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Depositional Environment Prediction of Damoh Area of Vindhyan Basin using Natural Gamma Ray Log

Abstract:

Gamma ray logs are used for three main purposes: correlation, shaliness and mineral analysis. Natural gamma radiation in rocks is entirely influenced by three main sources i.e elements thorium (Th), uranium (U) and potassium (K) (Dypvik and Eriksen, 1983). The relative contributions of these elements to the total gamma ray (GR) log profile of a bore hole can be differentiated by a spectral gamma ray logging tool. The spectral gamma ray log measures the concentration of all the three gamma ray emitters separately and its spectrometry can be used to predict the depositional environment. Th/U ratio is used to differentiate between the depositional environments of various reservoirs under study. Analysis of the sources of natural gamma radiation gives us added information about the composition and probable lithology of the formation. Elemental concentration thus calculated is correlated to depositional environment and clay type. Based upon the elemental composition of the uranium and thorium it was found that natural gamma ray log can also help in distinguishing the areas proximal and distal from the sea, while the uranium concentration variation along the depth can be used to predict the transgression and regression marine cycles. In this paper, an attempt has been made to determine the type of depositional environment of formations encountered in Upper and Lower Vindhyan in the Damoh area of Vindhyan Basin.

Introduction:

The Vindhyan Supergroup of India is one of the largest and thickest sedimentary successions of the world and likely to contain valuable information on the evolution of atmosphere, climate, and life on our planet. In this paper an attempt has been made to determine the type of depositional environment of formations encountered in three bore hole in the Damoh area of Vindhyan Basin. Sets of gamma ray log are vastly used in exploration industry. Gamma log is based on Natural gamma radiation in rocks and their main source elements are thorium, uranium and potassium. GR log in a bore hole records composite of emissions produced by isotopes of potassium (K), thorium (Th), and uranium (U) (Dypvik and Eriksen, 1983). The relative contribution of these elements can be differentiated by a Spectral Gamma Ray logging tool which is extensively used in estimating mineralogy that is further used in estimating differential depositional environments, and recognizing significant stratigraphic surfaces because of its characteristic response to specific environmental conditions (Schlumberger,1982; Davies and Elliott, 1996; North and Boering,1999). Radioactive element detected by peak of element Energy value. This is done by measuring the gamma ray count rate for three energy windows i.e 1.46 MeV for potassium-40, 1.76 MeV for the uranium-radium series, and 2.62 MeV for the thorium series (O. Serra, Elsevier, 1984). These readings represent the gamma ray radioactivity from each of these sources.

In continental or land type environment, due to weathering, Uranium concentration decreases as it is more soluble than thorium hence develops high Th/U whereas a low Th/U ratio is distinctive of marine environments. When Th/U is less than 2 (i.e. Uranium Rich) the depositional environment is most commonly Marine whereas Th/U more than 7 (i.e. Uranium Poor) indicate oxidizing, possibly terrestrial environment (Adams, J.A.S. and Weaver, C.E. , 1958). Shale is a mixture of clay minerals, sand, silts and other minor materials. With the help of Th, K, U data we can identify the clay minerals. Kaolinite has almost no potassium whereas illite contains between 4% and 8% potassium. Montmorillonite contains less than 1% potassium. Natural radioactivity may also be due to the presence of dissolved potassium or other salts in the water contained in the pores of the shale. (Hassan et al.,1975; Fertl et al., 1980; Luczaj, 1998). Histograms of TH/K ratio and potassium-thorium cross plots are used in the recognition of clay mineral types and the diagnostic properties of Th/U ratio are used to differentiate between the depositional environments of various reservoirs under study.

Clay Mineralogy:

Clay typing has been carried out in the entire formation encounter in three well of Damoh area Well A, Well B and Well C.

Clay typing has been carried out in **Basuhari Shale**. Th vs. K crossplot has been prepared. Values of Th are in the range of 11-25 ppm and that of K is in the range of 2.5-5%. As observed in the Th-K cross-plots (Fig.1), points fall in mixed clay layer zone.

The crossplot for **Rohtas Limestone** is carried out in two parts as lower and upper Rohtas, and values are quite interesting. In Lower Rohtas, values of Th are in the range of 6-20 ppm and that of K is in the range of 0.8-4%. As observed in the Th-K cross-plots (Fig.1), points fall in mixed clay layer zone, but values are quite denser towards Montmorillonite. In Upper Rohtas, Values of Th ranges from 5-12 ppm and that of K is in the range of 1-5% in Well A and decreased to 1 to 2% towards Well C. As observed in the Th-K cross-plots (Fig.1), points are closer to illite i.e. mixed-layer illite-Montmorillonite.

In **Kaimur Sandstone,** the cluster of points appears as broader and more dispersed cloud, which is expected for a mixed sequence of sandstones, shale and silt sands. A dense compact cloud is observed in the Mixed Clay region. Values of Th are in the range of 05-25 ppm and that of K is in the range of 1.5-5%. Some points are observed in the Montmorillonite region. The major portion of the cloud is tilted towards the Illite zone indicating presence of Illite also. As observed in the Th-K cross-plots (Fig.1) in well-A points are closer to illite zone and as we move towards well C, it is shifted towards mixed clay layer and Kaolinite, an overall cloud falls in mixed clay layer zone.

The cluster of points in Th-K cross-plots from the **Jhiri Shale** are very less as expected because of lesser thickness, however, a good number of points show a prominent trend towards Mixed Clay Layer zone. In well-A Values of Th are in the range of 12-22 ppm and that of K is in the range of 2.5-5%, and as we move towards Well-C clouds get more dispersed as Th is in the range of 6-25 ppm and that of K is in the range of 1.5-5% (Fig.1).

In crossplots of **Rewa Sandstone,** values of Th are in the range of 5-25 ppm and that of K is in the range of 0-5%. The cluster of points in crossplots show a wider and more diffused cloud (Fig.1) but can be grouped in two zones, Mixed Clay region and Kaolinite zone. In well-B some points are observed in the Illite region. In well-C a portion of the cloud is shifted towards zero K i.e. the heavy mineral zone indicating presence of Heavy Mineral also. Some scarred points are also falling towards 100% Kaolinite zone indicating continental and near shore sediment.

The cluster of points from the **Ganurgarh Shale** forms a dense cloud of points which falls in the Mixed Clay Layer. From Well-A to Well-B to Well-C dense cloud of points significantly shifting towards the Montmorillonite region (Fig.1). In Well-A and Well-B Values of Th is in the range of 11-25 ppm and that of K is in the range of 1.8-5%, in Well-C Value of Th is in the range of 5-20 ppm and that of K is in the range of 0.5-5%. In this formation, in all the three bore well, Illite is completely absent.

The Th-K cross plot of **Nagod Limestone** shows compact cloud of points around Mixed Clay Layer area (Fig.1). Values of Th are in the range of 06-25 ppm and that of K is in the range of 0.5-5%. In Well-A there is complete absence of Montmorillonite but as we move from Well A to Well-C points in Montmorillonite zone increases.

In **Shirbu Shale,** crossplots showing compact cloud of points and values of Th are in the range of 15-25 ppm and that of K is in the range of 1-4.2%. The major portion of cloud is above 100% Kaolinite, Montmorillonite, Illite “Clay Line” and some points also fall in Mixed Clay Layer (Fig.1).

Depositional environment

Studies have shown a relationship between the Th/U ratio and depositional environment and also evidence in the recognition of "geochemical facies" in sedimentary rocks. The distribution of thorium and uranium in sedimentary rocks is mainly determined by immobile Thorium left behind in adsorbed on clays and hydrolyzates after oxidation and leaching of uranium during weathering. The amount of weathering that the zone has undergone affects the standard deviation of the groupings (William E. Youngblood). Uranium has an insoluble tetravalent state that is fixed under reducing conditions, but is transformed to the soluble hexavalent state which may be mobilized into solution. Histogram of Th/U has been prepared for all formation encounter in three borehole well-A, well-B and well-C (Fig.2).

The Basuhari formation of Meso-proterozoic age overlies Mohana formation in the Semri Group of Lower Vindhyan. The part of the formation having Th/U ratio 3-7 (Fig.2) are incompletely weathered and leached of Uranium or are mixtures of materials from low and high ratio. Environment indicates that fluctuating marginal, can be lagoonal to shallow marine environment in nature and it is corroborating with established geological data.

Histogram of Th/U (Fig.2) of **Rohtas Limestone** showing range of 1.5 to 3.5, are typical of marginal marine conditions. Some inter tidal to lagoonal environment of deposition Ratio below 2 shows intermediate marine environment of deposition. Hence, NGS log verifies with geological data.

Kaimur Group histogram of Th/U (Fig.2) shows a wide range from 0.2 to 9 which indicates mixed type of depositional environment i.e. from fluvial to marine. Basal part of Kaimur shows clastic deposits which could be of fluvial or tidal channel or tidal bar. The central part of Well-A shows typical marine environment of deposition whereas well-B and well-C indicates supra-tidal bar deposits. Upper Kaimur again shows values 2.5 to 5 that could be tidal bar. Hence it verifies with geological data.

Jhri Shale histogram of Th/U (Fig.2) in well-A shows a range from 1.5 to 2, this indicates marine and shifting towards reducing depositional environment. Well-B shows a range from 3 to 4 i.e. tidal channels type of depositional environment, well-C shows a range from 3 to 6.5 i.e. tidal flat type of depositional environment. Hence it corroborates with geological data.

Rewa Sandstone histogram of Th/U (Fig.2) in well-A, B & C showing a range from 1.5 to 5, this indicates mixed type of depositional environment but very low value K because of washed out K-mineral which is possible in beach type environment which leads to clean sand. Hence it validates with geological data.

Ganurgarh Shale histogram of Th/U (Fig.2) in well-A shows a range from 2 to 6.5 in all the three wells which indicates marginal shoreline and shifting towards slightly reducing depositional environment that could be tidal flat or lagoonal type of depositional environment. From basal to upper part, depositional environment changes from marginal shoreline to tidal flat i.e. regression cycle, hence it corroborates with geological data.

Nagod Limestone shows a range from 1 to 7.5 in histogram of Th/U (Fig.2) in all the three wells indicating shifting of depositional environment from tidal flat to marginal shoreline. In basal part Th/U value is 7.5 that indicates fluvial type of deposition and further lower value indicates tidal flat type of deposition i.e. transgression cycle. Three such cycles can be seen in Nagod Formation.

Sirbu Formation histogram of Th/U shows a range from 3.5 to 7 (Fig.2) in all the three wells which indicates inter tidal to sub-tidal depositional environment. A consistent value of Th/U signifies no change in the depositional environment throughout the formation.

Conclusions

An effort has been made to explore the diversity of clay minerals using the ratio of Thorium concentration to Potassium and Uranium concentration. Analysis of the clay minerals from different logs indicate that major clay minerals occur in abundance in between 2 to 7 range i.e. transitional from tidal flat to shallow marine depositional environments which fortifies the well-known data. Clay mineral below 2 and above 7 also exemplify consistent coincidence between specific clay minerals and specific depositional environments. To conclude, the majority of clay minerals in sedimentary rocks strongly reflect the character of their depositional environments and the above findings show commendable agreement with the known petrography of the field.

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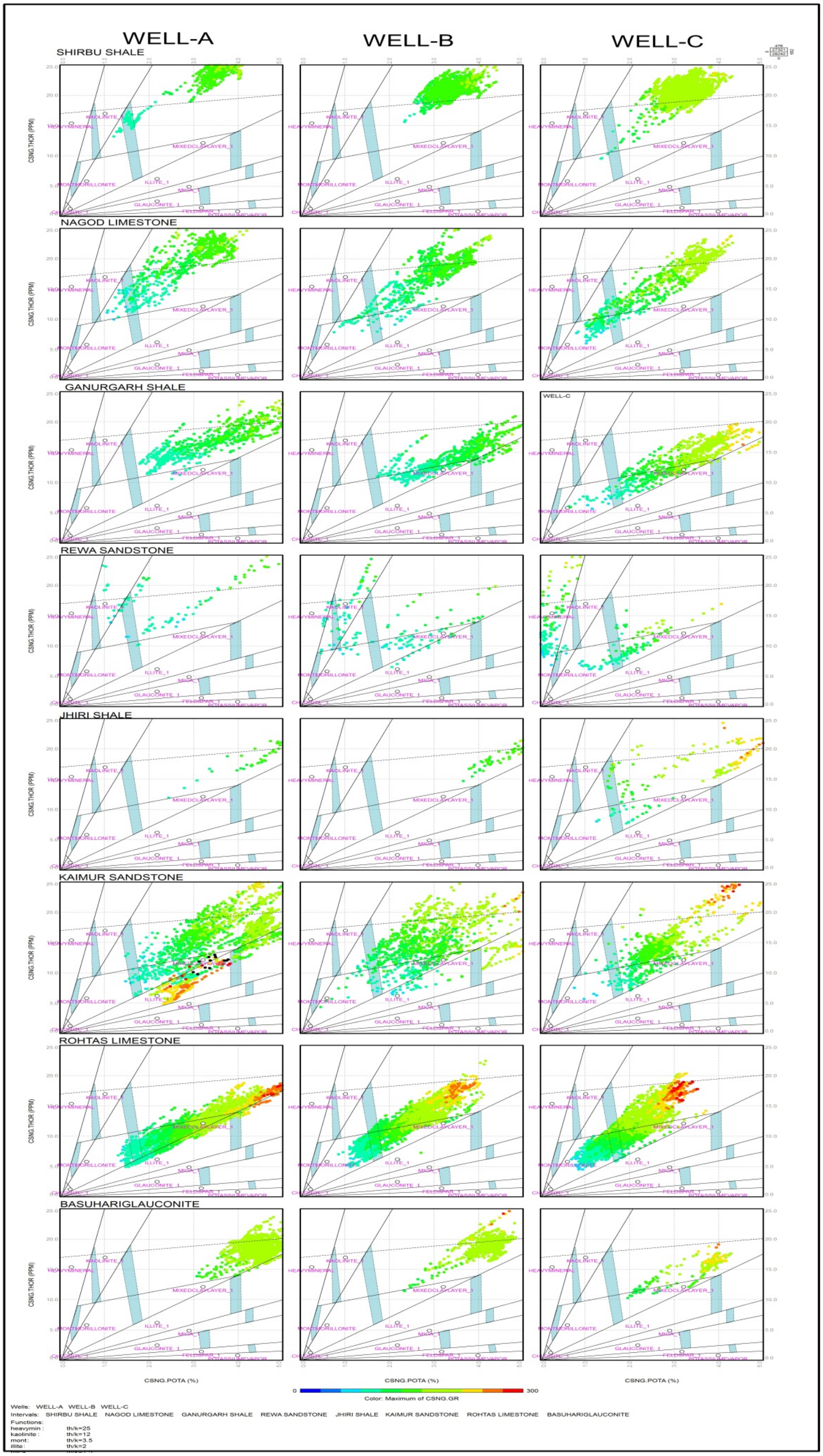
WELL-A
WELL-B
WELL-C
SHIRBU SHALE
NAGOD LIMESTONE
GANURGARH SHALE
REWA SANDSTONE
JHIRI SHALE
KAIMUR SANDSTONE
ROHTAS LIMESTONE
BASUHARIGLAUCONITE
CSNG.THOR (PPM)
CSNG.POTA (%)
KAOLINITE_1
HEAVYMINERAL
MIXEDCLAYLAYER_1
MONTMORILLONITE
ILLITE_1
MICA_1
GLAUCONITE_1
FELDSPAR_1
POTASSIUMEVAPOR
0
300
Color: Maximum of CSNG.GR
Wells: WELL-A WELL-B WELL-C
Intervals: SHIRBU SHALE NAGOD LIMESTONE GANURGARH SHALE REWA SANDSTONE JHIRI SHALE KAIMUR SANDSTONE ROHTAS LIMESTONE BASUHARIGLAUCONITE
Functions:
heavymin : th/k=25
kaolinite : th/k=12
mont: th/k=3.5
illite: th/k=2

Fig.1 Crossplot of Well-A, Well-B & Well-C in all formation encounter

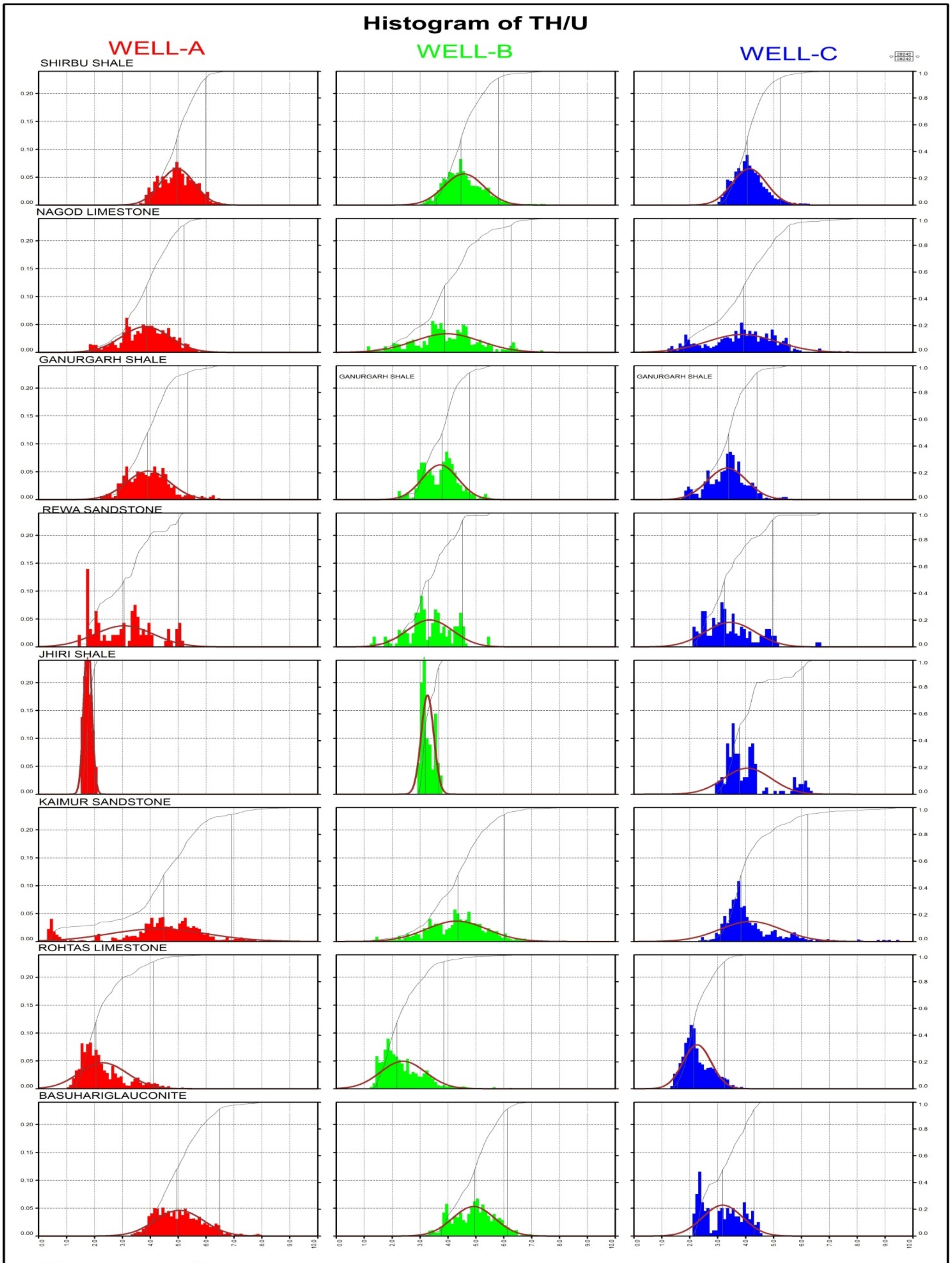

Fig. 2 Histogram of Well-A, Well-B & Well-C in all formation encounter.