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Heavy Mineral Studies Of The Subsurface Tipam Sandstone Formation In Parts Of Upper Assam Basin

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ABSTRACT

The subsurface Tipam Sandstone Formation of Upper Assam basin is characterized by various types of heavy mineral suites. The low value of zircon, tourmaline and rutile indicates that the sediments are mineralogically immature. The low maturity index and presence of unstable heavy minerals reveals a short distance of transportation, rapid and deep erosion following intense deformation in the source area and quick deposition of the sediments in the basin. The deposition took place in fluvial environment influenced by unidirectional current.

Keywords :Heavy mineral, Tipam Sandstone, subsurface, Upper Assam,Basin

Introduction:

The Tipam Sandstone Formation constitutes a significant percentage of the known hydrocarbon reserves of Assam Geological Province. During Late Miocene period the Tipam Sandstone was deposited in a fluvial deltaic environment. Due to the wide aerial extent and depositional & diagenetic complexities, the reservoir characterization of these sands is a major challenge. The heavy mineral analysis is immensely useful in provenance study of clastic sandstones. In interpreting source rock, the heavy minerals are grouped into genetic suits such as reworked sedimentary, low and high grade metamorphic and authigenic suits (Carver,1971). Heavy minerals are the minor constituents in terrigeneous sediments and characterized by specific gravity higher than bromoform (1.89).

Objective & Methodology:

The main objective of present study is to make a quantitative estimation of the heavy minerals of the oil bearing Tipam Sandstones in parts of Upper Assam Basin to establish its source areas along with the transportation and depositional history. Drill core samples are collected from Oil India Limited, Duliajan with due permission from its management and the heavy minerals are studied under petrological microscope within the magnification limit between 100x and 200x. The distribution of heavy minerals in the present study is shown in Table -1 and shown in Figures 1,2 &3.

Results & Discussion:

Zircons are mostly colourless, however, the pinkish to yellowish brown varieties are also reported. Grains are mainly euhedral to subhedral. Prismatic grains with well developed crystalline faces are also recorded. Well rounded grains are rare in occurrence. The grains are easily identifiable because of their high relief and high order of interference colour. Thinner fragments exhibit bright yellow, orange, green and red tints. The minerals show parallel extinction and most of the grains show well defined zoning. Generally the grain contains inclusions of rod shaped and glass bubbles. The proportion varies between 10-1.5 %. The tourmaline grains are prismatic, elongated, spherical, euhedral to irregular in shapes, with terminations at one or both ends of prismatic variety. Striations and partings are common. Inclusions and overgrowths are frequently seen. Colours vary from pale to dark green, pale yellowish brownish and sometimes colourless. Zoning is frequent, pleochroism is sharp and distinctive. The proportion varies from 5.7 to 1.5 % . Rutile grains are sub rounded to slender, prismatic grains with well developed terminations or breakage. Grains are mostly dark red, brownish red to yellowish brown in colours and show distinct pleochroism. The proportion varies from 0 to 20 %. Garnets are easily identifiable because of their high relief and isotropic nature is euhedral, rounded, sub rounded or irregular grains with uneven or conchoidal fractures. Colours vary from pinkish brown, pale red, pale pink to colourless. Inclusions are occasionally present. The proportion varies between 12 to 35.4%. Kyanite grains are angular, bladed or prismatic, dominantly colourless, weakly pleochroic and exhibit characteristic cross-fractures and step-like features. Interference colours range from first order grey to yellow and second order orange, purple and blue. The proportion varies between 0.6 and 4.6%. Epidote grains are greenish yellow to dark green in colour, sub-angular to sub rounded. Pleochroism is observed as green to greenish yellow. The proportion varies between 1.1 to16%. The hornblende grains are of variable shapes i.e. slender, prismatic, subhedral to anhedral, showing perfect prismatic cleavages. Bluish green, brownish green and brown coloured grains are present but green variety is comparatively more than the others. Cross-fractures are present, distinctly pleochroic in shades of bluish green. The proportion varies between 0.2 to 8.4%. Staurolite grains are straw yellow in colour, sub-angular to sub rounded and fractures are seen. Some grains highly pleochroic. The proportion varies between 0.6 and 3.5%. The titanites are generally recorded as colourless to pale green. Pleochroism is weak, in the extinction position it seems to be dark blue in colour. The proportion varies between 0.4 and 2%. Sillimanites are long, slender, elongated, prismatic or irregular in shapes. Besides prismatic, the fibrous variety is also identified. Prismatic grains are colourless, whereas, fibrolites appear with a pale green to pale brown. Sillimanites show distinct cleavage, rarely pleochroic, parallel extinction, second and third orders interference colours with yellow, green and deep pink as a dominant shades; slight twinkling is noticeable on rotation. The proportion varies between 0.4 to 8.2%. Enstatites are long, prismatic, irregularly terminated fragments with perfect cleavages. It shows moderate relief, parallel extinction and first order interference colours. The proportion varies between 0.5 to 4 %. Chlorite grains are irregular; colour is variable from green to yellowish green. The minerals are pleochroic from light yellowish green to green under plane polarized light. The proportion varies between 42 & 1.4%. The opaque minerals form the dominant fraction. This group of mineral consists primarily of hematite but small amount of magnetite and ilmanite are also seen. The opaques are mostly sub rounded, but some of them are irregular in shape. The haematite are reddish brown in colour while magnetites are brown to black in colour. In some samples the opaques cannot be identified as they don't show

any distinctive property. The proportion varies between 34.9 & 10 %

Transportation history: It is observed that except the ultra stable minerals, most of the heavy minerals are angular to subangular and irregular in form. It perhaps indicates a short distance of transportation of the detritus under rapid upheaval and quicker deposition. The round and almost oval shaped zircon and tourmaline grains, through few in number, suggest to the reworking of the pre-existing sedimentary rocks or point towards more than one source. The presence of the rounded zircon and tourmaline grains favours the presence of sedimentary sources rather than long distance of transportation. This fact has also been supported by the presence of a good number broken zircon grains in the sediments. Higher proportions of euhedral zircons over the rounded grains indicate their short distance of transportation.

Depositional history: The mineral association in the depositional basin is controlled by combination effects of energy conditions of the transporting medium, mode of transportation, physical as well as chemical resistance or stability of minerals, mixing of minerals from different source and rate of sedimentation. The minerals under the effects of these factors may very in size, shape, concentration and orientation from horizon to horizon. Heavy minerals which are resistant to physical and chemical processes are able to occur as distinct association in the beds. The prolific association of zircon, tourmaline and opaque in the Tipam Sandstones witnessed a strong energy action that prevailed in the environment under which less stable species like garnet, epidote, hornblende, staurolite, kyanite, silimanite etc. eliminated from the arenaceous fractions. Less stable species indicate the lowering of energy level in transportation and deposition medium. The long axes parallel alignment of elongated hornblende and flaky minerals like mica in Tipam Sandstone sediments reflects the prevalence of unidirectional current in the medium and that the grains on attrition became fractured along their weak planes of characterization. In the finer facies of the formation the contents of silimanite, hornblende, chlorite are relatively high than in the rest.

Provenance: The heavy minerals have a long been used as indices of provenance. That certain species are characteristics of certain source rocks is well known. Sedimentary petrologists have defined certain detrital heavy mineral associations each indicative of a major class of source rock. In present study, the heavy mineral assemblages indicate different source for their derivation. Detrital chlorite, garnet, epidote, silimanite, kyanite and hornblende indicate complex low to high grade metamorphic sources. Presence of staurolite suggests crystalline schist as probable source rocks. Abundant pink and colourless garnets along with reddish brown rutile also suggest metamorphic source for the sediments. Presence of higher proportion of opaque minerals indicates an igneous source. Although zircon and tourmaline of the present sandstone show much affinity towards metamorphic source, yet their igneous derivation cannot be ruled out. Prismatic, angular and long slender zircon grains as well as angular greenish tourmaline grains favour their derivation from igneous source. Colourless and purple zircon grains indicate their derivation from metamorphic sources; whereas brown and zoned zircon grains indicate their derivation from igneous sources. Presence of both opaque and non- opaque inclusions in zircon grains also indicate their derivation from igneous and metamorphic sources; and grain without these inclusion indicate their derivation from pegmatites. Euhedral and slender zircon grains represents their derivation from igneous and metamorphic rocks and also indicates their short distance of transportation. Prismatic, euhedral, colourless, green and pink colour tourmaline with inclusions indicate their derivation from granite and metamorphic terrain, while, inclusion free grains suggest a pegmatite injected metamorphic terrain. In our present study , the tourmaline grains are prismatic, euhedral and green to pink coloured and both with and without inclusions are recorded. The rounded and broken tourmaline grains are supposed to be the product of abraded detritus mixed type.

Conclusion:

From the study it is concluded that the detritus of the Tipam Sandstone Formation were derived from varied source. Presence of kyanite, staurolite, sillimanite, tourmaline and epidote indicates the derivation of the sandstones from high rank metamorphic source. Rounded zircon grains indicate their derivation from reworked sedimentary sources. The low value of zircon, tourmaline and rutile indicates that the sediments are mineralogically immature. The low maturity index and presence of unstable heavy minerals indicate short transportation, rapid and deep erosion following intense deformation in the source area and quick deposition of the sediments of the Tipam Sandstone Formation and the deposition took place in fluvial environment

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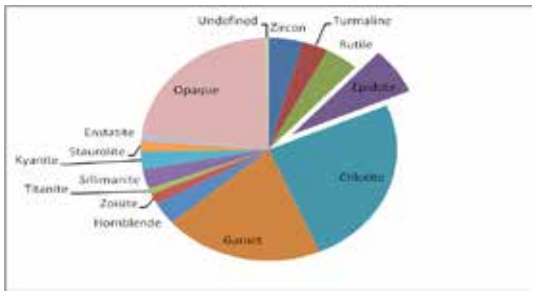

Figure 1: Pie Diagram showing Heavy Mineral Distribution in Tipam Sandstone Formation

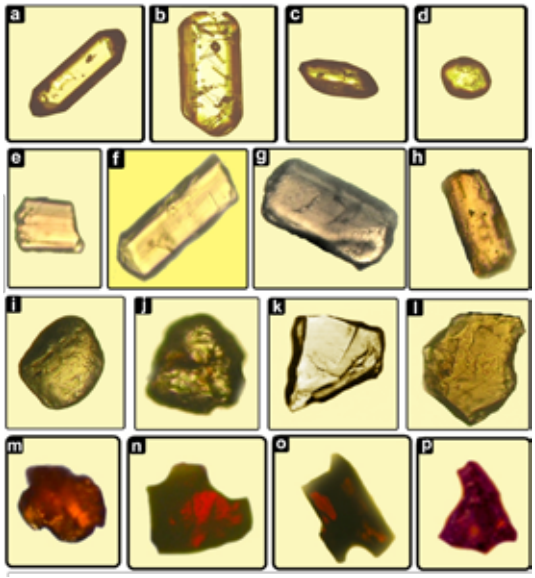

Figure 2: Photomicrograph showing heavy minerals (100x); (a-d) typical zircon grains showing variable shapes from prismatic to rounded along with inclusion; (e-h) tourmaline grains of various sizes; (i-l) rounded to angular grains of garnet minerals, and (m-p) typical rutile grains that are observed under microscope from certain samples of the present study.

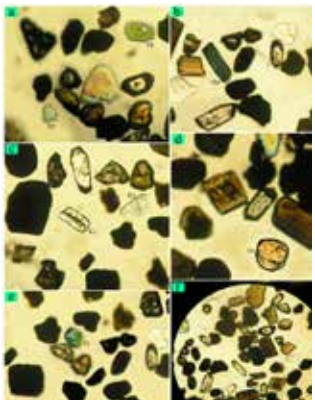

Figure 3: Photomicrograph showing heavy minerals (100x); (a) Epidote (Ep), (b) Hypersthene (Hpt),

(c) Kyanite (Ky), (d) Staurolite (Str), (e) Titanite (Ti) along with Opaque minerals (dark grains), (f) Assemblages of different heavy minerals.

Table 1: Volumetric distribution of the heavy minerals in the Tipam Sandstone Formation in the study area expressed in percentage

SampleNo.	Zircon		Turmaline		Rutile		Epidote		Chlorite		Garnet		Hornblende		Zoisite		Titanite		Sillimanite		Kyanite		Staurolite		Enstatite		Opaque		Undefined	
	%	Fr	%	Fr	%	Fr	%	Fr	%	Fr	%	Fr	%	Fr	%	Fr	%	Fr	%	Fr	%	Fr	%	Fr	%	Fr	%	Fr	%	Fr
1	1.6	2	3	3	0	1	8.8	5	42	7	12	5	7.2	5	1.4	2	1.8	2	0.4	1	1.6	2	1.8	2	-	-	18.4	6	-	-
2	1.5	2	2	2	2	2	7	5	35.8	7	14	6-	8.2	5	1.5	2	1.5	2	1	1	1.5	2	2	3	2	3	18	6	2	3
3	2	3	1.8	2	1.5	2	8	5	40	7	13	6-	6.6	5	2	3	1.3	2	1.2	2	1	1	1	1	1	1	19.6	6		
4	3.2	4	3	4	2	3	11	5	10	5	18	6	2.5	3	4.5	4	1.5	2	6.5	5	3.3	4	2.1	3	1	1	31.4	7¯		
5	1.4	2	2	3	3	3	8.8	5	15	6	21	6	2.6	3	4.2	4	1.8	2	8.2	5	3.4	3	1	1	-	-	21.6	6	6	4
6	4.1	4	3	3	2	2	10	5	12	5	20	6	2.3	3	3.7	4	1.6	2	5	4	2.8	3	2.3	3	1.2	2	30	7¯		
7	5.2	4	4	4	3	3	13	5	4.8	4	19	6	1.6	2	4.4	4	2	2	3.8	3	4.2	4	3	3	-	-	32	7-	-	-
8	1.2	2	2	3	1	1	9.2	5	37	7	15	6-	7.6	5	1	1	0.8	1	3.2	3	1	1	1.6	2	4	4	14.4	6-	1	1
9	1.5	2	2	2	0.8	1	10	5	33.6	7-	13	5	4.3	4	1.1	2	1.1	2	2.7	3	0.7	1	1.2	2	3	3	25	6		
10	1.4	2	3	3	1	1	12	5	34	7-	12	5	5.4	4	2.6	3	0.8	1	1.4	2	1.2	2	1.2	2	-	-	24	6+	-	-
11	1.7	2	1.5	2	1.2	2	10	5	33.2	7-	13	5	4.4	4	2.2	3	1	1	1.2	2	1	1	1.1	2	2	2	26.5	6+		
12	3.2	3	2	3	2	2	11	5	20	6	22	6	5.6	4	0.8	1	2	2	5.2	4	2.2	2	2.8	3	1.4	2	14.8	6-	5	4
13	4.6	4	1.5	2	2	2	12	5	19.5	6	23	6+	4.5	4	1	1	1.2	2	4.5	4	2.5	3	2.5	3	1.2	2	20	6	-	-
14	9.8	5	5	4	1	2	11	5	1.4	2	35	7-	0.2	1	0.6	1	0.6	1	2.2	2	6	4	0.2	1	-	-	27	6+	-	-
15	5.5	4	3.5	4	8.5	5	14	6-	16	6-	20	6	2.5	3	1	1	1	1	1.4	2	3.3	4	2	2	1.3	2	20	6	-	-
16	4.4	4	2	3	20	6	16	6-	21	6	12	5	6.8	4	-	-	0.8	1	2.6	3	2	2	1.2	2	1.2	2	10	5	-	-
17	5	4	4	4	12	5	13	5	16	6-	19	6	4.2	4	0.8	1	0.5	1	1.3	2	2.2	3	1.1	2	0.9	1	20	6	-	-
18	3.2	4	2.5	3	2.7	3	10	5	26	6+	18.9	6	3.1	4	1.7	2	1	1	4.2	4	2.2	3	1.1	2	0.8	1	22.6	6+	-	-
19	2.3	3	4.3	4	5.1	4	5	4	27	6+	20	6	3	3	-	-	-	-	3.4	4	4.2	4	3.5	4	0.9	1	21.3	6	-	-
20	6.5	5	3.2	4	3.1	4	7	5	20	6	28.5	7-	2	2	-	-	-	-	3.4	4	2.6	3	2.1	3	-	-	21.6	6	-	-
21	3.5	4	2	2	8.6	5	2	3	30	7-	20	6	1.4	2	1	1	-	-	4.4	4	2	2	1	1	-	-	24.1	6+	-	-
22	4.1	4	3.8	4	6.5	5	3	3	23	6+	29	7-	2.2	3	-	-	2	2	-	-	3.4	4	3	3	1	1	19	6	-	-
23	3.6	4	2.5	3	13	5	-	-	20	6	30.2	7-	3	3	2	2	1	1	3	3	-	-	-	-	-	-	21.7	6	-	-
24	10	5	5	4	5	4	2	3	28	7-	23	6+	2.5	3	0.5	1	-	-	2.3	3	1.1	2	-	-	-	-	20.6	6	-	-
25	6.2	5	2.8	3	1	2	1.5	1	29.5	7-	15.6	6-	-	-	-	-	1	1	3.2	4	2.8	3	1	1	0.5	1	34.9	7	-	-
26	3.3	4	4	4	2.1	3	2.3	3	33.2	7-	15	6-	1.6	2	3.7	4	0.8	1	1.4	2	4.2	4	0.6	1	-	-	27.8	7-	-	-
27	4.5	4	4.6	4	1.5	2	1.8	2	25	6+	20	6	2.3	3	3.2	4	-	-	2.7	3	2.5	3	1	1	-	-	30.9	7-	-	-
28	3.2	4	3	3	3	3	5.5	4	33.6	7-	16.7	6-	4.3	4	0.5	1	0.8	1	3.4	4	3.1	4	2.6	3	1	1	19.3	6		--
29	5.1	4	4.3	4	2	2	5.5	4	23.5	6+	20	6	5	4	1.2	2	-	-	2.2	3	3.4	4	1.6	2	1	1	25.2	6+	-	-
30	7.3	5	3	3	2.5	3	2	3	34.6	7-	21.1	6	1.6	2	-	-	-	-	2.3	3	3.3	4	2.2	3	-	-	20.1	6	-	-
31	6.6	5	2.5	3	4.2	4	-	-	25.4	6+	35.4	7	2	2	-	-	-	-	1.7	2	3.9	4	1.5	2	0.4	1	16.4	6-	-	-
32	5.8	4	4.5	4	7	5	3.4	4	22.8	6+	15.7	6-	1.8	2	0.6	1	0.4	1	3.1	4	1.8	2	2	2	1	1	30.1	7-	-	-
33	6.7	5	4	4	5.3	4	1.8	2	24	6+	27.3	6+	1.6	2	0.7	1	0.5	1	1.6	2	4.6	4	2.2	3	0.8	1	18.9	6	-	-
34	7.3	5	5.6	4	6.7	5	1.2	2	26.2	6+	21.6	6	2.4	3	1.3	2	-	-	2.1	3	0.6	1	2	2	-	-	23	6+	-	-
35	4.6	4	5.7	4	6	4	1.1	2	25.3	6+	22.0	6	2	2	2	2	1	1	2.2	3	3.5	4	1	1	0.9	1	22.7	6+	-	-
36	4.2	4	5	4	4.4	4	2	3	30	7-	22.3	6	1.6	2	3.7	4	0.4	1	3.2	4	3.4	4	1.2	2	0.6	1	18	6	-	-

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