Identification of Deep-water Depositional Features on Dipmeter and Borehole Image Logs- A Case Study from Cauvery Basin, India

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Summary

Sediment deposition in deep water environments takes place mainly as a) Submarine fan depositions and turbidites and b) Mass flow sediment depositions like debris flow, grain flow, slides and slumps. Lawrence,D.A et al (2003) and Johansson,M. (2003) have described recognition of some of these features from Borehole image logs. The present study pertains to a cretaceous sandstone formation S-II from Well-A and Well-B belonging to Tranquebar sub-basin of Cauvery Basin, South India. Examples presented clearly show debris flow, grain flow, shale-sand laminations,slumps and turbidites on Borehole image log. Some of these features can be interpreted from Dipmeter also. Two objects were tested in Well-A out of which one flowed hydrocarbons and the other water. Borehole image logs against these two objects show the differences in the reservoir facies.

Introduction

Tranquebar sub-basin of Cauvery basin underwent severe tectonic activity resulting in a series of basement controlled faults. This gave rise to a series of narrow and elongated fault blocks. The tectonic activity also induced metastable slopes over which sediments were deposited as slope fans and mass flow depositions which were again subjected to deformations due to sliding and slumping at some places. The formation S-II is a cretaceous sandstone which is a producer in this area. The faults are responsible for the migration of hydrocarbons from the source rocks deposited at the bottom of the basin. Cores in this formation indicate mainly sandstone with different facies. Sandstones are moderately hard, moderately compact, medium to fine grained and sub-angular to sub-rounded. Shale laminations and calcareous streaks are common. At some places there are clay clasts, chlorite clasts and specks of gluconite. Calcitic intergrowth in some places is quite common and looks like limestones. At some places sandstone is massive. Shale laminations are planar at some places but wavy and discontinuous at some other places. They also contain lenses and lenticular bodies of bituminous coal. Lenses of carbonaceous shales are found scattered in some shale-sandstone laminations. Micro faults and folds are also seen at some places. All these features show that the formation is highly heterogeneous and deposited under different environments.

Methodology adopted

Conventional well logs along with cutting data were used to identify major lithological units. Within the formation S-II, detailed study was carried out using High Resolution Borehole image log and Dipmeter data. Microresistivity measurements recorded by the Borehole image tool were divided into multi-color histograms and plotted as image log where the color of the pixel represents a range in the histogram in that segment. Thus white represent highly resistive and black represent highly conductive formation. Normally shales are represented as black to dark brown and sandstones as yellow. Variations in color represent the structure and texture of the formation. The minute details like shapes and sharpness of the contacts, thickness and grading of beds and intrusions are used in interpreting the depositional environments. An attempt was made to correlate these features with dip patterns. Two conventional cores were taken in S-II of Well-A. The image data is compared with core data in these intervals and found a good agreement between the two. There is no Borehole image data in Well-B but Dipmeter data is available. There is a good correlation between Dipmeter data and core data in Well-B.

Analysis of results

Identification of various features of deep water depositional environments is described below with examples.

a) Prograding slope fan system:

Figure-1 shows a section of the Borehole image log against S-II of Well-A. The interval from XY09 to XY04.5m shows a successively thickening up and coarsening up sandstone sequence. This represents a prograding fan system. The paleocurrent direction as seen from blue pattern of dips shown in figure-2 is towards SE direction which concurs with paleoslope. But the irregular features of conductive and resistive features show that the sediments are the result of reworking from the shallow levels and occasionally got mixed up with debris. The core sample in this section shows the presence of debris. An object tested against this interval flowed water. Presence of debris apparently results in a poor reservoir facies.

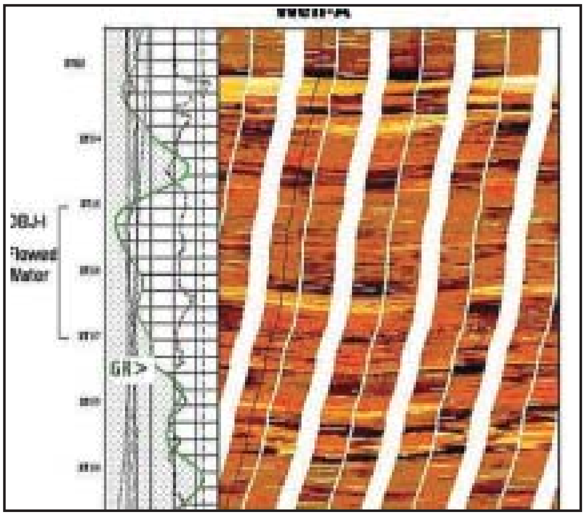

Fig. 1: Borehole image log showing prograding fan system

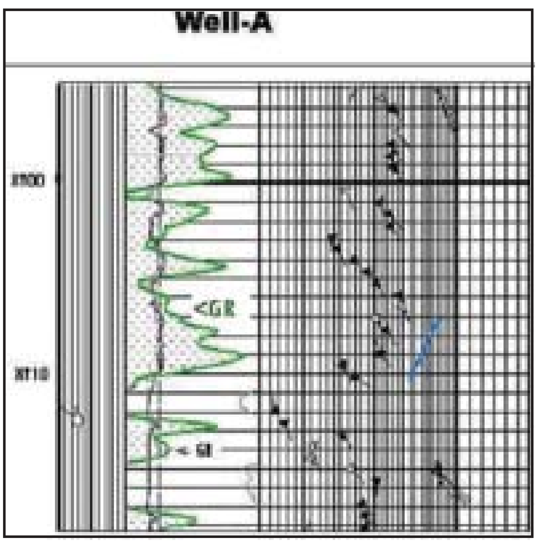

Fig. 2: Dipmeter log showing prograding fan system

b) Massive sandstone:

Borehole image log in figure-3 shows a massive sandstone deposition in the interval XX56-XX63m. This may be due to rapid deposition during high energy grain flow. Blue pattern on dips in figure-4 indicate a paleocurrent direction of SE which is in agreement with paleoslope. This interval shows relatively clean formation. An object tested in this interval produced gas and condensate. However dips above this interval shows reversal of structural dips which indicates syn-sedimentary sliding. Below this interval, the dips do not have any specific pattern indicating deformation due to slumping.

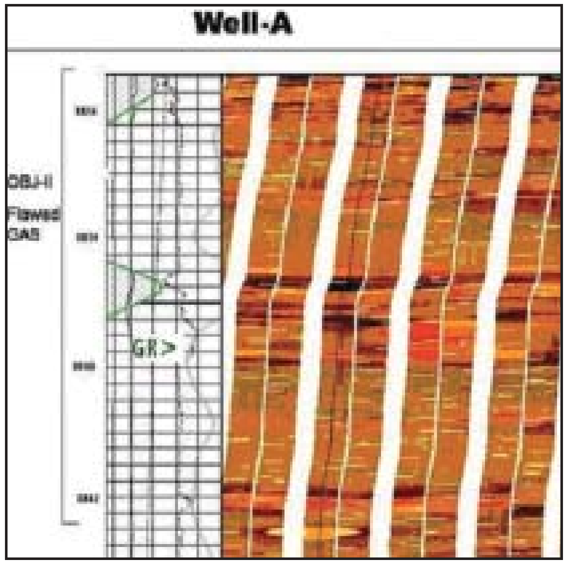

Fig. 3: Borehole image log showing massive sandstone system.

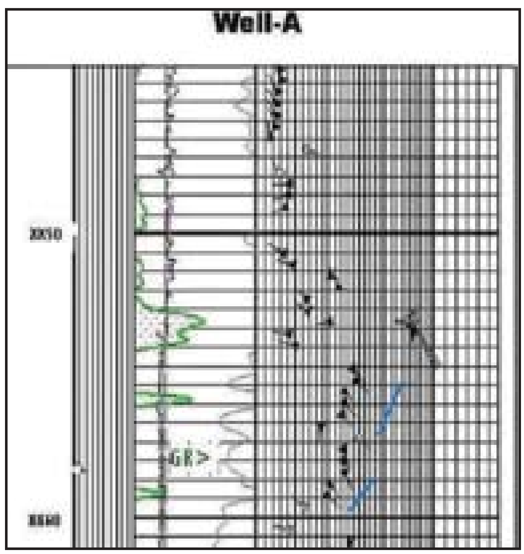

Fig. 4: Dipmeter log showing massive sandstone system.

c) Laminations:

Borehole image in figure-5 shows laminations of calcareous sandstone-silt-shale sequences. This indicates that the deposition took place due to high velocity turbidity currents. The thickness of the bed is related to longevity of the flow. The discontinuities in the contacts indicate that the sediments have undergone some deformation. Opposing dips against successive laminations in figure-6 also indicate deformation of formation like slumping.

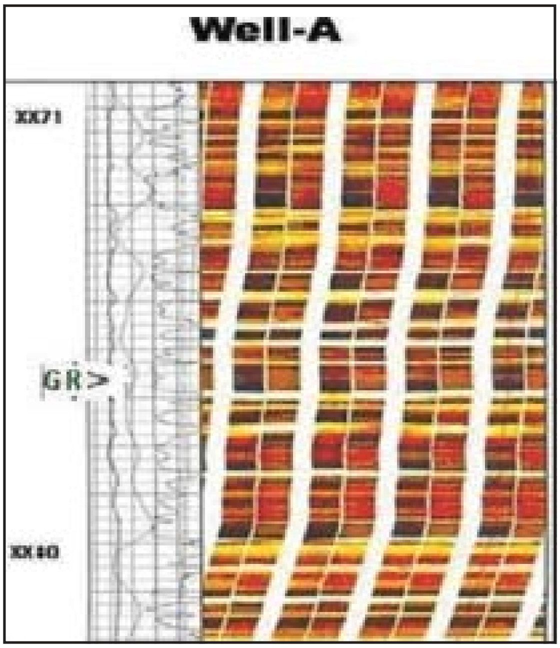

Fig. 5: Borehole image log showing laminations and deformations.

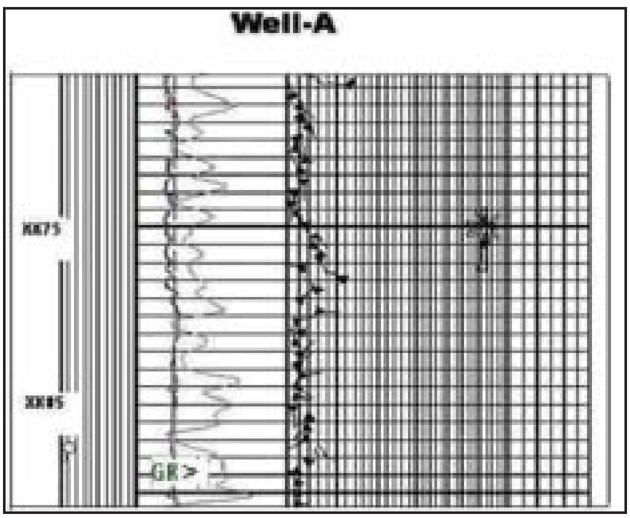

Fig. 6: Dipmeter log showing laminations and deformations

d) Debris flows and Slumps:

The slumps can be identified by successive concave-convex surfaces with randomly varying dips. Borehole image log in figure-7 shows slumping of the formation below XX75m. Also dips in figure-8 show successive series of opposing dips below XX75m indicating slumping of the formation. But there are no dips in the interval XX71-XX75m which indicates debris flows. Borehole image log in this interval not only shows debris flow but also show very thin convex and concave features indicating that the formation has undergone slumping. Similarly, Borehole image log in figure-9 and corresponding dips in figure-10 indicate slumping features.

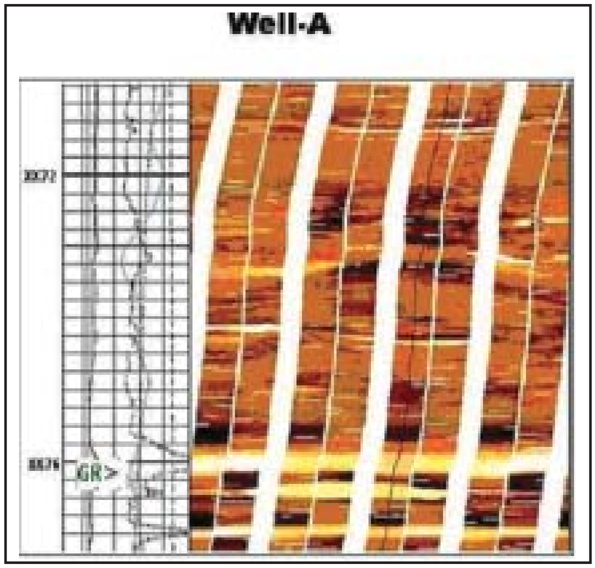

Fig. 7: Borehole image log showing slumping feature.

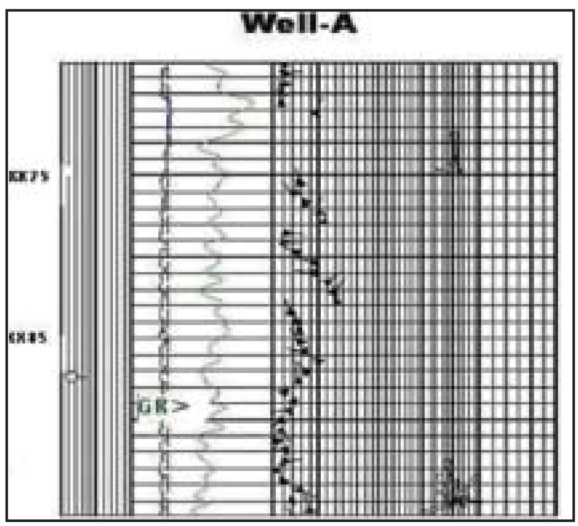

Fig. 8: Dipmeter log showing slumping feature.

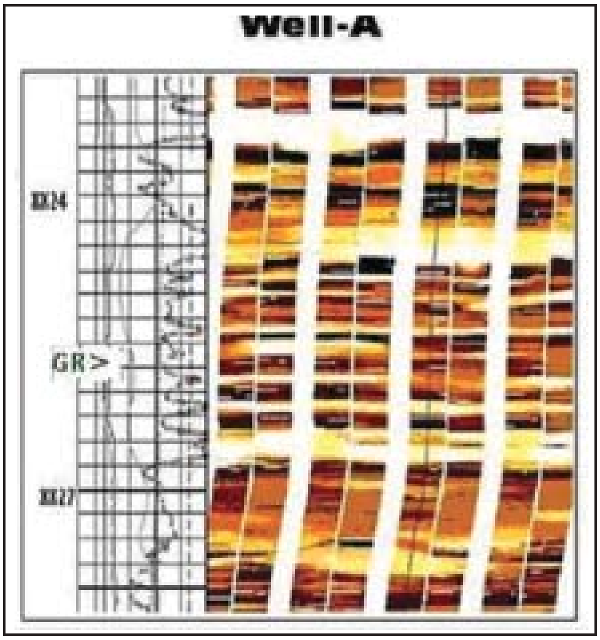

Fig. 9: Borehole image log showing slumping feature.

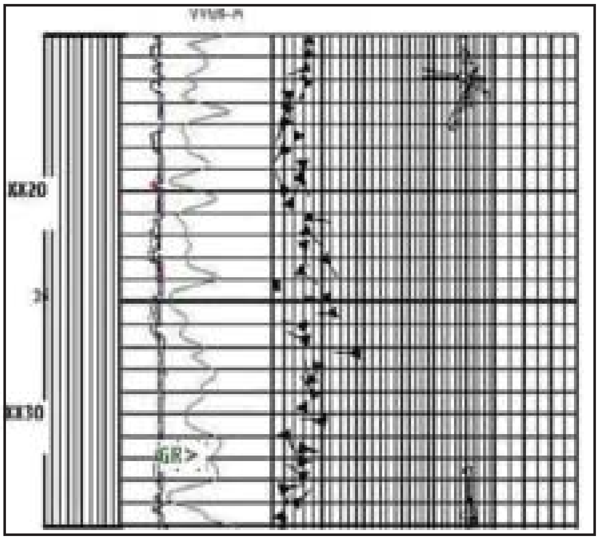

Fig.10: Dipmeter log showing slumping feature.

Figure-11 shows a section of Dipmeter log in Well-B of same field. In this well, there is no Borehole image log but a core was taken. In the interval XX34-XX36m, the dips show a bunch of nails indicating debris flow. In the interval XX36-XX37m, Dipmeter log as well as core show high dips. In the interval XX37-XX37.5m, it is a combination of high and medium dips. Apart from these dips, the core also shows micro-faulting at the bottom. These high dips and gravity faults indicate that the sediments are resting on a metastable slope. Interval XX40-XX42.5m in

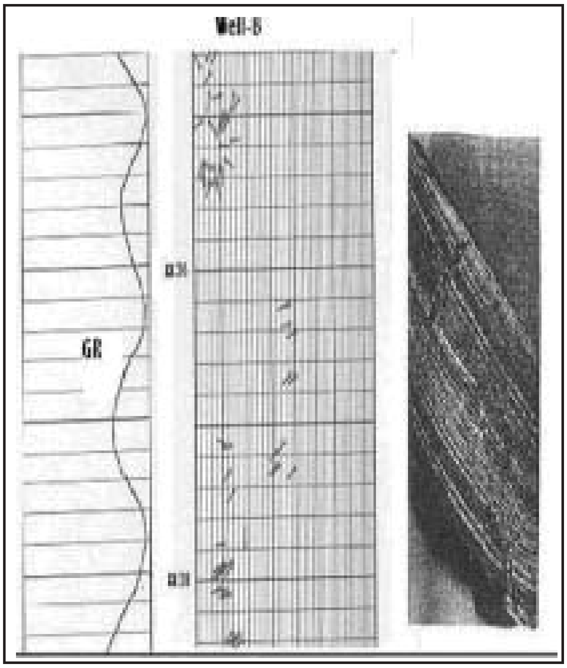

Fig. 11: Dipmeter log and core of Well-B showing high dips.

figure-12 of same well show a combination of high and low dips. The core in this interval shows alternations of sandstone and siltyshales dipping around 25 degrees. Micro-faulting is observed towards bottom. The type of deposition interpreted from core is slumping.

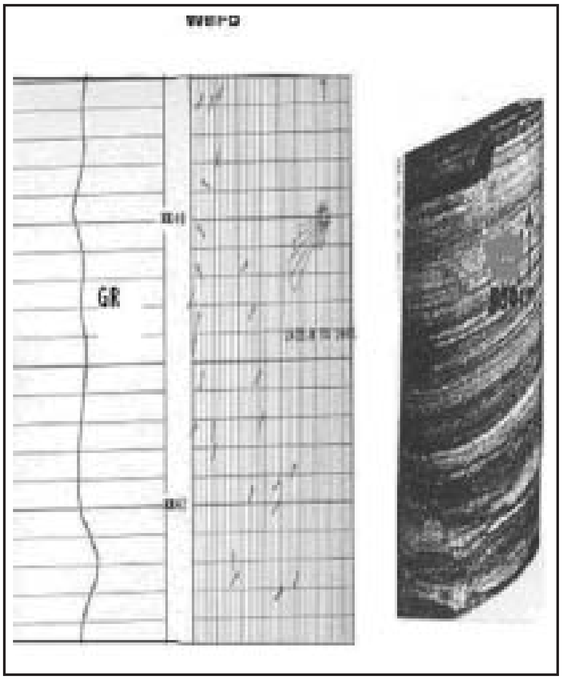

Fig. 12: Dipmeter log and core of Well-B showing slumping feature.

Conclusions

The present study shows Borehole image logs are very useful in identifying sedimentary features in marine slope depositional environments. Examples presented indicate identification of prograding slope fan system, massive sandstone depositions resulting from high energy grain flows, laminations resulting from turbidity currents and deformation of sediments due to sliding and slumping. The associated dips are also found to be useful in identifying some of these features and also in determining the paleocurrent directions. This type of information is very useful in geological modeling for successful exploration and exploitation.

Acknowledgement

The authors are thankful to ONGC for providing facilities to carry out this study and also for permitting to present this paper.

Views expressed in this paper are that of the author only and may not necessarily be of ONGC.

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