On the geothermal gradient anomalies of hydrocarbon entrapment in parts of Rudrasagar and Charali fields in Upper Assam

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Keywords
CGG, ESTI, Barails, Tipams, Bypassed

Summary

A new concept of compensated geothermal gradient (CGG) and extrapolated surface temperature intercept (ESTI) is used over the conventional geothermal gradient method to identify the missed/bypassed and prospective hydrocarbon traps in SW part of Rudrasagar and west of Charali fields. The corrected BHT data from logs using Neglia, 1979 are plotted against depth and the ESTI and CGG is calculated. The ESTI values for the Rudrasagar wells producing from Barails vary in the range 32-38^{0}C and the CGG is having constant value of 1.6^{0}C/100m. The ESTI values for the Charali wells producing from Barails vary in the range 31-45^{0}C and the CGG value is around 2-2.4^{0}C/100m. The ESTI values for the Charali wells producing from Tipams vary in the range 12-28^{0}C and the CGG is almost having constant value of 2.4^{0}C/100m. In the cross plot, the high ESTI-low CGG values are indicating Barail producers and the low ESTI-high CGG values indicating Tipam producers. From the stratigraphic sections along with the cross plot it can be inferred that well RD-1 is in bypassed area of hydrocarbon migration while RD-2 and C-19 seemed to be prospective for the deeper prospects.

Introduction

Assam and Assam-Arakan basin is a matured basin with almost 1500+ wells drilled. It has sedimentary column of near about 5000m thick towards the NW while the exact thickness in the SE i.e. below the Naga Schuppen Belt is yet to be established by drilling. In the basin, established reservoirs are encountered from 1500m in Girujan Clay to the deepest of 4300m in Tura Sandstones. In the present energy scenario context, exploration is very challenging especially in the matured basins. To identify the missed/bypassed and prospective traps and migrated/untrapped oil in such basin needs an additional understanding of the fluid migration.

Preservation of the accumulated hydrocarbons through various surface and subsurface earth processes over a long geological time is full of uncertainties and complexities. Hydrocarbon traps function as focal points of migrating connate or recharge waters, passing through or past the trap leaving behind the hydrocarbons. Observations indicate geothermal gradient anomalies to be associated with the hydrocarbon traps. These anomalies are probably the by-product of the heat transporting processes associated with migration and entrapment of hydrocarbon. If a deep seated source rock generating hydrocarbon is migrated to shallower traps the higher temperature of the source will be reflected in the shallower reservoir through the fluid of the reservoir. This geothermal gradient study is more or less a correlative tool with respect to the oil occurrences within the area of study and thus it seemed to be very helpful in the matured basins. A new concept of Compensated Geothermal Gradient (CGG) and Extrapolated Surface Temperature Intercept (ESTI) is used over the conventional geothermal gradient method (Fig-1A) for the geothermal study. This method is proven in mature basins like North Sea, Syria, Libya, Iraq etc to locate the missed and bypassed hydrocarbon traps and to infer prospective areas (Ibrahim, 1994).

Theory and methodology

In the conventional study, graphically or statistically calculated mean geothermal gradient involves a surface temperature intercept; such as mean air, mean ground surface, mean sea bed or extrapolated surface temperature. By forcing one regional surface temperature (Fig.-1A) on the bottom hole temperature (BHT) gradient the true geothermal gradient is not depicted. An isotherm in an area does not mean equal depths. So, in order to have different depths for an isotherm for two wells having same geothermal gradient it must have different surface temperature intercepts. Further, As the last stages of subsidence and deeper thermal zones have the most significant effect on generation, migration and accumulation of hydrocarbon while shallow or surface temperatures have nearly no effect at all; therefore geothermal gradient should be representative of the overall subsurface thermal profile. So the new compensated geothermal gradient method is applied in the present study where the sub-surface temperature is extrapolated to determine the surface temperature (Fig.-1B).

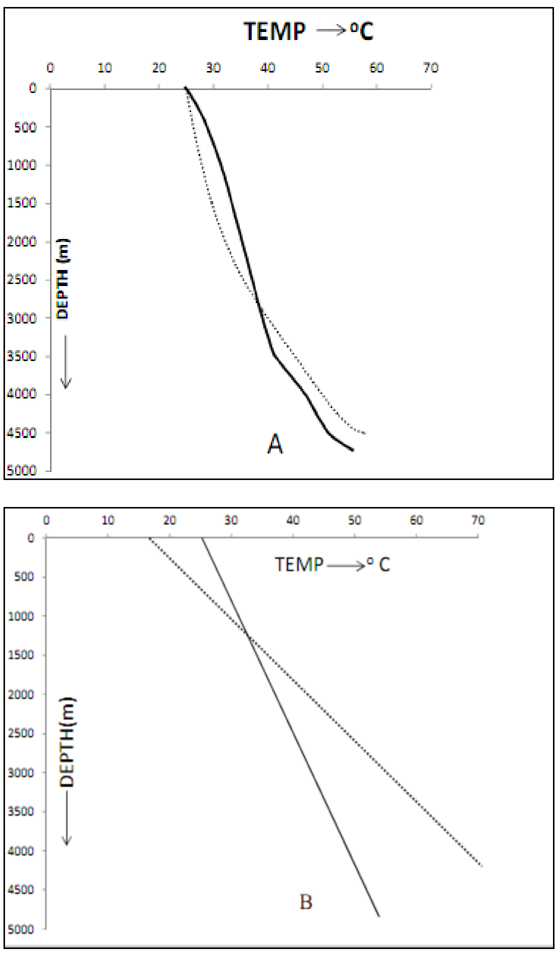

Fig-1: Comparison of conventional (A) and compensated (B) geothermal gradient

The compensated geothermal gradient method is based on calculating the compensated geothermal gradient (CGG) and the correlative extrapolated surface temperature intercept (ESTI). According to CGG-ESTI concept higher geothermal gradient - low extrapolated surface temperature anomalies (High CGG-Low ESTI) signals vertical water movement (and hydrocarbon if available) into shallower traps (Ibrahim,1994). In old compacted basins with deep traps the above anomalies indicate seepage along young faults and may signal dissipation of entrapped hydrocarbon and breach of sealing rocks. Tilting of trap, accentuation of domal and anticlinal structures causing tensional micro fractures at the crestal parts etc are some effects of post-accumulation tectonics causing fluid migration to existing or newly developed younger updip traps. The low CGG-High ESTI anomalies can be associated with high impedance seals and undamaged traps (Ibrahim, 1994). As for example, a regional cap rock acts directly as a regional barrier to large scale upward migration of oil and gas to higher levels and eventual escape. If the potential hydrocarbon traps are affected by a fault with low or moderate throw, the “leaking” effects may be neutralized by a thick and extensive cap rock.

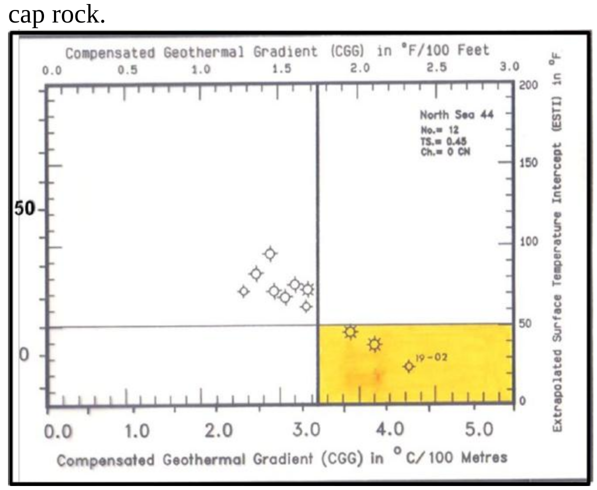

Fig-2: Cross plot of CGG-ESTI (Ibrahim, 1994)

After the computation of CGG and ESTI, clustering of producers versus non producers can be interactively explored by cross-plotting the CGG/ ESTI to identify and establish optimum CGG and ESTI boundaries that seclude the anomalous CGG and ESTI association (Fig-2) This is used for identification of missed/bypassed area and to infer new prospective areas.

The following steps are followed to carry out the present study:

1. Generate a BHT data base for the wells drilled in the study area.
2. Using the necessary correction to the data.
3. Sorting out the data to bring maximum accuracy to the study at different steps of the project work.
4. Plotting the data in a temperature vs depth plot to determine the geothermal gradient and surface temperature intercept (ESTI).
5. Cross plot of geothermal gradient and ESTI.
6. Identifying the CGG-ESTI anomalies and determining the proven anomalies i.e. anomalies associated with hydrocarbon bearing pool.
7. Comparing the proven anomalies with all the anomalies of other wells of the study area and identifying the prospective anomalies.
8. Preparing of geological cross section along with stratigraphy and plotting the oil window temperature contours in the range from 60-80^{0}C (lower limit) (After Pussey, 1973).

Data processing

The source of for this study temperature data at different depths of the drilled wells is needed. The scarcity of reservoir study data automatically left log header BHT data as the only available and abundant source of data. For the use of BHT data from logs in any study some corrections needed to be applied in order to reflect the true formation temperature. For the present study we have discussed and reviewed the corrections given by Horner's plot, by Neglia (1979), Waples (2004). These corrected data are plotted and compared with each other graphically and available reservoir temperature data is also plotted in the same plot (Fig-3). This helped in finding the accuracy of the different correction methods of BHT data in the study area. It is evident from Fig.-3 that, the reservoir temperature in C-14 is near to the Neglia corrected best fit line.

The BHT data generated from the Rudrasagar and Charali Field are corrected by Neglia, 1979 look up table as other corrections are not applicable due to scarcity of BHT data corrections parameters. Though it is generalized correction but results from the C-14 well supported the viability.

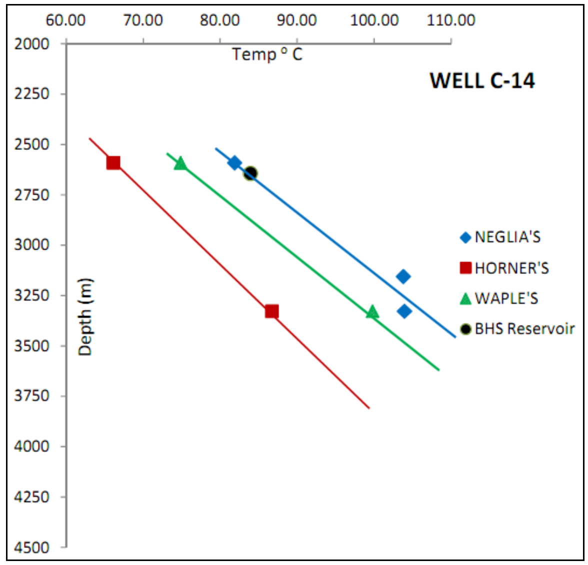

Fig-3: Plot showing various corrections applied to BHT data in well C-14

Study area and objective

The Rudrasagar antiformal structure lies in the North Assam Shelf of Assam and Assam Arakan Basin and Charali Field is a fault-bounded anticlinal structure located at south-east (SE) of the Rudrasagar field. It is located in south of Brahmaputra arch and Disangmukh high and North of Kalugaon low. The Barail Main Sand (BMS) package of the Demulgaon formation is the main pay with subsidiary pays of Barail Coal Sands (BCS-I, BCS-VIII) and Tipam Sands (TS-IV) at places for Rudrasagar. Charali is a major pop-up structure bounded by two southern dipping normal faults which are subsequently bisected into compartments by later generated cross faults. The field is having two distinct structural and accumulation pattern. The NE-SW trending fault block covers the main Charali field in the central part in which both BCS and Tipam sands are the producers, whereas the NW –SE trending Structural trends are producers from BMS.

The drilled wells in SW corner of Rudrasagar and west of Charali field for Barail reservoir were abandoned without lowering the production casing. A recent exploratory well RD-14 mapped its first oil discovery in BCS and this lead to review the prospect of few old wells in the same part of the Rudrasagar and west of Charali field (Fig-4) RD-1, RD-2 & C-

19. In a similar situation, the CGG-ESTI concept has proven its potential applications in screening mature basins of Middle East for remaining prospective acreage and in selecting wells or areas for detailed investigation. Further it can also infer prospective areas and bypassed areas by mapping the migration paths of hydrocarbon.

The primary objective of the present study is to identify the prospective areas in SW part of Rudrasagar and West of Charali field using CGG-ESTI concept.

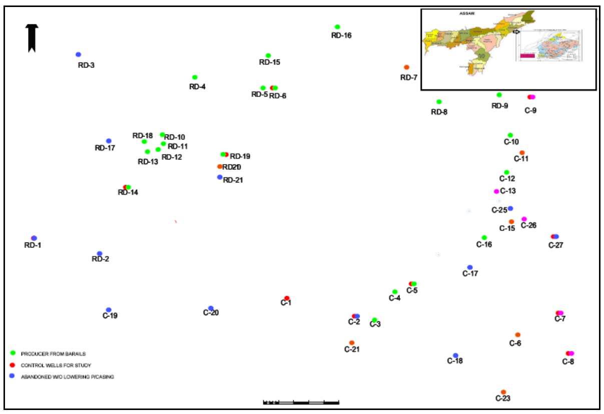

Fig-4: Location map of the Rudrasagar & Charali area

Result & Discussion

The corrected BHT data using Neglia, 1979 look up table are plotted against depth and the ESTI and CGG is calculated (Fig-5). ESTI is the X-axis intercept while the CGG is the gradient of the best fit line. The calculated ESTI and CGG are plotted in a cross plot (Fig-6).

The ESTI values for the Rudrasagar wells producing from Barails vary in the range 32-38^{0}C and the CGG is almost having constant value of 1.6^{0}C/100m. The two abandoned wells of Rudrasagar area show ESTI values 12^{0}C and 30^{0}C; while the CGG values are same 2.4^{0}C/100m for both of the wells.

The ESTI values for the Charali wells producing from Barails vary in the range 31-45^{0}C and the CGG value is around 2-2.4^{0}C/100m. The ESTI values for the Charali wells producing from Tipams vary in the range 12-28^{0}C and the CGG is almost having constant value of 2.4^{0}C/100m. The abandoned wells of Charali area show ESTI values in the range 10-48^{0}C; while the CGG values varies in between 1.4-2.8^{0}C/100m.

In the cross plot as per theory (after Ibrahim, 1993) the high ESTI-low CGG values are indicating Barail producers and the low ESTI-high CGG values indicating Tipam producers.

To add more value to the study, geological cross sections are prepared; Section AA' from W-E (Fig-7) and section DD' from N-S of the study area (Fig-8). Over the cross section oil window temperature contours are superimposed for 60^0 C, 70^0 C and 80^0 C. This temperature range is the lower limit of the oil window temperature range (Pusey, 1973). The probable reservoirs within the Oil Window Temperature range are identified.

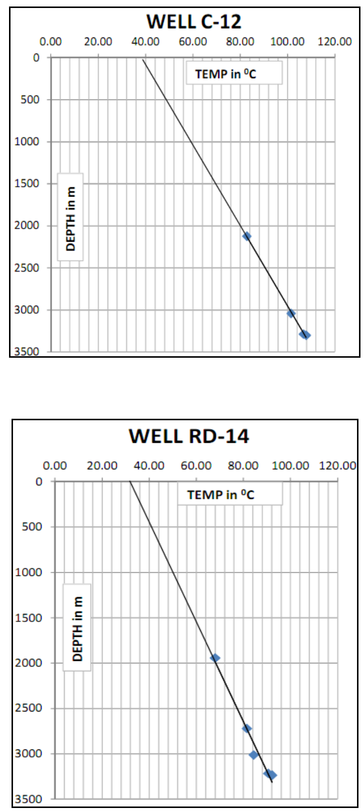

Fig-5: Plot showing CGG-ESTI determination in well no C-12 and RD-14

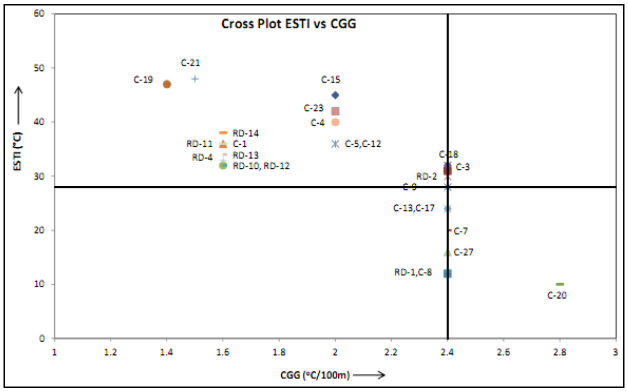

Fig-6: Cross plot of CGG-ESTI for the wells in the study area

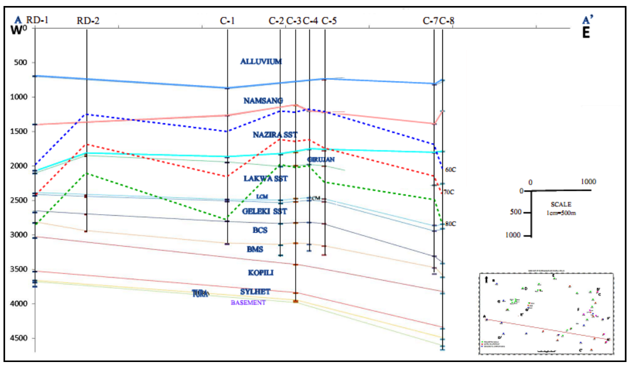

Fig-7: Stratigraphic cross section AA' (W-E)

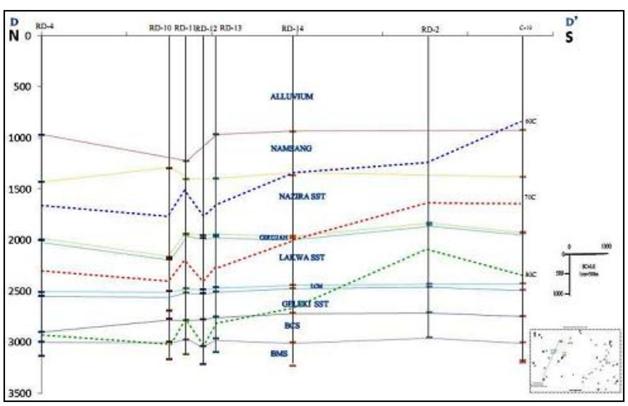

Fig-8: Stratigraphic cross section DD' (N-S)

From the study it can be inferred that the well RD-1 is in bypassed area of hydrocarbon migration while RD-2 and C-19 is seemed to be prospective for the deeper prospects.

The temperature values for oil window varies in the range 65.5-149^{0}C as per the "hydrocarbon-liquid window" concept (Pussey, 1973). In the present study the stratigraphic section AA' indicate that the RD-2 well can be prospective for deeper prospect as the oil window temperature range is extended even up to the Pre-Barails considering the upper limits. Similarly, the stratigraphic section DD' indicate that the C-19 well is also potentially prospective for deeper prospect as the oil window temperature range is extended even up to the Pre-Barails considering the upper limits.

So deepening of C-19 and RD-2 wells may be prospective for the Pre-Barails. Further RD-1 indicating the bypassed area of hydrocarbon and discovery in RD-14 may be looked as a discontinuous stratigraphic trap. It is recommended to re-examine and re-analyze the available data of these wells for alternative interpretation as the dry holes may have missed bypassed or stopped short of a significant hydrocarbon reservoir.

The technique may help as an additional tool in exploration of a stratigraphic traps that display no seismic expression of sealed porous and permeable reservoirs by diagenetic or facies changes.

In conjunction with other hydrocarbon exploration methods, the discovery/dry-hole ratio can be improved by incorporating geothermal gradient maps and it should improve risk assessment of basins, blocks, prospects, and seismic anomalies and proposed or revised wells.

Acknowledgment

The authors would like to take this opportunity to express their gratitude to Basin Manager of A and AA Basin for giving permission for carrying out the study. Thanks are also due to the colleagues of Forward Base NAS for their support.

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