Strategy for identifying the Hydrocarbon prospects in tight /Shaly Silty reservoirs-An integrated approach a case study

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Abstract:

Shales have been by now recognized for the Source, Seal and Reservoir rock. The presence of sweet intercalations is an essential part for parameter evaluation in such reservoirs in the very first instance. In most of the hydrocarbon producing fields, shale forms the geologic seal that retains the hydrocarbon within producing reservoirs, preventing them from escaping to the surface. In few basins, however, shales are both the source and reservoir for hydrocarbons. These shales have one thing in common: They are rich in organic carbon. The conventional Petrophysical parameters for evaluating such shales are the Resistivity, Density and Sonic travel time. The low withdrawal formation testers and micro scanners (acoustic and electrical) can be of immense help in locating the relative sweet permeability spots in these reservoirs. The higher source rock content of the shale is essential for it to be a potential reservoir together with other geo-chemical parameters. Tight shaly/silty intercalations can be identified on the basis of organic content and clay regime in the total mass for the presence of hydrocarbon. The presence of silt seams in shale body can be a useful input also. Higher TOC values and presence of Silt with favourable Petrophysical parameters makes it a good candidate for exploitation.

The present paper studies such unconventional reservoirs which are tight shaly/ silty supported by shales having higher organic content. The study integrates Sedimentological and SEM outputs with spectral Elemental Gamma ray spectrometry components and TOC outputs on the core samples taken from two different units of Ragavpuram shale of Krishna-Godavari Basin. Core determined properties are integrated with log signatures to predict for targeting such potential unconventional tight shale/silty reservoirs. Such types of unconventional reservoirs are the target of future exploration.

Introduction

Conventional formation evaluation analysis has got its limitation in identifying hydrocarbon in unconventional reservoirs. The unconventional reservoirs can be both a source and reservoir rock however a quick look interpretation from conventional logs for source rock is possible. To know the hydrocarbon potential in these rocks geochemical analysis is required. An important objective of geochemical analysis is to define the areas and stratigraphic units incorporating the best petroleum source rocks and its hydrocarbon generation potential in a sedimentary basin.

Methodology

The identification of better source rock intervals can continuously be accomplished by well logs; of course it requires a validation from cores. Once the relationship is established conventional logs can be utilized for initial diagnostics. Geochemical analysis requires the input of surface and subsurface rock samples. Well cuttings and cores can be obtained from any drilled well. Coring has always been an area of concern. Before establishing some correlation for the identification of unconventional hydrocarbon reservoirs by well logs geochemical data to be integrated apart from evidences during the process of drilling.

The use of petrophysical techniques arises out of the need to assess source rocks for basin studies, where the database is restricted to basic log data and little or no geochemical information. Cross plot technique is developed for responses of wire line logs in relation to the increasing of organic matter. Association of the organic matter can be expected with increase in gamma-ray, sonic transit-time, neutron porosity, and resistivity with reduction in the formation bulk density. For calculating total organic carbon content (TOC), porosity/resistivity overlay technique is used and to provide an integrated "running" assessment of source capability for volumetric determinations.

A) Log characteristics of organic rich rocks

1-Sonic Transit-Time:

Increment in transit times is observed in Organic rich formations. The qualitative

increase from the normal trend is generally observed in transit time dependnding upon the compactness.

2-Bulk density:

The general reduction in density readings can be expected. The organic matter is generally as light as fluid (.9to 1.05gm/cc). Organic matter being a fraction of rock brings reduction in general trend in the density readings.

3-Gamma ray:

Increase in gamma ray values can be expected with rich organic matter although this is not always true. The total gamma ray (GR) value may increase by over 100 API or more across organic-rich rocks. Direct measurement of U concentration from the NGT (Natural Gamma Spectrometry) are potentially a more direct indicator of organic matter because this tool isolates the influences of Th and K associated with mica and clay minerals.

4-Resistivity:

Resistivity increases in the organics rich rocks in the present case study the lean rock has shown less resistivity as compared to the better source rock.

4-Neutron Porosity:

The neutron tool measures hydrogen concentration, which is present as water and hydrocarbons in rocks. The neutron response to OM is effected by shaliness and not quite distinguishable in potential and lean rock.

B) Sedimentological studies

Megascopic, SEM and XRD techniques are employed in sedimentological outputs. The lithology description and clay constituents and rock nature can be of immense help for knowing the clay content and silty nature of the rock sample. Present study integrates the Petrographic outputs of upper and lower units of Raghavpuram shale.

C) Geochemical studies;

It has been recognized by many workers that there is a threshold value of total organic carbon below which generation of hydrocarbon to form commercial accumulations is not possible this value is 1gm per 100 gm of rock. The source rocks are rated according to their organic richness as follows:

a) 0-0.5% poor source rock
b) 0.5-1.0% marginal source rock
c) 1.0-2.0% good source rock
d) 2.0 0r more % excellent source rock

Organic matter is subjected to increasingly higher temperatures with greater depth of burial. Over time these

higher temperatures cause the thermal degradation of organic matter to yield hydrocarbon. The depth interval in which a petroleum source rock generates and expels most of oil is called the oil window. Pyrograms are generated in Geo-chemical labs to understand the potential of a source rock. Heated rocks are analysed for S_1, S_2 and S_3 outputs the areas generated by the peaks P_1,P_2 and P_3 detected by flame ionization detector. Higher S_2 values are indicator of better hydrocarbon potential of rock. The maximum temperature corresponding to P_2 is known as T_{max}.

Case Study

Krishna- Godavari basin is a passive margin basin on the eastern cost of India. Raghavapuram Shale unconformably overlies the Kanukollu Sandstone and in turn is overlain by Tirupati Sandstone. The formation is predominantly argillaceous consisting of shale with minor inter-bedded sandstone. Raghavapuram Shale been assigned Lower Cretaceous age.

Ragahavapuram Shale can be divided into two distinct units based upon Gamma ray (GR) and Resistivity log characters. The 'Lower Unit' is marked by high GR and high resistivity. The 'Upper Unit' is characterized by relatively lower GR and lower Resistivity. The log responses and core analysis is being integrated to study the hydrocarbon potential in both lower and upper units.

Example-1 shows the upper unit of Ragahavapuram Shale. The High gamma ray valuesare not corroborated with high resistivity values.

Processed Log in the Upper unit {(R) LGR-R}is depicted in Example -1. Gamma Ray activity is due to presence of Thorium. Shale volumes are very high. Well condition is bad at the cored interval.

NGS study done in the core samples of this unit shows an increase in GR which is due to the higher concentration of Thorium. Thorium might be absorbed in the open lattice structure of silts Refer Fig-1.

NGS outputs in the core samples of above wells of same Basin is showing thorium concentration is well above 10 ppm.in both {(R) HGR-R} and {(R) LGR-R} absorption of Thorium in silts

The Petrographic description analyses the rock as claystone composed of carbonaceous clays and highly silty. Refer Fig-2.

The Geochemical Studies computed the organic matter well below 0.5 making it poor source rock. S_1, S_2 values shows less maturity and no hydrocarbon potential.

Refer Fig-3 & Refer Fig-4.

Example -2 is from the Lower unit of Ragahavapuram Shale. The high Gamma Ray values are associated with High values of resistivity. LLD corrected is reading as high as 10 Ω-m. as compared to2 Ω-m. in the upper unit.

Processed Log in the Lower unit {(R) HGR-R} is depicted in in Example-2. Gamma Ray activity is due to presence of Uranium. Shale volumes are very high are not realistic with GR.The average value is being calculated

Study of core samples in NGS Lab is indicative of high Uranium presence with high Thorium concentration. Refer Fig-1and 5.

NGS studies done in the core samples of two wells of Krishna-Godavari Basin .Lower Unit characterized by High Gamma-Ray and High Resistivity {(R) HGR-R} is showing the absorption of Uranium by organic material as compared to Upper unit of Raghavpuram shale{(R) LGR-R}

Silty Claystone-Silt sized quartz, feldspar and mica floating in ground mass of carbonaceous clay matrix is the petrographic description. Refer Fig-3 second SEM photograph.

Geochemical analysis showed the high value of TOC. The hydrocarbon potential is very good as indicated by high S_2 values. Refer Fig-6

Both the unit of Raghavpuram Formation are plotted .Source rock quality has become Excellent in the Lower Unit shown by red colour circles.

Presence of gas was reported at this depth. Refer conventional core description Table-1.

Conclusions

Conventional log output coupled with petrographic and geochemical analysis has indicated hydrocarbon potential in Lower Shaly-Silty and tight interval of Raghavpuram shale. The processed log output has shown no effective porosity indicating it as tight zone. Resistivity curve has shown increasing tendency in lower interval. NGS study on core samples has shown that High GR is due to high Uranium content as compared to upper unit.

The Value of Thorium is appreciable in both the units may be due to association of it with open lattice structure. It may bring some porosity element. The Petrographic outputs are indicating the carbonaceous nature of the rock. Geochemical outputs are suggesting high TOC and increased value of S_2 with good maturity. This means the rock in study has got some Hydrocarbon potential. It is clear from above that a single method of evaluation is not sufficient. The integrated output of Logging, Geological and Geochemical studies are essential for evaluation of hydrocarbon potential of such unconventional reservoirs.

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Example-1

Processed log of non source rock
Upper shale unit of Raghavpuram
High-GR,Low Resistivity

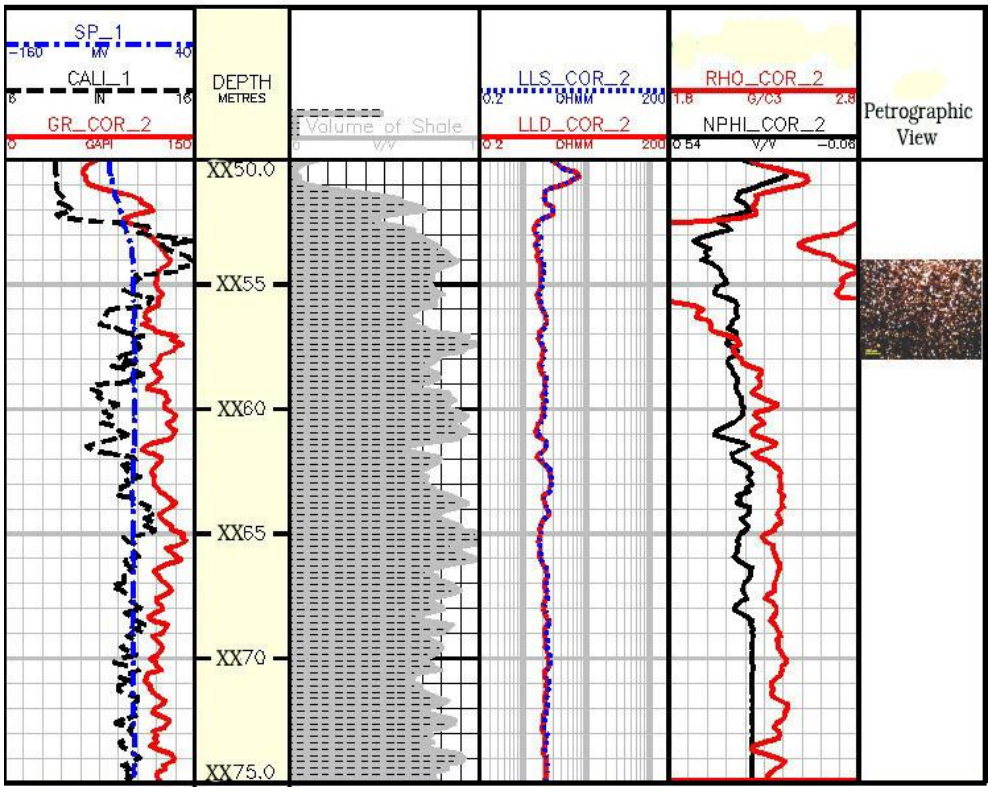

Fig-2