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A Study on Geochemical Composition and Source Area Weathering of the Tipam Sandstones from a Few Oil Fields of Upper Assam Basin, India

KEYWORDS: Tipam sandstone, chemical composition, mineralogical composition, chemical alteration index.

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ABSTRACT *An attempt has been made in this paper to report on the geochemistry of the sandstones of the Tipam Sandstone Formation of Miocene age of Upper Assam Basin, India. Moreover, based on the study of the chemical composition of these sandstones, source area weathering of the same has been appraised. The study has shown that these Tipam sandstones have different elemental oxide content as SiO2 from 45.91 to 64.13%, Al2O3 from 11.96 to 14.57%, Na2O from 2.21 to 4.43%, Fe2O3(T) from 2.44 to 6.08%, K2O from 1.14 to 2.68%, MgO from 0.18 to 3.12%, TiO2 from 0.41 to 1.16%, P2O5 from 0.03 to 0.27%, MnO from 0.06 to 0.47% and CaO from 0.35 to 8.47%. The values of chemical index of alteration (CIA) indicate moderate weathering in the source area. The study has shown that the source area was dominated by rocks of tonalitic and granodioritic composition and K-metasomatism played an insignificant role.*

Introduction

The Upper Assam Basin is the north easternmost extension of the Assam Arakan Basin, situated in the north eastern part of India. The Assam Arakan Basin is a major onshore petroliferous basin with a thick sedimentary cover of about 3.5 km in the shelf part and 10 km in the geosynclinal basinal part. It is a Polycyclic Tertiary basin which covers an area of about 1,16,000 km^2. The Tipam Sandstone Formation of Miocene age is a very important formation of Upper Assam basin which has been producing hydrocarbon in a number of oil fields of this part of our country. The present study deals with the geochemistry of the Tipam sandstones occurring in the subsurface of the Upper Assam plains. The studied samples are conventional core samples from four oil wells of three different oil fields, Naharkatiya, Jorajan and Rajgarh, all under Oil India Limited operational areas of Upper Assam Basin. The wells selected for the study are NHK#332, NHK#322 from Naharkatiya, JRN#2 from Jorajan and RGH#5 from Rajgarh. A well location map of these wells has been presented in Figure 1.

Figure 1: Well location map (After OIL)

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Geology of the study area

The Upper Assam Valley is an intermontane platform basin of Tertiary sedimentation. In most of the places thick succession of the Palaeogene deposits of the shelf area directly lie over the granitic gneiss. The shelf facies sediments grade into geosynclinal facies sediments, with the dividing line between the two facies occurring in the vicinity of the Naga Thrust, which is the northwestern margin of the Belt of Schuppen. The Tipam Sandstone Formation under study stratigraphically overlies undifferentiated grit beds of the Surma Group in the northeast and the Bokabil Formation in the southwest of Upper Assam plains and underlies the Girujan Clay Formation. Tertiary succession of Upper Assam shelf sediments after Handique et al. (1989) has been presented in Table 1.

Geochemical analysis

X-ray Fluorescence (XRF) analysis of the Tipam sandstones under study has been carried out in the University Science Instrumentation Centre (USIC), Gauhati University for the determination of the major elemental oxides. The results of the chemical analysis have been presented in Table 2.

Source area weathering

In order to understand the source area weathering of the Tipam sandstones under study, chemical index of alteration (CIA) after Nesbitt and Young (1982) has been calculated which is given by the following relationship:

$$CIA= [Al_2O_3 / (Al_2O_3+CaO^*+Na_2O+K_2O)] \times 100$$

where CaO* is the amount of CaO incorporated in the silicate fraction of the rock.

Table 1: Stratigraphic succession of Upper Assam shelf sediments, after Handique et al. (1989)

Epoch	Litostratigraphic Group	Units/Formation	Thickness (in m)	Major Lithological Types
Recent	-	Alluvium[1]		
Pleistocene	Dihing	Dhekiajuli[1]	1300-2000	Unconsolidated sands with clay and lignite sands.
~~		Unconformity		~~~~~~
Pliocene Miocene	Dupitila	Namsang Beds	0-1000	Poorly consolidated sandstone with clay and lignite sand.
~~		Unconformity		~~~~~~
Miocene	Tipam	Girujan Clay	100-2300	Mottled clay with sandstone lenses.
		Tipam (Upper	300-500	Essentially arenaceous Sequence.
		Sandstone (Middle	100-200	Sand/Shale alteration Sequence.
		(Lower	100-200	Arenaceous sequence.
	?Surmas[2]	Not subdivided		Sandstone with shale and grit bed.
~~		Unconformity		~~~~~~
Oligocene	Barail	Not subdivided	500-1200	(Upper Part: Mudstone/ shale with sandstone beds and coal bands (Argillaceous sequence). (Lower Part: Sandstone with shale bands (Arenaceous sequence).
Eocene[3]	Jaintia	Kopili alternations	280-500	Splintery shales with sandstone and fine-grained sandstone with coal bands.
		Sylhet Limestone (Prang		Splintary shales with
		(Narpuh	350-450	sandstone and limestone
		(Lakadong	60-170	bands.
	Therria			Sandstone, calcareous sandstone and limestone.
~~		Unconformity		~~~~~~
Precambrian Granitic Basement				

Note:
1. It is difficult to distinguish these two rock units. From regional geologic considerations, an unconformity could however, be inferred between them.
2. Development of the Surma Group which is extensive in the type area of Surma Valley is doubtful in the Upper Assam shelf area.
3. Including Paleocene rocks

Table 3: Results of chemical analysis

Sl. No.	Sample No	SiO_2	TiO_2	Al_2O_3	Fe_2O_3 (T)	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	CIA
1	332-A	51.81	0.77	13.31	4.38	0.08	0.35	1.54	2.24	1.31	0.07	24.14	72.34
2	332-C	59.14	0.73	13.32	3.94	0.06	1.67	0.86	2.22	1.51	0.05	16.50	74.37
3	332-E	48.42	0.69	12.64	5.34	0.07	2.24	1.16	2.21	1.31	0.05	25.87	72.98
4	332-G	53.81	0.71	13.73	5.46	0.08	1.31	1.93	2.26	1.48	0.06	19.17	70.77
5	322-A	57.23	0.48	13.09	3.36	0.07	0.95	0.93	2.23	1.54	0.04	20.08	73.58
6	322-C	61.96	0.53	13.16	3.21	0.07	0.18	1.48	2.25	1.48	0.05	15.63	71.64
7	322-E	51.85	0.57	13.49	4.38	0.08	1.23	1.87	2.25	1.57	0.04	22.67	70.33
8	322-F	51.19	0.64	13.91	4.70	0.08	0.30	2.12	2.25	1.42	0.05	23.33	70.61
9	JRN-1	48.12	0.61	12.12	5.51	0.08	1.21	0.47	2.21	1.14	0.05	28.48	76.03
10	JRN-3	54.52	0.47	11.96	2.44	0.47	0.22	8.47	2.74	1.15	0.03	17.53	49.18
11	JRN-5	53.23	0.96	13.04	4.19	0.06	0.24	0.44	2.21	1.46	0.07	24.10	76.03
12	JRN-7	56.26	1.03	12.87	4.11	0.08	0.26	0.35	2.22	1.35	0.07	21.39	76.65
13	JRN-8	64.13	1.16	14.57	6.08	0.19	0.44	3.34	4.43	2.68	0.27	2.71	58.23
14	RGH-1	54.10	0.66	12.5	3.74	0.06	1.62	0.44	2.21	1.42	0.06	23.18	75.44
15	RGH-3	53.47	0.51	12.87	4.16	0.09	2.53	2.08	2.24	1.41	0.05	20.59	69.19
16	RGH-5	54.50	0.41	13.04	3.54	0.08	3.12	2.37	2.26	1.46	0.05	19.17	68.16
17	RGH-6	45.91	0.59	12.33	4.73	0.17	0.96	2.23	2.23	1.14	0.05	29.66	68.77

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As there is no appropriate means in this study to differentiate carbonate CaO from silicate CaO, correction for secondary carbonate has not been carried out in this study. Here, the total CaO is considered for the determination of CIA following previous authors Roser et al., 1996; Al-Harbi and Khan, 2008 and Sen et al.; 2012. Thus the determined values are the minimum values which vary from 49.18 to 76.65%. In most of the samples, the values are below 80% indicating moderate weathering in the source area.

An approach to assess the composition of the original source rock is to plot the triangular plot A(Al_2O_3)-CN(CaO+Na_2O)-K(K_2O) after Nesbitt and Young, 1984. Such a plot is useful for identifying compositional changes of mudstones and sandstones that are related to chemical weathering, transport, diagenesis, metamorphism and source rock composition (Fedo et al., 1995; 1997). Trends in the A–CN–K compositional area can also be used to infer the average composition of the source by projection backward from data distributions along ideal weathering lines (IWL). The A-CN-K plot for the Tipam sandstones under study is shown in Figure 2.

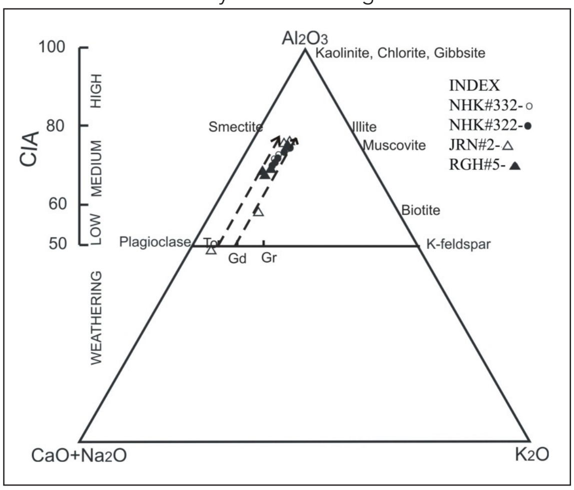

Figure 2: A-CN-K plot (after Nesbitt and Young, 1984). Dotted lines represent IWL.

It is apparent from this figure that the IWL is parallel to the A–CN join. The sandstones under study fall along the tonalite as well as granodiorite trend indicating source areas dominated by rocks of tonalitic and granodioritic composition. None of the samples fall parallel to the A-K join or close to the illite-muscovite area, which infers that K-metasomatism played an insignificant role in the study area.

Relationship between mineralogical and chemical composition

An attempt has been made in this study to understand the sources of the major elemental oxides present in these Tipam sandstones. For this purpose, results of petrography (Sarma et al., 2011; Sarma and Chutia, 2013) and heavy mineral study have been correlated with the results of geochemical analysis. The sources of SiO_2 in the studied Tipam sandstones are mainly quartz, feldspars and clay minerals, the abundances of which are apparent from the petrgraphic study. According to Pettijohn et al., 1973, abundant Al is in general related to the abundance of feldspars, micas and clays. Average percentage of mica is the lowest in the Tipam sandstones of the RGH#5 well (4.38%); they also have the lowest average percentage of Al_2O_3 (12.68%), which indicate that there is a positive relationship between percentages of mica and Al_2O_3. Similarly, average percentage of mica is highest in the Tipam sandstones of the NHK#322 well (13.41%) and the Al_2O_3 percentage of the same sandstones is highest (average 13.41%). It infers contribution of mica to the Al_2O_3 percentage of these sandstones. The sandstones of the RGH#5 well have the lowest average percentage of cement (10.60%). They have also the lowest value in the percentage of Al_2O_3 (12.68%). In these sandstones, argillaceous type of cement occurs in the highest amount. Thus the values of average percentages of Al_2O_3 and cement infer that argillaceous cement have contributed to the percentage of Al_2O_3 of the Tipam sandstones under study. The source of TiO_2 may be related to the presence of opaque minerals and rutile. From the study of the heavy minerals of these Tipam sandstones, we have observed that they have high percentages of opaque mineral. Among the four wells, the Tipam sandstones of the JRN#2 well contain the highest percentage of rutile (average 3.39%). The geochemical compositions have shown that the sandstones of this well have the highest percentage of average TiO_2 (0.85%). Thus it may be inferred that the rutiles present in these Tipam sandstones have significantly contributed to the percentage of TiO_2. The abundance of K_2O is related to the presence of K-feldspar and mica and the same of Na_2O is related to the presence of plagioclase feldspar. Petrographic study has shown the presence of both the types of feldspars as well as the mica. Average percentage of mica is lowest in the Tipam sandstones of the RGH#5 well (4.38%). In these sandstones, the value of K_2O (1.36%) is also lowest indicating a direct relationship between mica and K_2O percentages. The presence of CaO may be related to feldspar and calcite cement. Presence of both of them is apparent from the petrogrphic study. According to Pettijohn et al. (1973), Fe is found in the clays, mainly in chlorite with lesser amount in montmorillonite and illite and also as a minor constituent of feldspars as other silicates. As the Tipam sandstones were deposited in fluvial environment, the presence of higher proportions of Fe_2O_3(T) may be due to subarial deposition.

Conclusions

Thus, following conclusions can be drawn from this study-

- There was moderate weathering in the source areas which were dominated by rocks of tonalitic and granodioritic composition.
- K-metasomatism played an insignificant role in the area.
- Mica and argillaceous cement have contributed significantly to the proportion of Al_2O_3 present in the studied Tipam sandstones.
- Mica has contributed to the proportion of K_2O also.

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