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Factors Contributing to High Gamma-Ray Levels in Early Miocene Bhuban and Boka Bil Sandstone Reservoirs of Titas-15 Well

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Abstract

Sandstones of Surma group comprise the main reservoir of Titas gas field and have gamma ray intensities of 60-90 API units which are more than the average sandstone gamma ray level. The sandstones of Titas-15 may thus be considered moderately high gamma ray sand. Petrographic study has been used to identify the sources of radioactivity. Considering the fact that the sandstones are clean, the reason for the high gamma ray for these sands appears to be mineralogical. The high gamma ray background is considered to be due to potassium feldspar concentration of up to 18 % and this is enhanced by the presence of radioactive heavy minerals, particularly zircon. Contributions to radioactivity from organic matter, clays and lithic grains are minor. A failure to recognize the source of radioactivity in these sandstones can result in the assignment of high V_{shale} values and low porosity during log analysis and productive zone may be underestimated.

Key Words: Titas-15 well, Reservoir sand, Gamma ray response, Heavy minerals.

I. Introduction

The Titas gas field is one of the largest gas fields in Bangladesh and the most important gas producer to date. It lies at the skirt of the Brahmanbaria district town between latitudes $24^0 05' 00''$ N to $24^0 46' 00''$ N and longitudes $91^0 40' 00''$ E to $91^0 49' 00''$ E (Fig. 1). The Titas gas reservoirs comprise multiple sandstone layers in the Bhuban and Bokabil formations of Miocene-Pliocene age. The depth of the reservoir sands ranges from 2616m to 3124m below the surface. Major sands are A_2, A_3, A_4, B_3 and C_3 while minor sands include A_1, B_0, B_1, B_2, C_1 and C_2 (Fig. 2) [1.2].

The gamma ray logging is a method of using natural gamma radiation to characterize the rock or sediment in a borehole. It is especially useful to distinguish between shale (higher gamma ray) and sand (lower gamma ray) lithology. The gamma ray values of sandstones range from 20 to 50 API units. The argillaceous or dirty sandstone shows higher gamma ray value than clean sandstone because of the clay content. However, in some cases clean sandstones can show higher gamma ray value to the level of argillaceous or shaley sandstone or even shale. This may happen if the sand contains higher percentage of potassium feldspar or radioactive heavy minerals. This kind of sandstone is referred to as "high gamma ray sandstone" [3].

High gamma ray sandstone can negatively affects conventional gamma ray log interpretation, i.e., clean high gamma ray sandstone may be interpreted as dirty/argillaceous sandstone and this may result in the underestimation of reservoir pay. If high gamma log responses are not properly identified, whether the responses are from radioactive minerals or shale, there is a possibility of recognizing the sandstone as having a high V_{sh} value and low porosity, and a productive zone may be under emphasized [4].

As a first indicator of lithology, the gamma ray log is one of the useful logs as it suggests where shale may be expected. The radioactivity of some typical lithologies other than shale shows high gamma ray value. For this, any lithology indicated by the simple gamma ray log must be confirmed by other logs. Gamma ray log with resistivity log is a good indicator of lithology. Generally, shale shows high gamma ray value and low resistivity value, and sandstone shows low gamma ray value and high resistivity value.[3]

High gamma ray sands have variously been reported as caused by high mica, feldspar, and heavy mineral contents and are now considered to be more common than previously realized. Upper Jurassic sandstone reservoirs of the Claymore oilfield, North Sea show high gamma ray level. This high gamma ray level is due to high percentage of K-feldpar, zircon and monazite in the sand. The Middle Jurassic high gamma ray deltaic sandstones in the Northern North Sea have high mica and feldspar contents. The same phenomenon is observed in the Upper Jurassic sandstone reservoirs with highly radioactive zircons that produce anomalous gamma ray picks in the Piper Sandstone Formation of the Piper field, North Sea. It was found that detrital monazite is associated with high gamma ray anomalies in the same formation.[4]

Spiky gamma ray picks in sandstones reaching levels greater than in adjacent shales are due to heavy mineral placer deposits in the sandstones of Nigeria.[3]

This work is aimed at to determining the factors contributing to the high Gamma ray level for the reservoir sandstone based on analysis of core samples and logs of Titas -15 well.

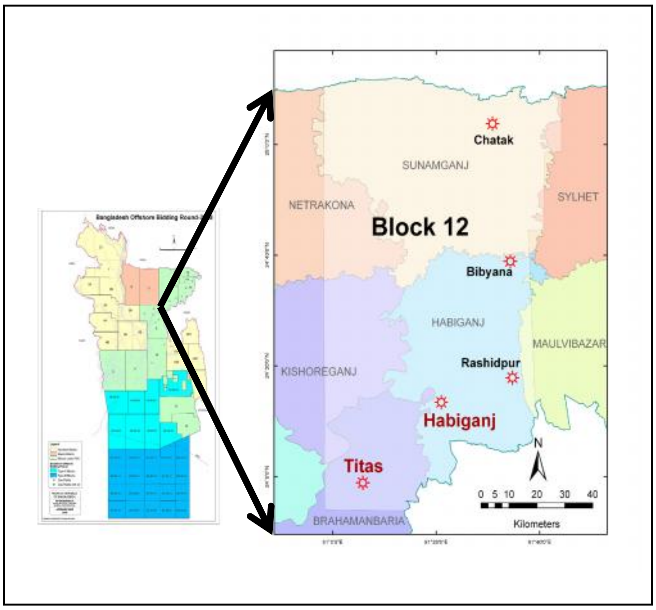

Fig. 1. Location map of Titas gas field.

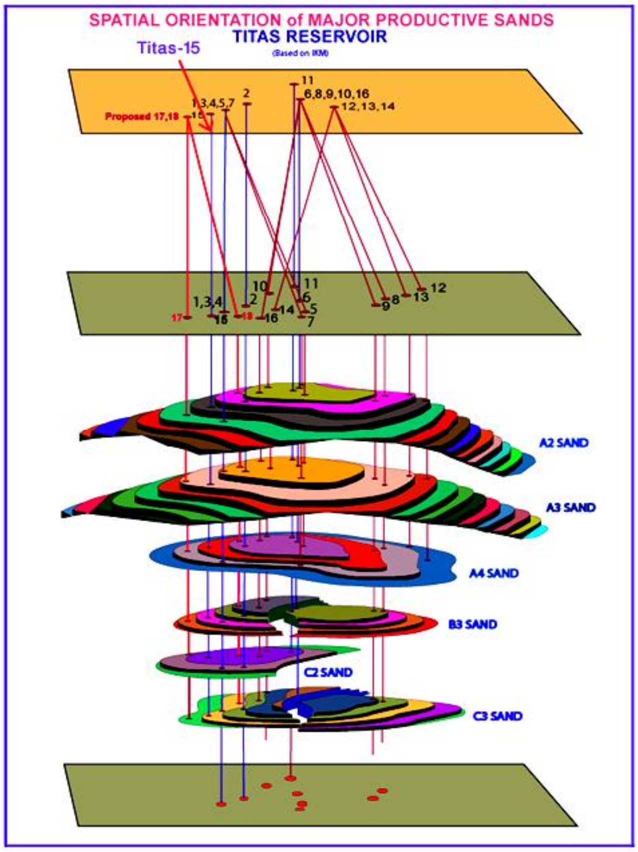

Fig. 2. Wells & major gas zones in Titas gas field [6].

II. Data and Methods

The petrographic study of core samples was carried out to delineate the causes of their high gamma ray values. For this purpose, visual examination of the core samples was made in conjunction with gamma ray logs. Core samples were selected to determine the composition of high gamma ray sands. Laboratory techniques used to analyze the core samples included thin sections study, electric microscopy, mineral counting or point counting etc.

In this research work, mainly wireline logs data were used which were obtained from Bangladesh Gas Fields Company Limited (BGFCL). The core samples were obtained from Bangladesh Petroleum Exploration & Production Company Limited (BAPEX).

III. Gamma Ray Log of Titas-15 Well

The gamma ray values of shales recorded from down hole logs of Titas-15 well generally range from 90 to 125 API units and locally reach 140 API units. On the other hand, the gamma ray values of the sandstones range from 60 to 90 API units which are more than the average sandstone gamma ray level. The sandstones of Titas-15 may thus be considered moderately high gamma ray sand. Considering the fact that the sandstones are clean, the reason of the high gamma ray for these sands is mineralogical. Here focus has been concentrated on the main gas bearing sands of Titas-15 well. The main gas bearing sands of Titas-15 well are A_2, A_3 and A_4 sands [6].

A_2 sand starts at 2730 m and reaches up to 2740 m (Fig. 3.), which is clearly recognized from its gamma ray and resistivity log values. The gamma ray log value of A_2 sand ranges from 82 to 92 API units and locally reaches that of shale (Table 1). Thin section petrographic study has shown these sands to be clean and matrix poor. The high gamma ray level of A_2 sand may be because of its subarkosic nature or heavy minerals. The increased resistivity log values also help to locate the A_2 sand. Gamma ray log in combination with resistivity log clearly indicates A_2 sand.

A_3 sand starts at 2750 m and continues up to 2789.5 m (Fig. 3.), which is clearly detected by its gamma ray and resistivity log values. The gamma ray log value of A_3 sand ranges from 72 to 88 API units (Table 2).

The depth of A_4 sand ranges from 2800m to 2826m (Fig. 3.). Shale intercalations occur within this sand bed from depth 2825.5 m to 2831 m. The gamma ray log values of sand range from 65 to 92 API units. Interbedded shale of this sand shows gamma ray values of 90 to 140 API units (Table 3).

Table. 1. Gamma ray and Resistivity log values of A_2 sand

Depth in meter	Gamma ray log value in API unit	Resistivity log value in ohm-meter
2730	100	15
2732	85	17
2734	90	14
2735	82	14
2737	90	16
2740	92	13

Table. 2. Gamma ray and Resistivity log values of A_3 sand

Depth in meter	Gamma ray log value in API unit	Resistivity log value in ohm-meter
2750	88	18
2755	77	23
2760	80	20
2765	87	17
2770	80	20
2775	73	20
2780	80	20
2785	78	19
2789	72	23

Table. 3. Gamma ray and Resistivity log values of A_4 sand.

Depth in meter	Gamma ray log value in API unit	Resistivity log value in ohm-meter
2800	90	12
2805	76	9
2810	80	11
2815	108	7
2820	74	9.5
2825	74	10
2830	60	5

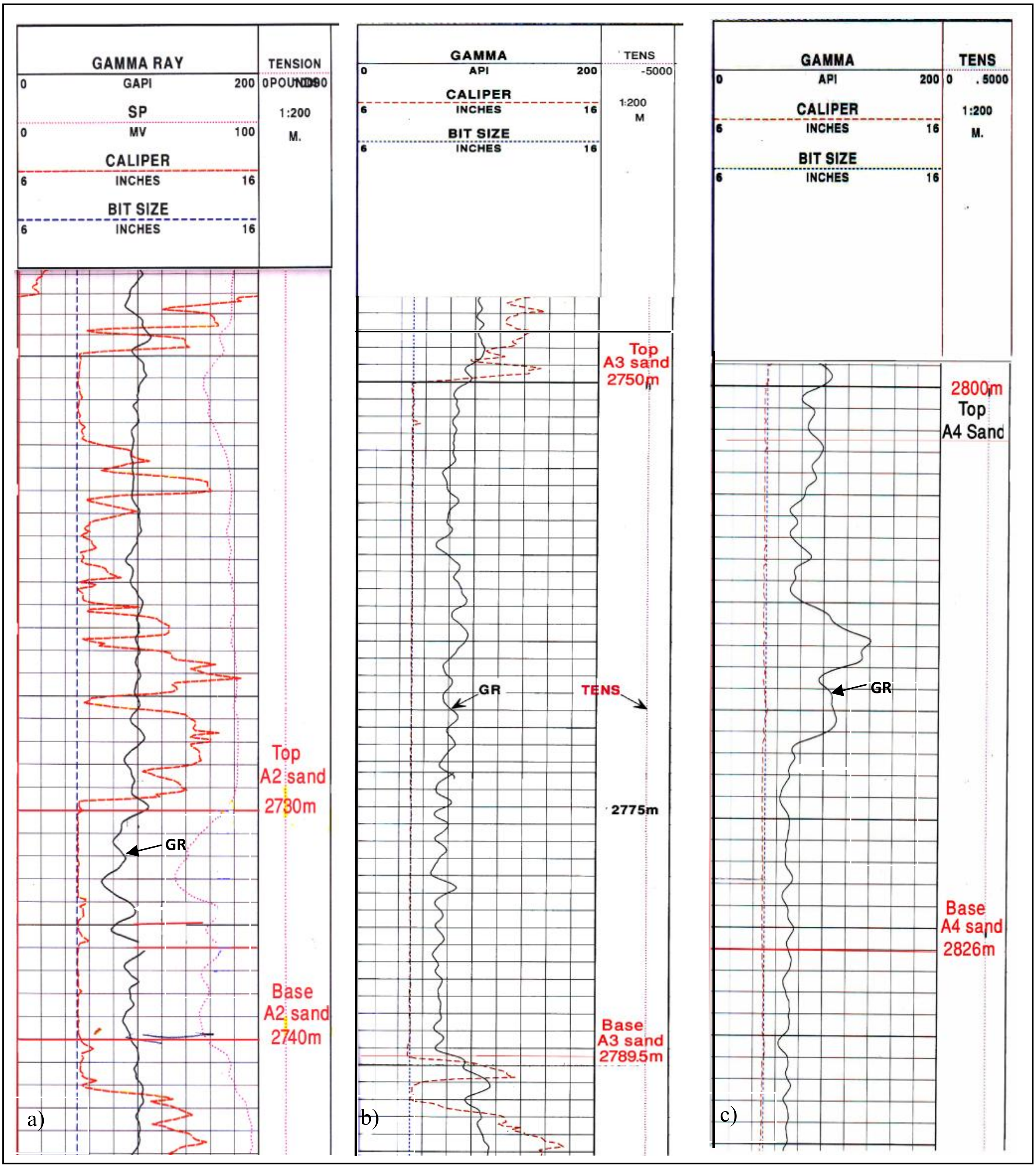

Fig. 3. Gamma ray log of a) A_2 sand, b) A_3 sand and c) A_4 sand of Titas-15 well [5].

IV. Mineralogy of Sand of Titas-15 Well

Mineralogical composition of the sands showing high gamma ray log values was determined by petrographic microscopy in order to see any relationship between the mineralogy and gamma ray log values. Visual examinations were also made of the cores in conjunction with gamma ray logs. Cores are selected for detailed studies on the basis of their high gamma ray levels. Four samples were examined in thin section to determine the quantitative mineralogical compositions (modal analyses by point counting), with emphasis on mica, potassium feldspar and heavy minerals.

Microscopic study reveals that sandstones are fine to very fine grained, very well to well sorted, generally clean and texturally mature, with subangular to subrounded grains (Fig. 4). The sandstones are mainly composed of quartz, feldspar, mica, lithic grain, organic matter and heavy minerals (Table 4). The sandstones are feldspathic with average quartz: feldspar: lithics ratio of 61:17:8 (Fig. 5). The sandstones are, therefore, subarkose type. The feldspars are mostly potassium feldspars. The lithic grains include shale, siltstone and chert.

The sandstones of Titas-15 well are micaceous sandstone. The average mica content is 13%. Muscovite and biotite are the common minerals of mica group. The heavy minerals constitute about 1% of the total rock components. Zircon, rutile, apatite, corundum, monazite, garnet and hornblende are the main heavy mineral species of these sandstones. Among these, zircon, rutile and apatite are the most common non-opaque heavy minerals with some monazite. The studied sandstones are cemented by calcite cement and quartz overgrowth.

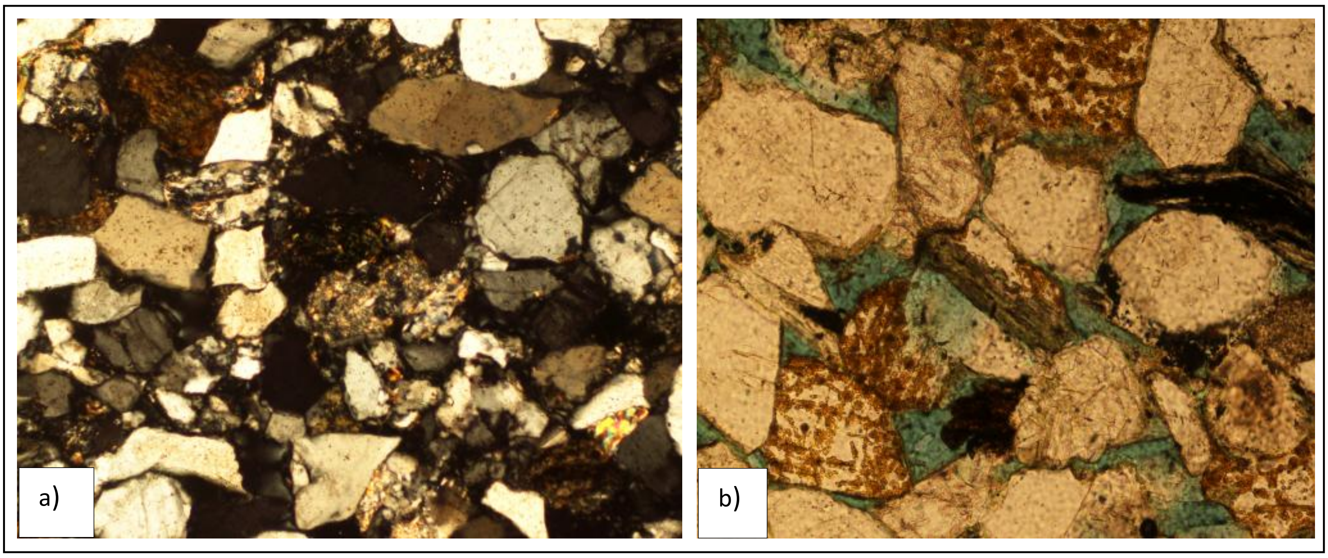

Fig. 4. Fine to medium grained sub angular to sub rounded well sorted sandstone, (a) Slide no. T-1 (depth 2735.5m) and b) Slide no. T-4 (depth 3133.5m).

Table. 4. Petrographic, log and core analysis parameters of samples from Titas-15 well.

Core depth (m)	Grain size	Grain shape	Grain sorting	Log derived gamma ray level (API)	Percentage of total rock components					
					Quartz	Feldspar		Mica	Lithic grain	Heavy mineral
						KF	PF			
2735 to 2736	Very fine to fine	Sub-angular to Sub-rounded	Well sorted	75	60	18	3	8	10	1
2775 to 2776.5	Very fine to medium	Sub-angular to Sub-rounded	Moderately sorted	72-82	61	11	1	14	8	1
2829.5 to 2831	Very fine to medium	Sub-angular to Sub-rounded	Moderately sorted	70-81	62	14	4	12	7	1
3133 to 3134	Fine	Sub-angular to Sub-rounded	Well sorted	80-90	64	10	5	13	5	1

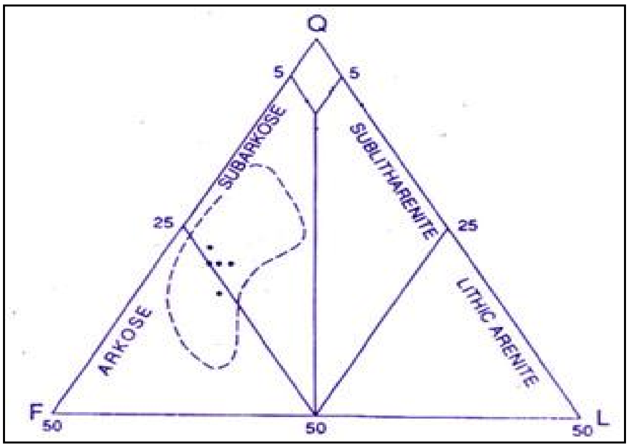

Fig. 5. QFL plot of sandstone samples from the Titas-15 well.

V. Contributors of Radioactivity

Sandstones of Titas-15 well show high gamma ray level due to presence of mica, potassium feldspar, heavy minerals and lithic grains.

Mica

Mica constitutes 8-14% of the rock samples with an average of 11.75% in these sandstone samples. The percentage of mica in these sandstones is high (Fig. 6), and mica is considered to be a major contributor to the high gamma ray intensity shown by these sandstones.

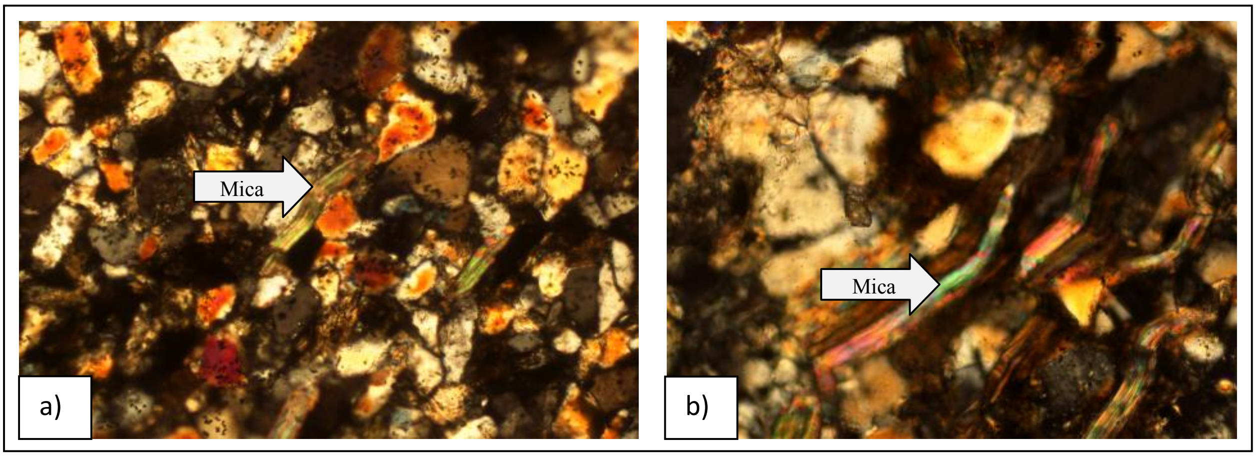

Fig. 6. Oriented mica at a) T-1 slide (2735.5m) and at b) T-3 slide (2830m).

Potassium feldspar

Point counting of thin section reveals potassium feldspar contents of 10-18% in the sandstone of Titas-15 well with an average of 13.25% of the rock components (Fig. 7). The radioactivity of potassium feldspar is the highest among the common rock forming minerals due to K^{40} radioactive isotope. (Radioactivity of quartz is 0, orthoclase 200, muscovite 140, Biotite 85, albite 0 and calcite 0 API units) [3].

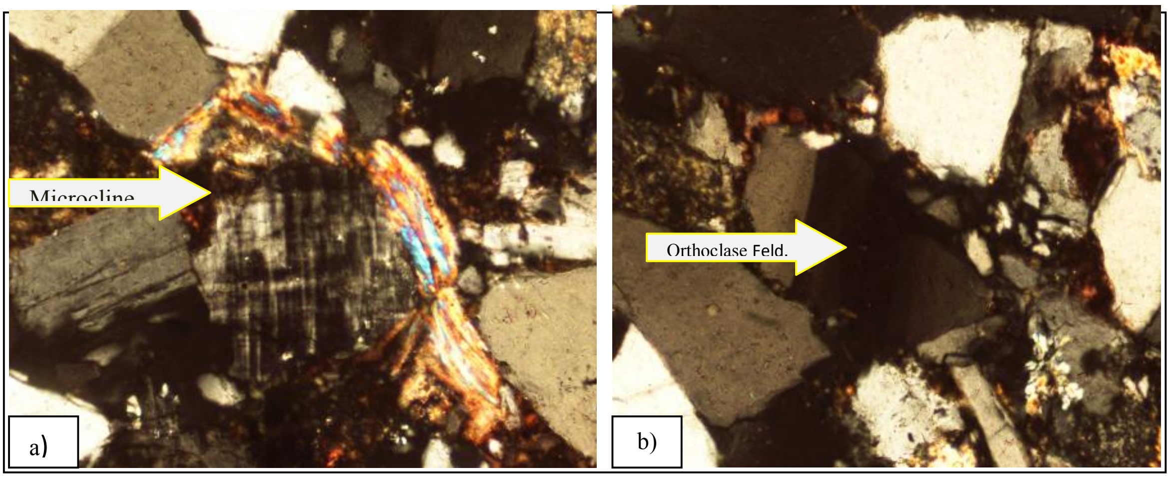

Fig. 7. Microcline Feldspar at a) Slide no.T-2 (2776m) and b) Slide no.T-4 (3133.5m).

Heavy minerals

Heavy minerals constitute about 1% of the total rock components of Titas-15 well's samples (Fig. 8). Their relative abundance varies with grain size, being more common in finer grained sandstones. Most of the heavy mineral grains are silt to fine sand size. In few samples the heavy minerals are observed to be concentrated in distinct laminae. The identification of heavy minerals is based on optical microscopy.

Zircon occurs in rounded, elongated, euhedral and tetragonal shapes (Fig. 9). Rutile varies from rounded to euhedral in shape. Apatite and corundum occurs as hexagonal prismatic grains. Monazite is present in all the samples and occurs as rounded grains.

The abundance of radioactive zircon with some highly radioactive monazite in all the samples probably contributed to the general high gamma ray levels in Titas-15 well sandstones.

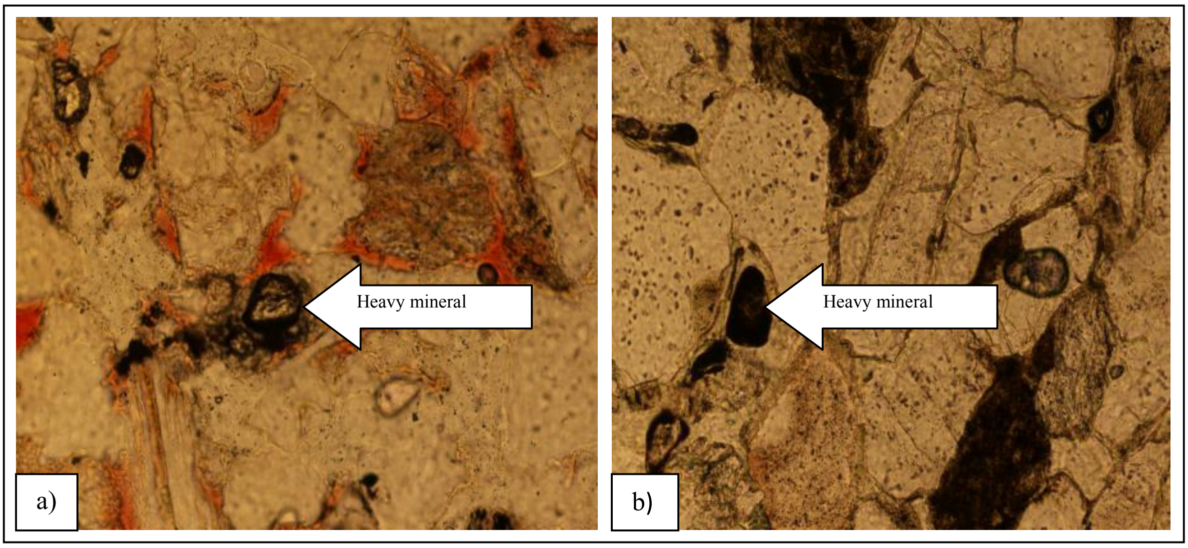

Fig. 8. Heavy mineral band in the fine grained porous, subarkosic sandstone at a) Slide no.T-2 (2776m) and b) Slide no. T-4 (3133.5m).

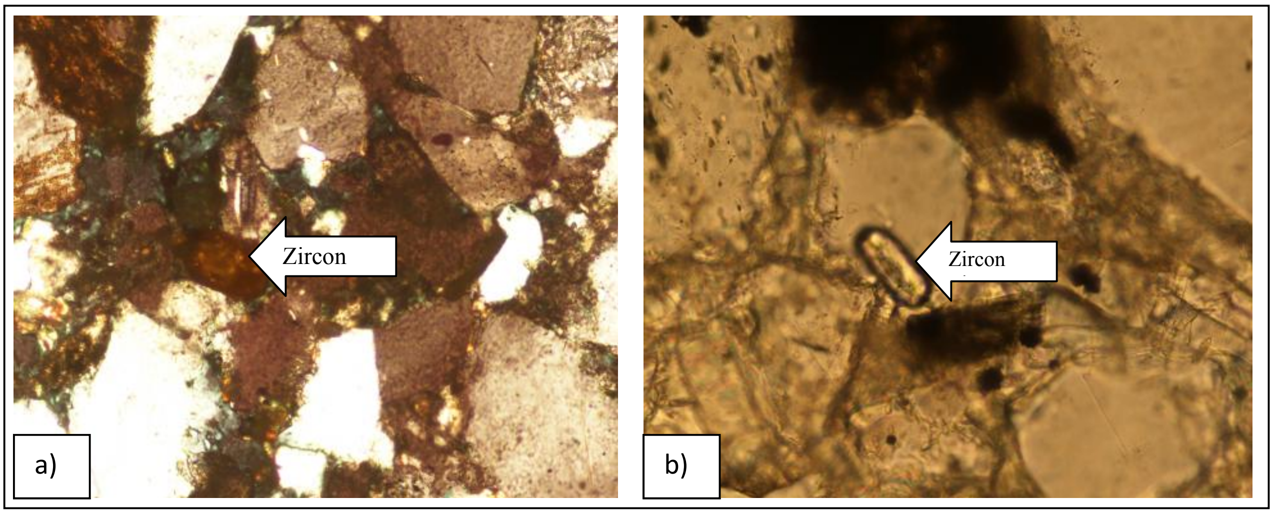

Fig. 9. Zircon crystal at a) Slide no.T-3 (2830m) and b) Slide no.T-4 (3133.5m).

Lithic grain

Lithic grains range from 5 to 10%, with an average of 7.5% of the rock components and include a wide variety of rock types including shale, siltstone and chart (Fig. 10). No specific study of the grains has been attempted due to the difficulty of separating such grains.

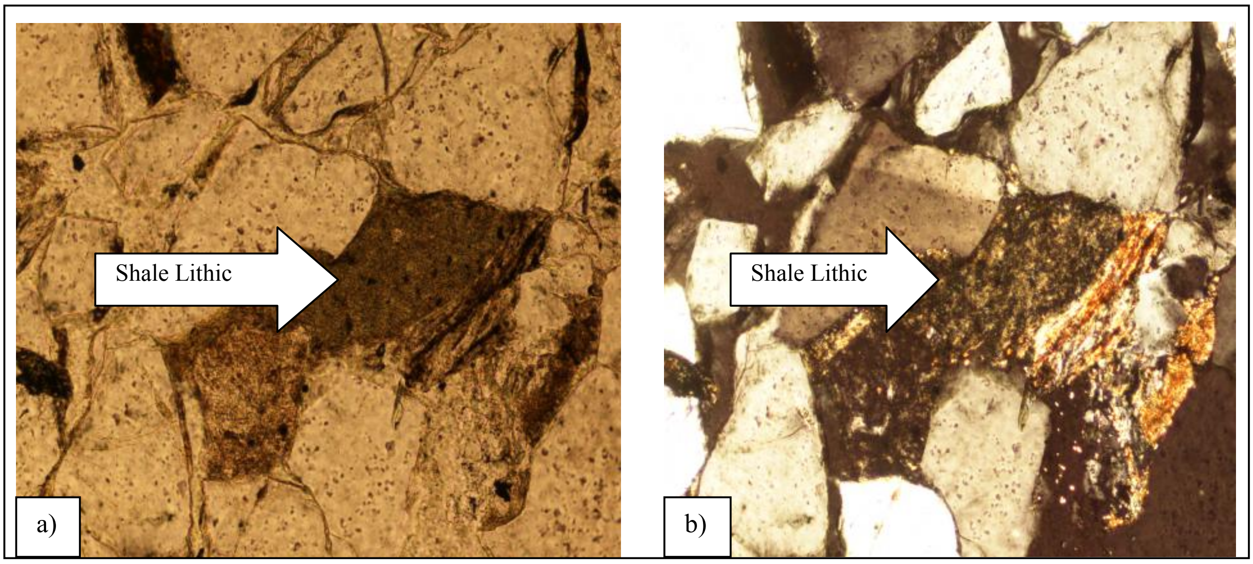

Fig. 10. Shale lithic at a) Slide no. T-3 (2830m) under plane polarized light (×20) and b) under crossed polarized light (×20).

VI. Conclusion

The present study indicates that high gamma ray levels of 70 to 90 API units in the sandstone reservoirs of Titas-15 well are principally caused by a high concentration of mica, potassium feldspar and presence of heavy minerals. These sandstones are clean and matrix content is too low. Therefore, contribution of clay towards gamma ray is minimum. This is a case similar to many of the high gamma ray sands described in the literature where gamma ray contribution is principally because of radioactive detrital minerals. The importance of the above conclusions lie in the fact that gamma ray log values of Titas 15 well sand reservoirs may be misinterpreted by petroleum producers in the sense that clean good quality sand may be overlooked as dirty argillaceous poor quality sand reservoirs.

The present study has limitations because of lack of sufficient core samples. The number of cores studied compared to the net pay is low because of the non availability of core or permission to access the cores. However, considering the implication of such study in the economics of the gas production, it looks very important that a comprehensive study should be undertaken for the whole pay sand zone in Titas-15 to identify the high gamma ray sandstones and its relation to the sand mineralogy.

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