Generation and Distribution of nitrogen in Natural Gas of Jaisalmer Basin, Rajasthan

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Abstract

In the scenario where Natural Gas is increasingly gaining credence all over the world as a clean eco-friendly fuel for various energy needs, it becomes imperative on the part of explorationists not to ignore the possibility of exploitation of gas from settings other than conventional, however small the potential may be. The Jaisalmer Basin has a good potential of natural gas, with higher amount of nitrogen and CO2 contents, show a wide variation even in various gas field of the same basin. This association of nitrogen along with natural gases degrades the quality of hydrocarbon. This occurrence, generation and evolution model of N2 will established the relation of nitrogen, carbon dioxide with the discovered gas fields. Proper monetization of nitrogen will leads to a good potential for many industries in current economic scenario.

Keywords: Natural gas, Nitrogen, CO2, Jaisalmer Basin

Introduction:

The generation of natural gases is much more complicated in comparison with liquid petroleum because natural gases could be generated from both humic and sapropelic organic matter at different stages and that natural gases could be organic and inorganic in origin. Nitrogen and CO2 are non-hydrocarbon gases commonly found in natural gases. Natural gases found in the Jaisalmer basin display a wide variation in the contents of hydrocarbon gases, C1-C5 (20%-75%), nitrogen (70%-30%) and carbon dioxide (0.1%-10%), such high amount of N2 provides an ideal case for studying the origin and genesis of nitrogen, and for establishing a combined generation model of natural gases of both organic and inorganic origins. The purpose of this paper is to establish the natural gas generation model and its response in the accumulated fluids in the Jaisalmer basin by combined geological and geochemical studies.

Geological setting:

The Rajasthan shelf, located to the west of Aravalli ranges, constitutes a gently westerly dipping vast area. The Jaisalmer Basin which lies in the western part of Rajasthan shelf, as part of a greater pericratonic Indus Basin which is located to the west of Delhi-Aravalli Orogenic System. Exploration frontiers have been opened since late sixties with some of the commercial discoveries of hydrocarbon, dominantly gas (Fig.1). Within ONGC acreage presence of gas has been established in different fields like Manhera Tibba, Kharatar, Ghotaru, Bankia, Chinnewala Tibba, Sadewala, Bakhri-Tibba and Chanwarwala Dara (Fig.2). But the N2 association is major concern in most of the fields, as it degraded the total calorific value of hydrocarbon. The basin is mainly producing from Tertiary and Mesozoic sediments, in general, comprise of humic organic facies of predominantly Type-III to Type-IV kerogen having poor to fair gas-prone source potential. Shales of Baisakhi-Bhadesar, Pariwar and Lr. Goru formations have been identified as major source rock. Source rock richness In general increases towards west and north-west direction along the basinal slope. Top of the oil window, in the basin, ranges from 1950m to 2800m in consonance with the basinal geometry where Mesozoic sequences have attained threshold to adequate thermal maturation to deliver the hydrocarbon to the basin. The richness of organic matter of each interval in the Jaisalmer basin is good-fair, with average total organic carbon (TOC) content varies from 1-2% and Rock-Eval hydrogen index (HI) less than 200 mg/g TOC.

Hydrocarbon gases, N2 and CO2 in different fields:

The hydrocarbon gas maturity in the basin is high, but accumulations are relatively small, suggesting early escape of generated hydrocarbons. This fact is consistent with the late Pliocene traps formation and explains the high N_2 concentrations. Further, N_2 is considered to have evolved as an end-product towards the end of organic maturation. In the Manhera Tibba area, the average composition of the gas is (in %) is – Methane: 60-70, Ethane: 0.6-0.8, Carbon Dioxide: 5-8, Nitrogen: 20-25 in shallower objects and in deeper objects has Methane: 40-50, Ethane: 0.1-0.04, Carbon Dioxide: 1-5, Nitrogen: 50-60. In Kharatar area, the average composition of the gas is (in %) is – Methane: 10-35, Ethane: 0.05, Carbon Dioxide: 5-10, Nitrogen: 65-70. In Bankia area, the average composition of the gas is (in %) is – Methane: 20-30, Ethane: 0.3-0.5, Carbon Dioxide: 2-10, Nitrogen: 70-80, In Ghotaru area, the average composition of the gas is (in %) is – Methane: 20-30, Ethane: 0.3-0.5, Carbon Dioxide: 5-10, Nitrogen: 70-80. In Chinnewala area, the average composition of the gas is (in %) is – Methane: 60-70, Ethane: 3-8, Carbon Dioxide: 2-8, Nitrogen: 20-25. In Chanwarwala Dara area, the average composition of the gas is (in %) is – Methane: 60, Ethane: 12.43, Carbon Dioxide: 0.01, Nitrogen: 23.01. The spatial distribution of different fields is shown in Fig. 3.

Origin of N2 and CO2 in Natural Gases:

There are several theories proposed regarding the presence of N2 and CO2 in the natural gases are listed below:

1. Nitrogen may be derived from high-maturity coals and woody organic matter during maturation, especially in metagenetic to metamorphic stage, are captured by late-formed traps. Similar study is performed in Yinggehai basin, China and it has been interpreted that nitrogen-rich gases could be generated not only in the metamorphic stage (source rock Ro>3.0%), but also within the catagenetic stage (source rock Ro >2.0%) (Fang et al., 2003).
2. Nitrogen can be derived from magmatic sources, most of the volatile elements stored in the mantles of terrestrial planets escape through volcanic degassing and intrusive activities, although magmatic nitrogen is not a common component in high-nitrogen gases as they are mostly associated with sufficient amount of Helium (Mikhail et al., 2014).
3. Mingram et al., 2005 has studied the behaviour of fixed ammonium in clay minerals of organic-rich Palaeozoic sediments in the eastern part of the North German Basin as a major source of nitrogen-rich natural gases.
4. Thermochemical sulfate reduction or "TSR" is a process that concentrate of nitrogen gas accumulation in major petroliferous basin by a process that destroys the hydrocarbon components of the gas. In brief, TSR is the reaction of calcium sulfate and hydrocarbons (beginning at temperatures of 120-140 deg. C) to form H_2S and calcium carbonate.

$$CaSO4+HC \xrightarrow[120^\circ C]{140^\circ C} H2S+Ca$$

Natural gas and N2 generation in Jaisalmer Basin:

The basin has a number of gas fields namely Manhera Tibba, Bankia, Ghotaru, Kharatar, Sadewala, Chinnewala and Bakhri Tibba. Production in Jaisalmer Basin comes primarily from Tertiary-Paleocene to Lower Eocene Khuiala (C2-C4 & B4 Limestone Member), Sanu (Paleocene), Lower Goru and Pariwar formations (Lower Cretaceous). Presence of oil in Lower Goru and Pariwar formations is proved in Ghotaru, Chinnewala and Bankia fields respectively during production testing. The natural gas found in the area has high amount of N2, reduces quality and calorific value of hydrocarbon. The possibility of generation of N2 discussed earlier the first reason for the presence of high amount of N2 is derived from high-maturity coals, especially in metagenetic to metamorphic stage is not feasible. As the nitrogen content increases, CO2 content increases and methane content decreases. Thermaly degradation of organic matter will represent a positive N2 correlation with CH4 and negative with CO2. Nitrogen content decreases as CH4 content increases, which indicates that nitrogen and CH4 have different sources and CO2 and He increase with N2 indicates they are from the same source. Hence the possibility of N2 generation form over cooking of type III and type IV kerogen are ruled out. (Fig 4 (a,b,c,d)).

The second probability of generation of nitrogen through mantle looks more feasible as because N2 derived from magmatic sources is has higher content and isotopic composition of helium as it is a sensitive indicator of mantle gases, our study area natural gases are He rich. As shown is TWT map at Jaisalmer level (Fig.5) there is a deep rooted fault present in between the study area, separating Manhera Tibba, Bankia, Kharatar and Sadewala field from Chinnewala and Chanwarwala Dara field. The fields falling in the vicinity of the faults are rich in N2 ranging (60-80%) whereas fields away from the fault has low N2 ranging (20-30%) with high methane content. This deep rooted fault may be a conduit for N2 gases, trapped in shallow reservoirs along with thermogenic gases.

Discussion and Conclusion:

Based on the analysis on the origin and genesis of the N2 in natural gases of the Jaisalmer basin the following conclusions have been drawn:

1. The nitrogen, helium and CO2 have positive correlation with each other and hence have the same origin i.e. mantle degassing at different stages through deep rooted faults.
2. The inter-reservoir compositional heterogeneities of the gas found in the basin are due to mantle degassing at different stages, and the complexities in the composition of the natural gases in the basin are a combined result of multi-stage gas generation and multi-period natural gas migration and accumulation.
3. The shallower reservoirs (Tertiary) has lower nitrogen than that of deeper reservoirs (Mesozoic) is because most of the nitrogen generated by degassing are trapped in first found structure at deeper levels.

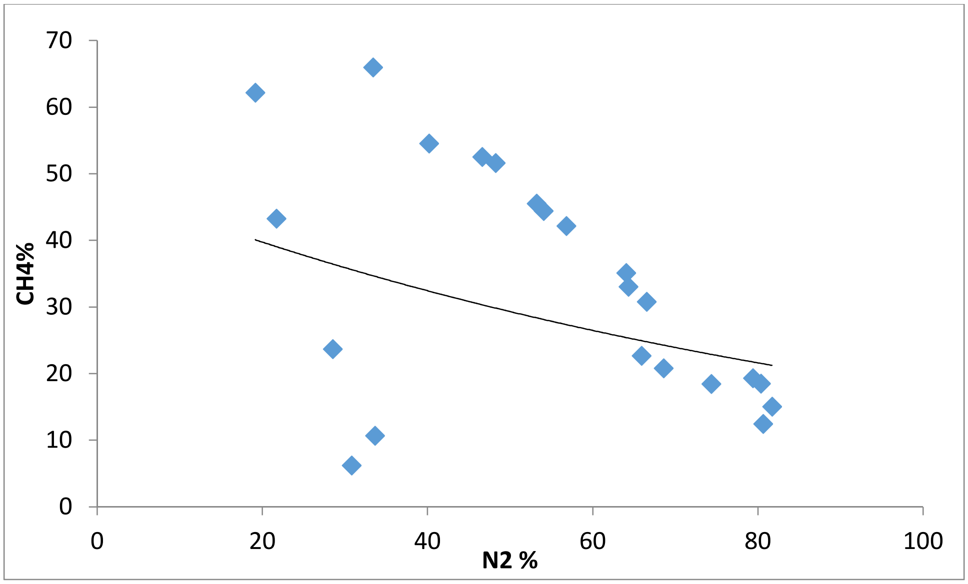

Fig. 4a. Graph between CH4 (wt. %) vs. N2 (wt. %)

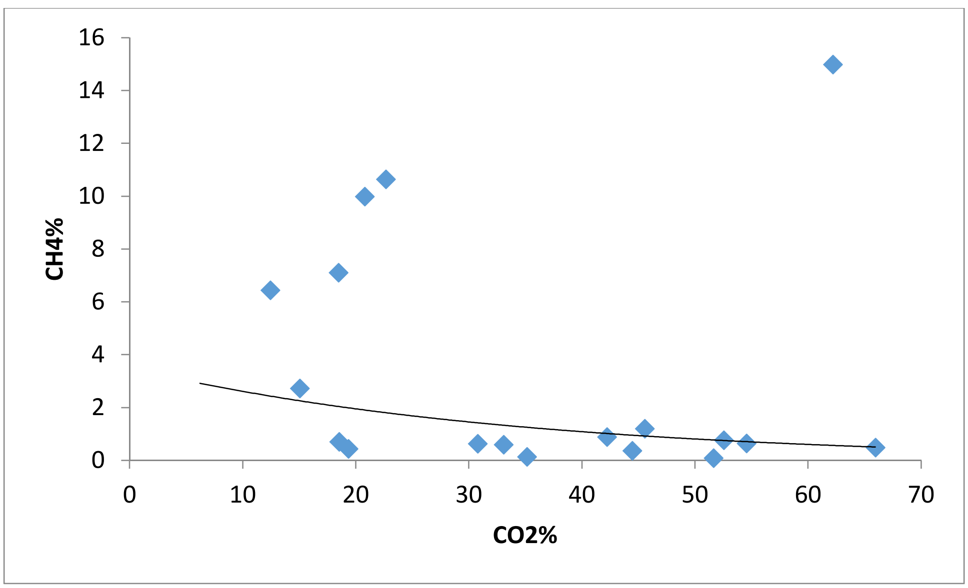

Fig. 4b. Graph between CH4 (wt. %) vs. CO2 (wt. %)

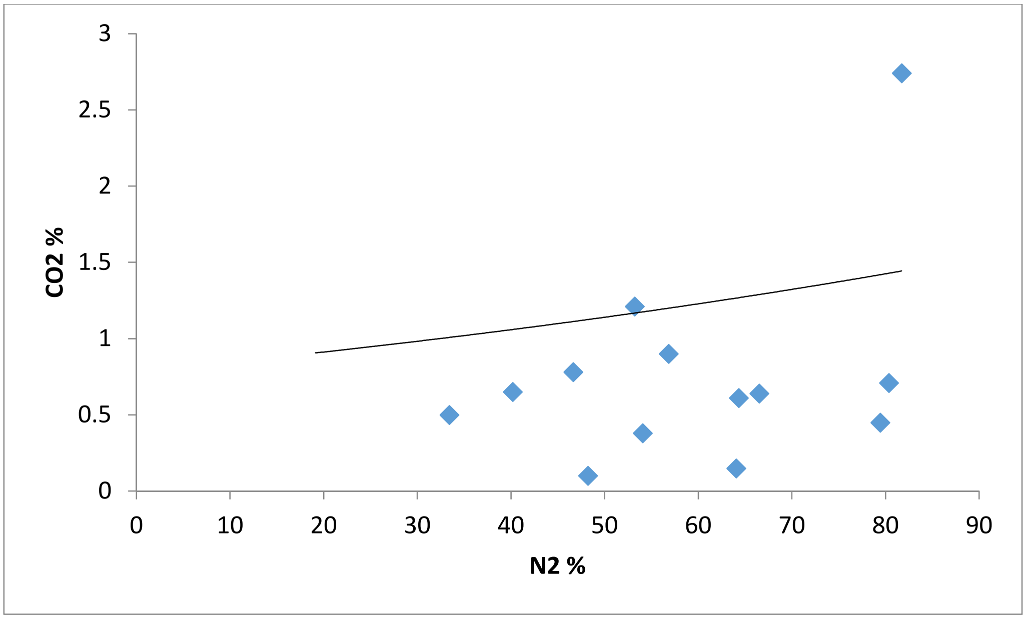

Fig. 4c. Graph between CO2 (wt. %) vs. N2 (wt. %)

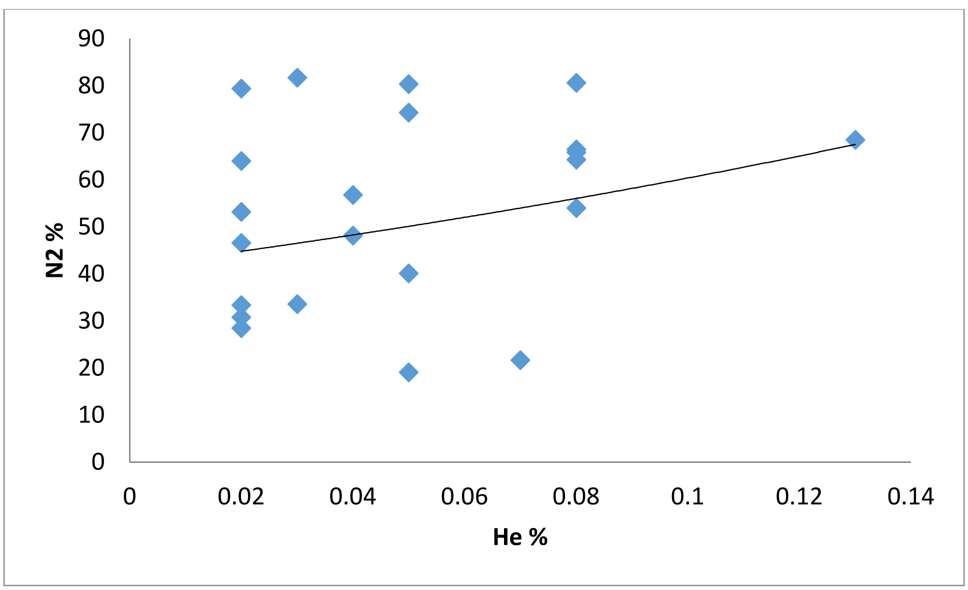

Fig. 4d. Graph between N2 (wt. %) vs. He (wt. %)

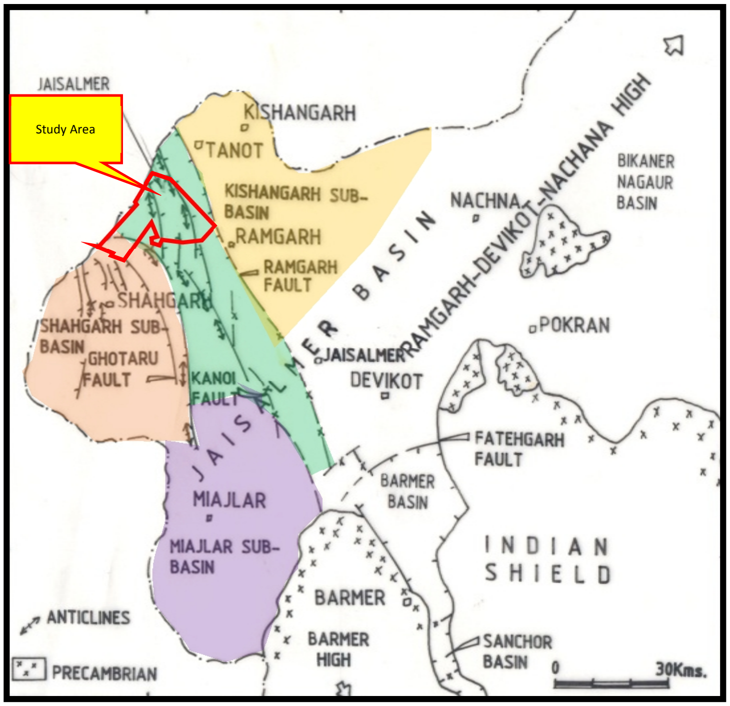

Fig 1. Tectonic map of Jaisalmer Basin

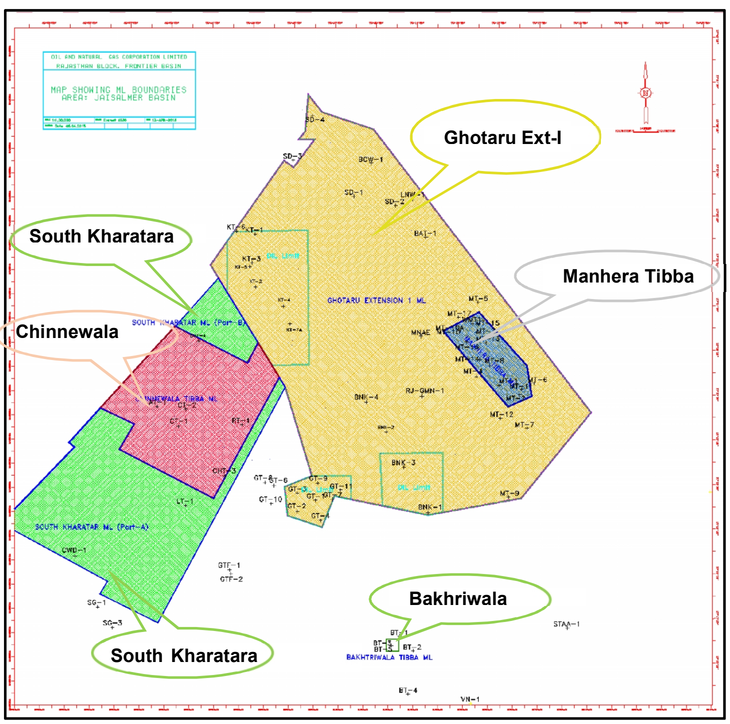

Fig 2. ML area of ONGC in Jaisalmer Basin

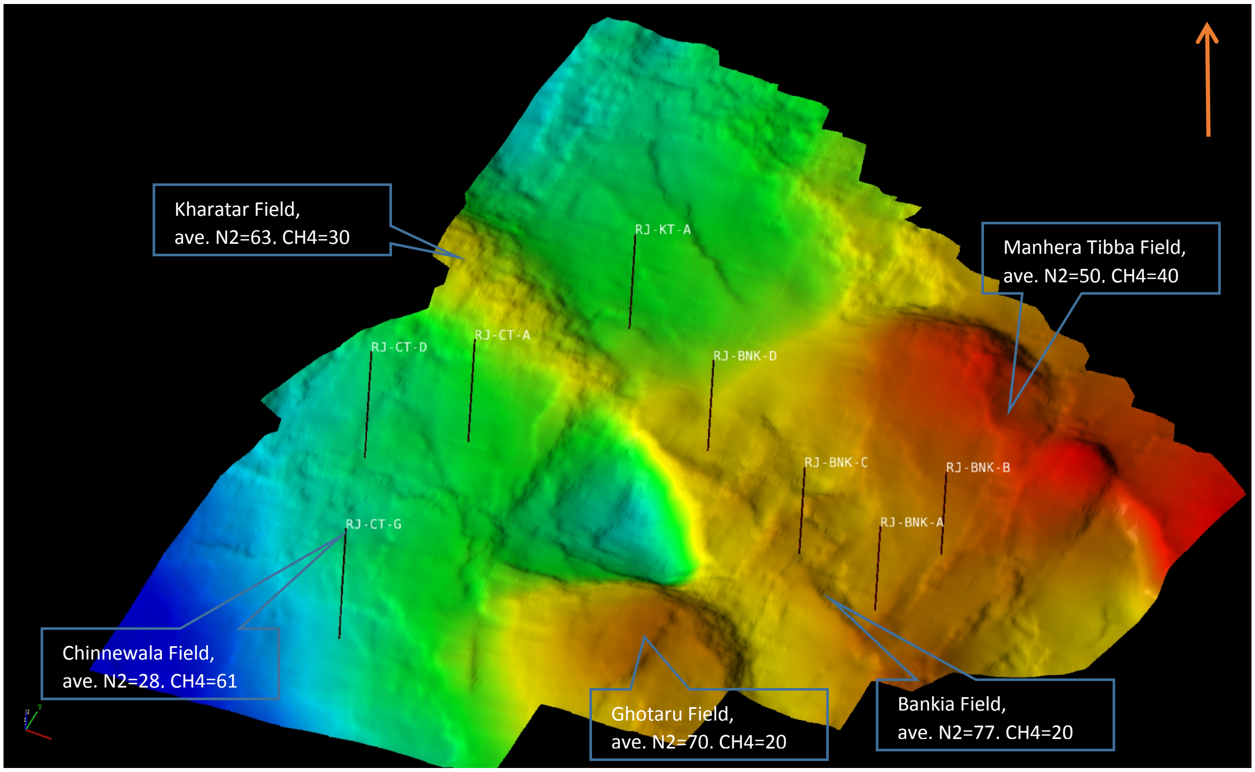

Fig 3. Spatial Distribution of different fields with Gas Composition

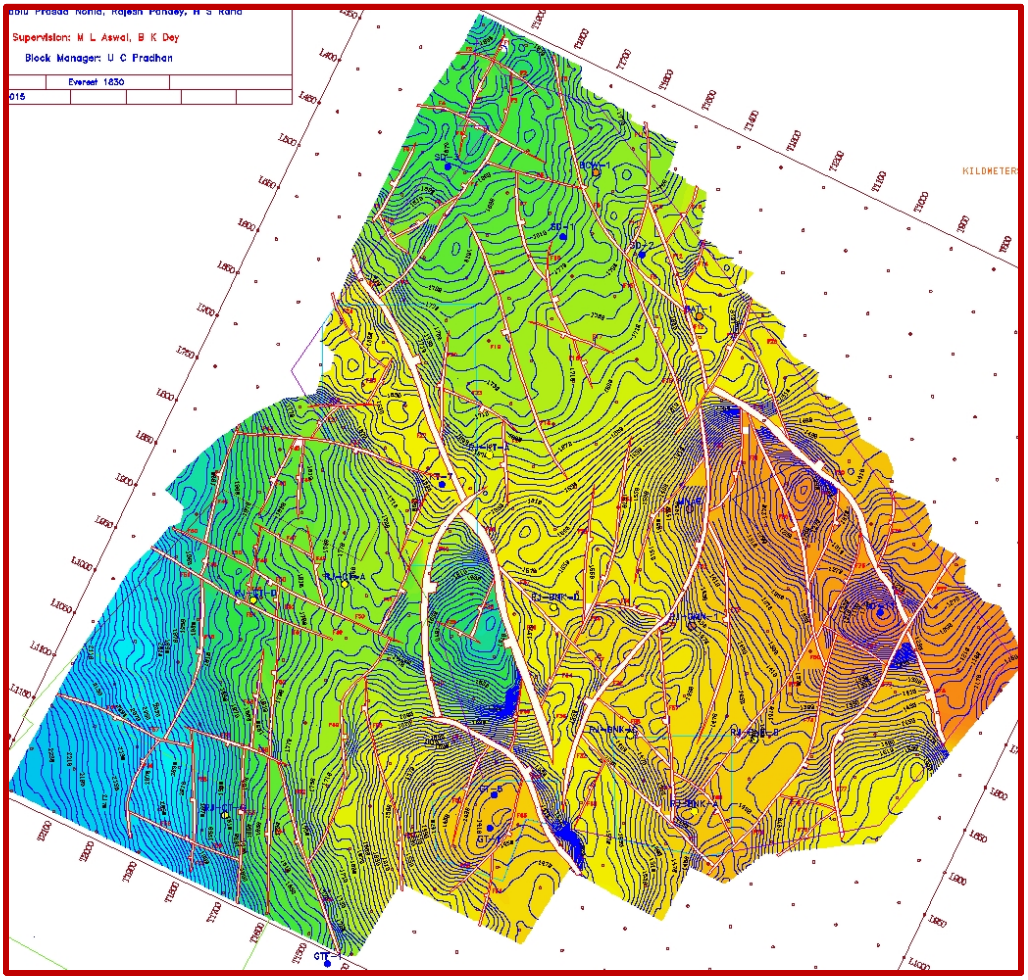

Fig. 5 TWT map near to top of Jaisalmer Formation with major fault systems and deep rooted faults in the centre.

Reference;

Dai, J. X., Song, Y., Dai, C. S. et al., 1996, Geochemistry and accumulation of carbon dioxide gases in China, AAPG Bulletin, 80: 1615_1626.

Huayao, Z., Baojia, H., 2003, Natural gas generation model and its response in accumulated fluids in the Yinggehai basin, Science in China (Series D), 46, 11.

Krooss, B.M., Littke, R., Miiller, B., Frielingsdorf, J., Schwochau, K., Idiz, E.F., 1995, Generation of nitrogen and methane from sedimentary organic matter: implications on the dynamics of natural gas accumulations Chemical Geology 126 (1995) 291-318.

Mikhail, S., Sverjensky, D.A., 2014, Nitrogen speciation in upper mantle fluids and the origin of Earth's nitrogen-rich atmosphere, *Nature Geoscience* **7**, 816–819.

Mingram, B., Hoth, P., Lüders, V., 2005, The significance of fixed ammonium in Palaeozoic sediments for the generation of nitrogen-rich natural gases in the North German Basin, Daniel Harlov International Journal of Earth Sciences, 94, 1010-1022.