion in Badin concession area located near Karachi, Pakistan. Model based inversion is applied for computation of total porosity and total organic carbon (TOC) content because it provide a greater bandwidth and detail of variation of the acoustic impedance over the study area. The empirical relation for Total Organic Carbon (TOC) content has been derived through Passey et al. (1990) technique using data from Zaur-Deep 01, while for porosity a simple relation between impedance and porosity is used. The TOC and porosity models indicate that the unconventional reservoir potential is significantly greater over the northern region while it tends to decrease towards the southeastern area.

1. Introduction

Hydrocarbon production from organic-rich shale formations has significantly increased since the advent of sophisticated recovery techniques which allow for economical productions from such formations. Organic rich rocks that contain sufficient amounts of organic carbon to generate hydrocarbons are called source rocks. Some of the properties that help operators to determine whether a formation can be economically produced include total organic carbon (TOC) content, thermal maturity, hydrocarbon saturation, porosity, mineralogy and brittleness. With the development of unconventional organic-rich shale formations, greater effort to characterize the formations has been put forth through the collection of seismic data. However, the information of source rock quality derived only from well data does not give regional views of source rock potential in the sedimentary basin.

The Lower Indus Basin of Pakistan is enriched with thick sequence of shale formations as a source and has a proven petroleum system. A significant amount of gas has been trapped within the unconventional reservoirs a part from oil and gas resources within the conventional reservoirs. The conventional reservoirs have been explored and developed in Pakistan; however very little work has been done so far in developing these unconventional reservoirs. Pakistan has approximately 200 trillion cubic feet (TCF) of unconventional gas resources within the shale formations. Studies have identified that approximately 70% area of Pakistan is covered by shale gas. It is estimated that most of the shale resources are in mature stage for hydrocarbon generation and are estimated to be thicker than the shale plays in North America. Therefore these shale resources in Pakistan have potential to become good resource play (Abbasi et al., 2014a,b). In their study on Talhar Shale identifies that Pakistan on average has shale gas ranging from 70 to 80 TCF.

An integrated approach using mineralogy, lithology, and Total Organic Carbon (TOC) content data combined with petrophysical logs are used for accurate prediction of the unconventional reservoir characteristics (Chopra et al., 2012; Brindle et al., 2015). The porosity prediction from post stack seismic inversion technique provides insight

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into porosity variations away in case of limited well data control. Seismic inversion can enhance characterization of shale-gas reservoirs (Ouadfeul and Aliouane, 2016a,b; Das et al., 2017). Quantitative interpretation of the seismic data has enabled us to extract more information about the reservoir properties as compared to conventional interpretation. In seismic inversion, the amplitude data is translated into quantitative properties of the reservoir particularly like porosity, fluid content, TOC, etc. Quantitative properties of reservoir become more important as they are shifted from the conventional reservoir to the unconventional reservoir (Tight sands/shales). Therefore quantitative properties due to their significance in seismic inversion are considered to be more reliable as compared to the spatial properties (Gonzalez, 2006).

This study including estimation of total organic carbon (TOC) content and total porosity using seismic and well logs data in terms of prospective shale gas potential within the Talhar Shale, Pakistan, is based on seismic inversion and well logs analysis. This present research is able to overcome the problem of evaluation of hydrocarbon potential. In this case study, the source rock properties has been established by model based inversion. Seismic acoustic properties are determined by inverting the seismic amplitude data. A correlation between the results deduced equations to transform seismic inversion-derived acoustic properties to source rock properties through regression analysis. It is the accurate and cheap way to check the hydrocarbon potential of unconventional reservoir formation in the absence of geochemical and core data. The reliability of the results are verified by calibrating the seismic and well log data. This quantitative interpretation of the reservoir properties helped in understanding the potential of the source rock (Talhar Shale) in the Badin field, Lower Indus Basin, Pakistan.

2. Geological setting of the study area

Badin is the most prolific with respect to oil and gas exploration located in the Sindh Monocline. The Sindh Monocline is a part of the Lower Indus Basin situated in the south eastern corner of Pakistan (Kadri, 1995). The slope of the sedimentary succession covering the Sindh Monocline generally dips westward bonded on the east by the Indian Shield (Nagar Parker granite area). Towards its western limits include the Kirthar Fold and Thrust Belt and Karachi Trough where it merges with a tectonically different entity (Bender and Raza, 1995; Abbasi et al., 2014a,b). The area lies between the latitude 25° N and 24° N and longitude 68° E and 69° E as illustrated in Fig. 1(a). The data set included the 3D seismic data and well logs of Zaur-Deep 01, Chakri −01 and Babu-01 as illustrated in Fig. 1(b).

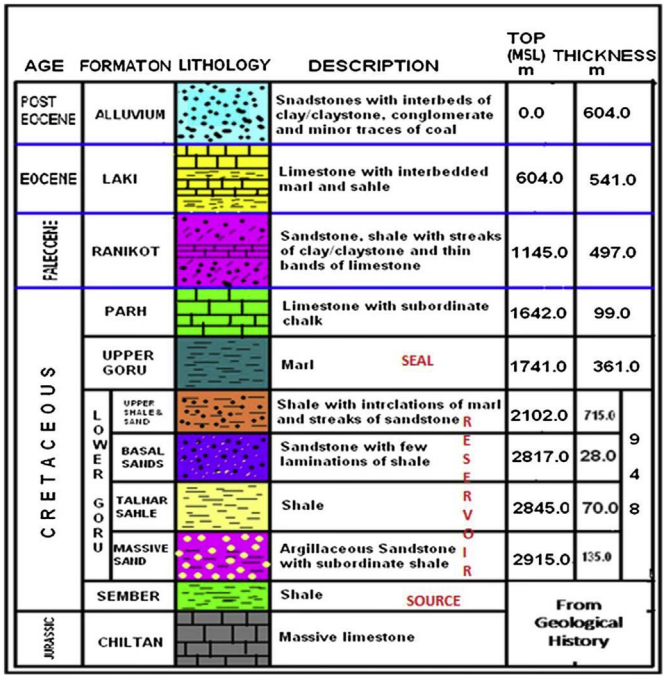

Fig. 2. Lithostratigraphic column for the study area, Lower Indus Basin (Akhter et al., 2015).

3. Geological characteristics of the Talhar Shale

The Lower Goru Formation with medium to coarse-grained sediments of Cretaceous age, which acts as a primary source of hydrocarbon in the Indus Basin Pakistan. These sediments have alternate bedding of shale and sand which are favorable for the hydrocarbon exploration (Sheikh and Naseem, 1999). The shales sediments of the Lower Goru Formation have fault/fracture system with high TOC values zones which are favorable for the future unconventional resource exploration (Naseer and Asim, 2017). Talhar Shale is a member of the Lower Goru

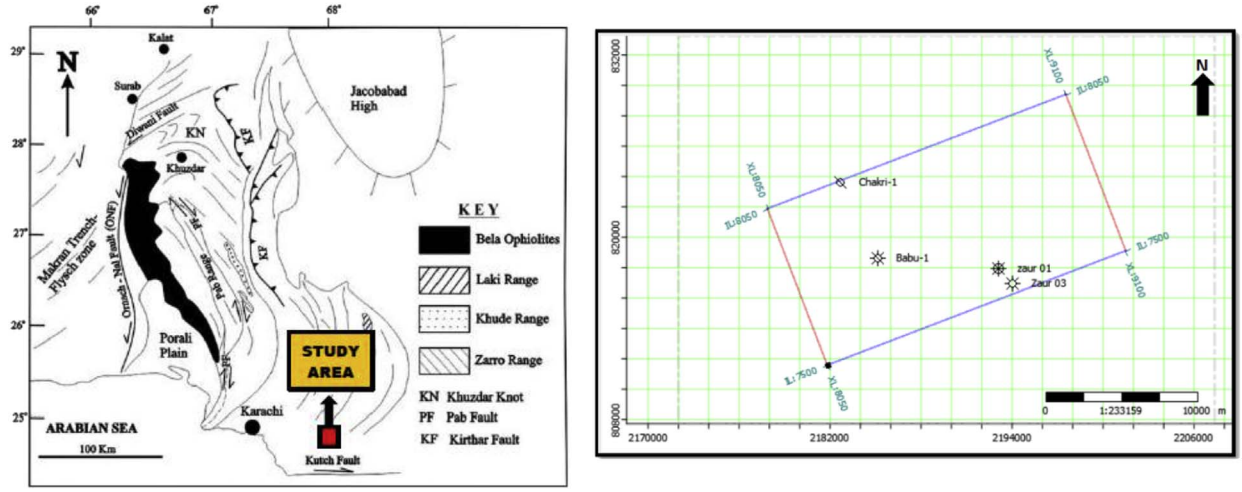

Fig. 1. (a) Location map of the study area (Badin Block), Lower Indus Basin along with geologic setting of Lower Indus basin. The red color square show the location of the study area (after Bannert et al., 1992) (b) Base map of the study area with marked well locations. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)