INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN: 2278 – 0211 (Online)

Petrography And Geochemistry Of Shallow Subsurface Sediments Of A Part Of The Brahmaputra Valley In Assam, India

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Abstract:
The Brahmaputra Valley comprises very thick Quaternary alluvium in Upper Assam. The alluvium had been drilled for coring up to about 50m at four sites, viz. Dhola, Dum Duma, ChotaTingrai and Naharkatiya, which are almost equally placed in a north-south direction from the river Brahmaputra towards south close to the foot of the Naga Hills. From the sediment cores of each bore hole about seven thin sections had been prepared at equal intervals by impregnating the loose sediments with binding resin in undisturbed condition for petrographic study. The petrographic study reveals that quartz grains are angular to sub rounded, elongated to equidimensional in nature and of variable in shape and size. The detrital minerals in the sediments indicate it to be lithic arenitic in composition. QFL triangular plot infers that the sediments of two wells were derived from recycled orogenic sources. Q_mFL_t triangular plot shows that the provenance of the sediments of Naharkatiya was only transitional recycled, those of Dhola was quartzose, transitional, lithic recycled and mixed, those of Dumduma and ChotaTingrai was transitional and lithic recycled, mixed and dissected arc. The plot of the recalculated percentages of undulatory, non-undulatory monocrystalline and polycrystalline quartz (> 3units) in Diamond diagram indicates that most of the sediments were derived from plutonic and metamorphic sources except in Naharkatiya sediments where the contribution from plutonic sources is not evident.
Geochemical analysis of sediments of each well was carried out from six different depths to estimate particle density, bulk density, pH, LOI, acid insolubles, Ca, Mg, Na and K. Most of these parameters show the highest values in the sediments of ChotaTingrai well.
Key words: *detrital modes, major oxides, provenance, recent sediments, Brahmaputra valley Assam*

1.Introduction

The study area represents the extreme north-eastern part of the Upper Assam valley. It is demarcated by the Brahmaputra River in the north-west and Burhi-Dihing in the south and Noa-Dihing in the east and covers about 4800 km^2 area.

The present area of investigation is covered by the Survey of India topographic sheets - 83I/11, 83I/12, 83I/14, 83/15, 83/16, 83M/2, 83M/3, 83M/5, 83M/6, 83M/7, 83M/8, 83M/9, 83M/10, 83M/12, 83M/13, 83M/14, 83M/15, 92A/2 , 92A/3 and lies between longitudes 96º11´30´´E and 94º41´23´´E and latitudes 27º48´44´´N and 27º12´49´´N (Fig. 1).

Although modern sediments have gained importance in sedimentological research, but investigations on Recent alluvial sediments in North Eastern India are still very limited. Scrutiny of the literature reveals that no elaborate sedimentological studies of the recent alluvial sediments of the Upper Assam valley have been carried out so far except a few isolated studies. Sarma (1980) had carried out sedimentological and geomorphological studies on the alluvial sediments of Burhi-Dihing river.

In this paper an attempt has been made to understand the petrographic character and geochemistry of the shallow subsurface sediments from the samples of undisturbed sediment cores of the four bore holes.

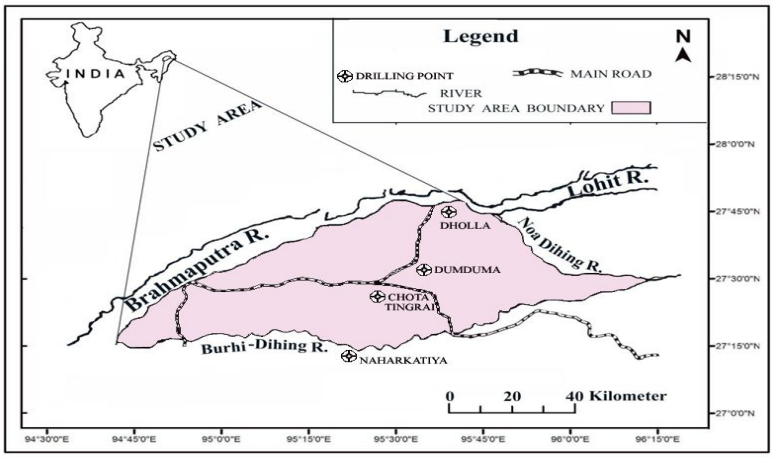

Figure 1

2.Geology Of The Area

Upper Assam valley is an alluvial plain of the river Brahmaputra and forms a part of the shelf area of the Assam-Arakan basin. Here the Precambrians are overlain by thick Tertiary

sediments. The Tertiary sediments are unconformably overlain by the Quaternary sediments. Kar et al.1997 have classified the Quaternary sediments of the basin into Older Alluvium and Newer Alluvium. In the southern part of the Upper Assam valley the recent alluvial deposits rest unconformably over the Dihing Group of Plio-Pleiosocene time. The Older Alluvium forming High Level Terraces and the Newer Alluvium superimposed over the Older Alluvium close to the foothills as fans and within narrow flood plain of the present rivers defined by their paleo banks as Low Level terraces. Mazumder *et al.*(2001) have recognised four major episodic Terraces in Quaternary Alluvial sediments of Upper Assam Valley, viz.T_5,T_2,T_1 and T_0. Disposition of these Terraces is believed to be structurally controlled and related to the major tectonic phases (subsidence and uplift). A generalized lithostratigraphic succession of the Quaternary deposits of Brahmaputra basin by Kar *et al.* (1997), is given in Table 1

<table>
<tr><th colspan="2">Age</th><th>Lithostratigraphy</th></tr>
<tr><td rowspan="4">Holocene</td><td rowspan="4">Newer Alluvium</td><td>Channel Alluvium (T_0)</td></tr>
<tr><td>Terrace Alluvium (T_1)</td></tr>
<tr><td>Terrace Alluvium (T_2)</td></tr>
<tr><td>Alluvial Fan (F_a)</td></tr>
<tr><td colspan="2">Disconformity</td><td></td></tr>
<tr><td rowspan="3">? Middle
to
Upper Pleistocene</td><td rowspan="3">Older Alluvium
Unconformity</td><td>Older Terrace Alluvium T_3)</td></tr>
<tr><td>Older Terrace Alluvium T_4)</td></tr>
<tr><td>Older Terrace Alluvium T_5)</td></tr>
<tr><td>Upper Pliocene
To
Lower Pleistocene</td><td colspan="2">Kimin (Upper Siwalik) and Dihing Formation</td></tr>
</table>

Table 1: A generalized lithostratigraphic succession of Quaternary deposits of Brahmaputra valley.

3.Method Of Study

For petrographic study, thin sections are prepared from sixteen samples from all the four wells viz., Naharkatiya, Dhola, ChotaTingrai and Dum Duma at different depths for mineral identification. Slides for petrographic study are prepared from the drill core samples. The samples are loose sediments, so the slides are made from the solidified lumps of sediments. The sediments are by using a solution (mixture of equal proportion of clear lacquer and acetone). Point counting has been done following Gazzi–Dickinson method, counting sand-sized minerals included in lithic fragments as mineral phase rather than the host lithic fragments (Ingersoll et al., 1984). At least 400 framework points has been counted per sample. For provenance study, Diamond Diagram of Basuet al. (1975) has been considered and recalculated values of the different quartz types has been plotted. Recalculated values are also plotted in the Q_m-F-Lt (Q_m = monocrystalline quartz, F = monocrystalline feldspar and Lt = total polycrystalline lithic fragment) triangular plot of Dickinson *et al.* (1983) for determining the tectonic setting of the source area.

To study the Geochemistry of shallow subsurface sediments of the four wells viz., Dhola, Dum Duma, ChotaTingrai, and Naharkatiya, 24 samples were analysed. Chemical analysis of the major oxides are carried out by the X-ray Flourescence (XRF) method. For this purpose the samples are crushed and grinded to 200µ size diameters. The powered materials is then put on a boric acid evenly and passed with the help of a Hydraulic Compression Machine with a weight of 15,000 Kg for 10-15 minutes. This pressure makes a film of solid mat of the sample over the boric acid and thus, the preparation of pellet is completed for the XRF study of the sample. The XRF study is carried out in the Sophisticated Instrumentation Centre (SIF), University Scientific and Instrumentation Centre (USIC), Gauhati University.

4.Results And Dicussion

4.1.Petrographic Study

Petrography of the recent sediments of Noa Dihing and Burhi Dihing river has been done from the thin sections prepared from conventional core samples. The minerals constituting these sediments are as follows:

- Quartz: Quartz is the dominant mineral constituent in all the sediments. The grains are elongate to equidimensional. Both two dimensional and three dimensional subrounded to rounded grains are present. Various types of quartz grains e.g. monocrystalline and polycrystalline variety are present. The percentage of monocrystallineundulose variety of quartz varies from 0.00 to 22.22 in case of Naharkatiya Dhola, ChotaTingrai, Dum Duma samples. The percentage of non undulose monocrystalline variety varies from 8.27 to 23.95, 10.39 to 32.35, 10.30 to 34.42 and 4.21 to 22.33 for the sediments viz., Naharkatiya, Dhola, ChotaTingrai and Dum Duma respectively. The percentage of 2-3 crystals per unit grain type varies from 0.00 to 25.43 for the sediments of the four wells. And the percentage of >3 crystal units per grain type varies from 11.17 to 22.46, 3.33 to 14.76, 7.77 to 28.55, 7.65 to 21.30 for Naharkatiya, Dhola, ChotaTingrai and DumDuma respectively. Of the polycrystalline quartz with '>3 crystal units per grain type', different types such as stretched metamorphic quartz, schistose quartz, and polygonized quartz are present. In case of Naharkatiya sediments lots of chert grains are present.
- Fedspar: Feldspar grains are subrounded as well as subangular. Both plagioclase and K-feldspar are present. The total percentage of feldspar varies from 0.00 to 18.61 for the sediments. Some of the weathered plagioclase grains show bending and displacement of twin lamellae within the broken grains, which may be due to the effect of tectonism.
- Mica: Both muscovite and biotite are present. The total percentage of mica varies from 0.00 to 19.78 for the sediments of the fourwells. Both elongate and tabular flakes are present. Bending of the mica grains has also been observed.
- Lithic Fragments: - All types of lithic fragments, i.e. metamorphic, igneous and sedimentary are present. The total percentage varies from 28.96 to 41.91, 21.63 to 62.34, 18.20 to 49.54, 18.92 to 51.22 for the sediments of Naharkatiya, Dhola, ChotaTingrai and Dum Duma respectively. In Naharkatiya sediments, the sedimentary rock fragments dominant, in case of Dhola metamorphic variety dominates and in case of ChotaTingrai and Dumduma both metamorphic and sedimentary lithics are abundant.

- Characteristic mineral: Few grains of hornblende, augite, chlorite, garnet etc. are present. The total percentage of characteristic mineral varies from 0.00 to 10.84, 3.08 to 14.03, 0.00 to 17.52, 1.85 to 10.52 for the sediments of Naharkatiya, Dhola, ChotaTingrai and Dum Duma respectively.

Well No.	ample No.	Quartz				Total Quartz	Feldspar	Rock Fragment	Mia	Characteristic mineral
		Mono Undulose	Mono Non undulose	Poly crystalline 2 – 3	Poly crystalline >3					
NAHARKATIYA	NHK#10	11.63	17.45	3.65	22.46	55.19	5.27	28.96	3.5	7.04
	NHK#12	14.95	23.95	0.72	11.17	50.79	3.34	41.07	3.3	0.00
	NHK#14	21.87	8.27	3.31	12.87	46.32	0.00	41.91	0.9	10.84
	NHK#16	22.22	15.70	0.00	21.92	59.84	4.44	35.70	0.0	0.00
DHOLA	DHL#4	6.83	12.77	0.00	14.76	34.36	8.15	49.77	4.6	3.08
	DHL#12	2.43	10.39	0.94	7.15	20.91	2.69	62.34	0.0	14.03
	DHL#18	7.76	32.35	0.00	3.33	43.44	3.33	21.63	19.8	11.83
	DHL#22	6.56	27.31	0.00	12.02	45.89	18.61	29.86	3.3	6.69

CHOTA TINGRAI	CH.TNG#	0.00	10.30	0.00	21.32	31.62	4.41	49.27	14.0	0.00
	CH.TNG#	0.00	26.68	0.00	28.55	55.32	18.45	18.20	0.0	8.10
	CH.TNG#0	6.03	34.42	1.63	11.56	53.64	11.30	29.61	1.2	4.14
	CH.TNG#2	0.66	12.12	0.00	7.77	20.55	10.01	49.54	2.3	17.52
DUM DUMA	DMA#14	2.89	11.58	0.00	19.40	33.81	9.69	51.22	2.6	2.60
	DMA#16	9.94	4.21	25.43	7.65	47.28	11.47	18.92	11.5	10.52
	DMA#18	9.62	16.25	0.00	21.30	47.17	14.98	33.13	0.0	4.73
	DMA#20	8.82	22.33	0.00	17.07	48.22	8.53	37.84	3.5	1.85

Table 2: Result of modal analysis of the constituents of alluvium sediments

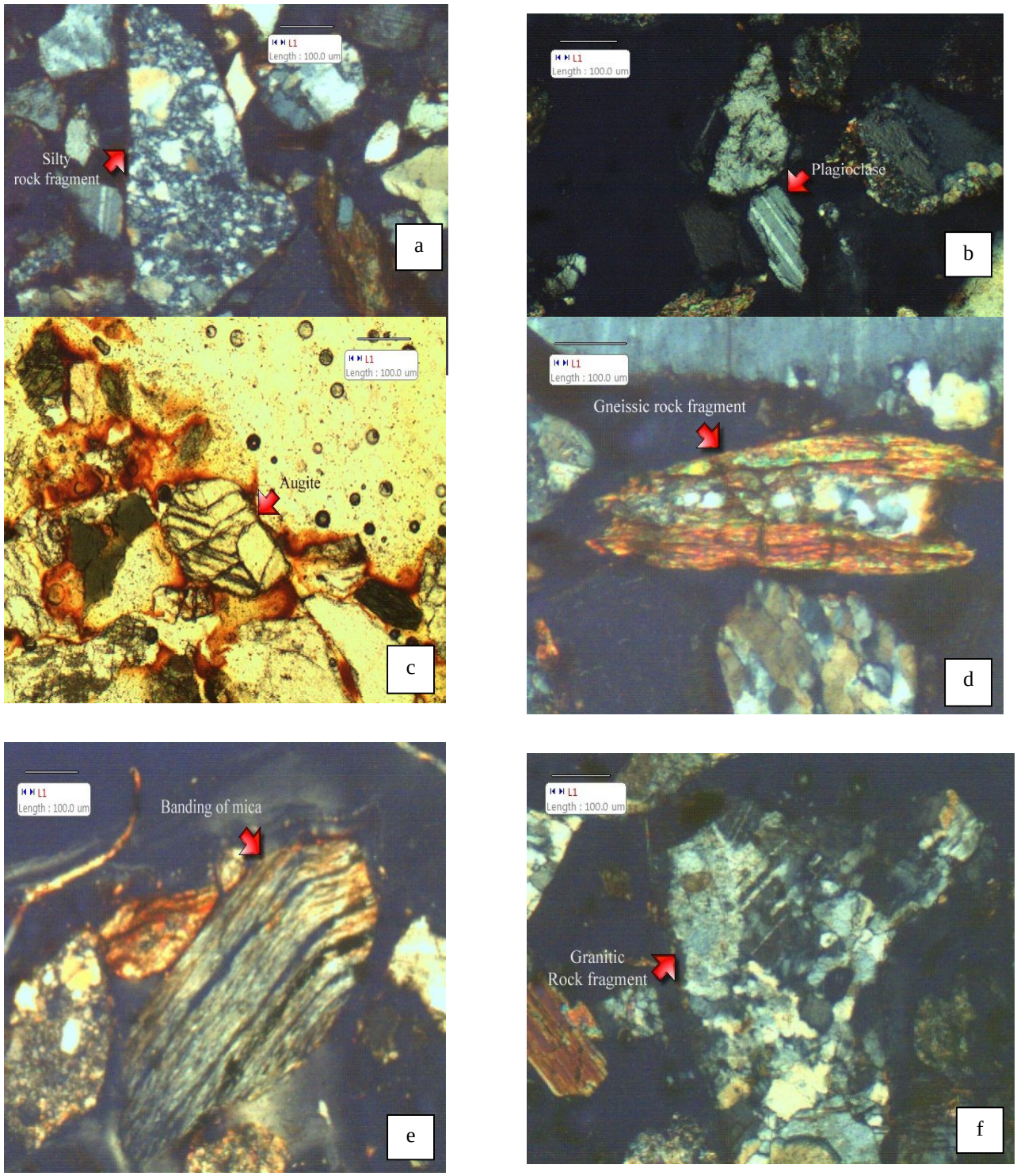

Figure 2: Representative photomicrograph of the constituents of sediments showing (a) silty rock fragments (b) plagioclase grain (c) augite in plane polarised light (d) gneissic rock fragments (e) bending of mica (f) granitic rock fragments

5.Provenance And Tectonic Setting

To study the provenance and tectonic settings of the sediments of the four wells we have considered the diamond diagram. Basu *et al.* (1975) developed a method of discriminating provenance into three types, viz. 'plutonic', 'middle and upper rank metamorphic' and 'low rank metamorphic' by plotting different quartz typesin a diamond diagram. Percentages of different quartz types of the sediments of four wells are given in Table- 3**.** In Diamond Diagram (after Basu *et al.,* 1975) indicates that the constituents of Naharkatiya sediments under study were derived from middle and upper rank metamorphic rock (Fig. 3). Like that the constituents of Dhola and ChotaTingrai sediments were mostly derived from plutonic, middle and upper rank metamorphic rock but constituents of Dum Duma sediments were derived from middle and low rank metamorphic rock.

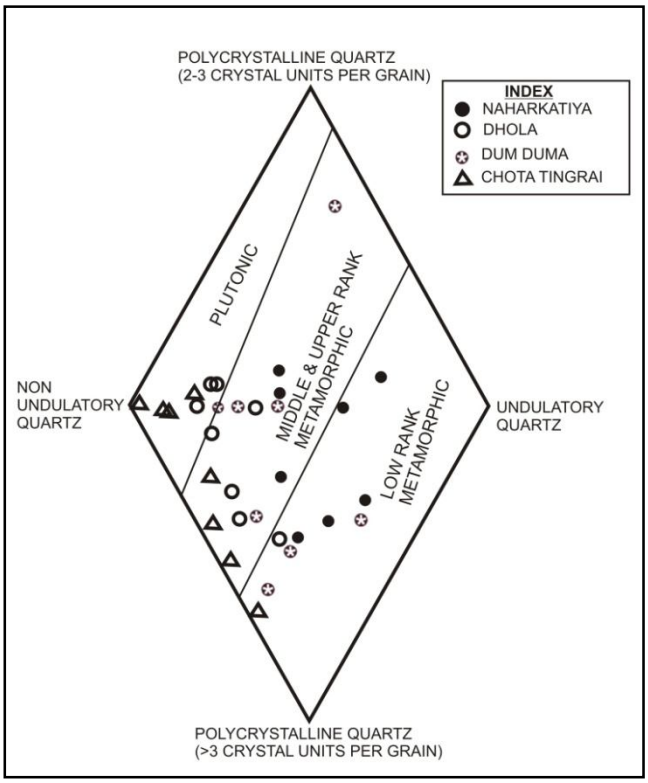

Figure 3: Diamond Diagram (showing provenance, after Basu et al.,1975)

Detrital framework mineralogy of the sediments is intiminately related to the tectonic settings of the provenance. To find out the tectonic settings recalculated framework grains were plotted in the subdivided triangular QFL and Q_mFL_t compositional diagrams of the Dickinson et. al. (1983). According to these classification sediments derived from the different kinds of provenance terrains controlled by plate tectonics, viz. 'continental blocks', 'magmatic arcs' and 'recycled orogen'.

From the QFL triangular plot, it is inferred that the sediments of the four well viz., Naharkatiya, Dhola, ChotaTingrai and Dum Duma under study were derived from recycled orogenic sources (Fig. 4).

The Q_mFL_t triangular plot (Fig. 5)shows that the Naharkatiyaseiments under study were mainly of transitional recycled origin, sediments of the Dhola were mainly of quartzose recycled, mixed and transitonal recycled origin however, sediments of ChotaTingrai and Dumduma were mainly of mixed, dissected arc and transitional recycled origin.

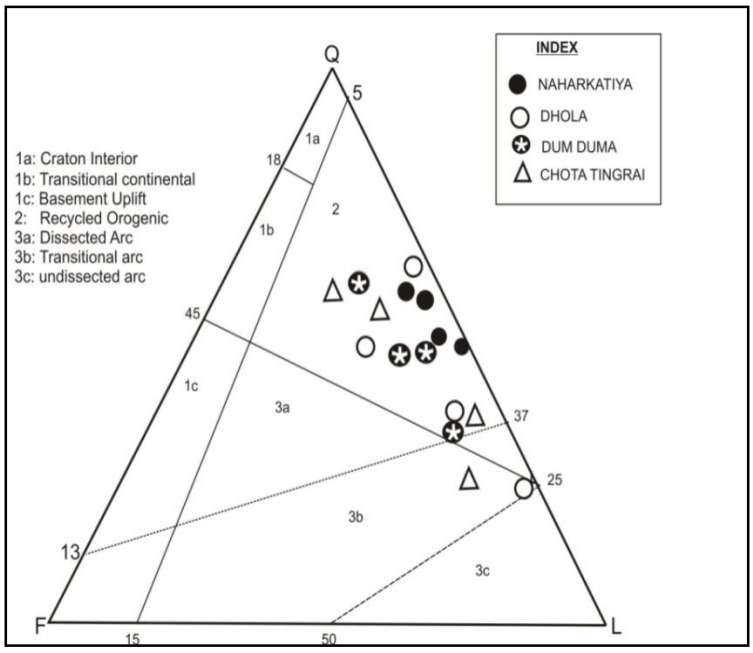

Figure 4: QFL triangular plot, after Dickinson et.al.1983

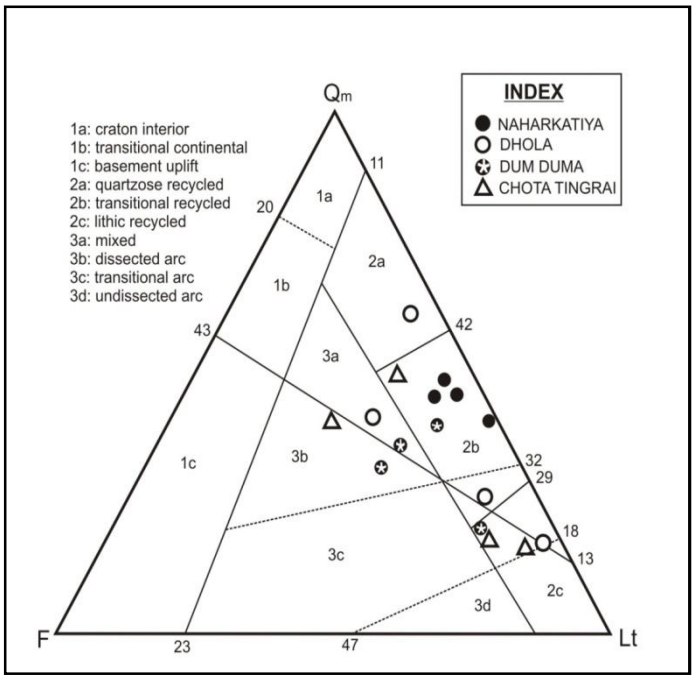

Figure 5: Q_mFL_t triangular plot after,Dickinson et.al.1983

6.Geochemical Analysis

- Major Elemental Analysis : XRF analysis of the shallow surface sediments of the four well viz., Dhola, Dum Duma, ChotaTingrai, and Naharkatiya reveals that major and minor constituents are present in them include SiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O, TiO_2, and P_2O_5 (Table- 3)

7.Chemical Composition Of The Sub-Surface Samples

7.1.Dhola

The value of SiO_2 ranges between 49.24-58.93% with an average of 51.49%; while the percentage of Al_2O3 ranges between 10.67-15.25% with an average of 14.05%; the value of Fe_2O_3 ranges between 2.99-8.04% with an average of 4.80%; value of MnO ranges between 0.07-0.21% with an average of 0.12%; value of MgO ranges between 0.48-1.87% with an average of 1.77%; value of CaO ranges between 3.68-6.30% with an average of 4.72%; value of Na_2O ranges between 2.39-3.13% with an average of 2.63%; value of K_2O ranges between 1.81-3.07% with an average of 2.15%; value of TiO_2 ranges

between 0.42-1.26% with an average of 0.70%; value of P_2O_5 ranges between 0.13-0.81% with an average of 0.30% for the sediments of Dhola.

7.2.Dum Duma

The value of SiO_2 ranges between 48.25-56.72% with an average of 53.16%; while the percentage of Al_2O_3 ranges between 12.58-18.06% with an average of 14.25%; the value of Fe_2O_3 ranges between 0.39-4.09% with an average of 1.81%; value of MnO ranges between 0.001-0.087% with an average of 0.034%; value of MgO ranges between 0.15-2.24% with an average of 1.04%; value of CaO ranges between 0.04-5.61% with an average of 2.40%; value of Na_2O ranges between 2.17-2.55% with an average of 2.27%; value of K_2O ranges between 0.98-2.36% with an average of 1.51%; value of TiO_2 ranges between 0.32-0.79% with an average of 0.57%; value of P_2O_5 ranges between 0.02-0.45% with an average of 0.107%; for the sediments of Dum Duma.

7.3.ChotaTingrai

The value of SiO_2 ranges between 45.47-56.36% with an average of 51.83%; while the percentage of Al_2O_3 ranges between 12.89-14.59% with an average of 13.69%; the value of Fe2O3 ranges between 1.05-3.40% with an average of 2.16 %; value of MnO ranges between 0.022-0.083% with an average of 0.048%; value of MgO ranges between 0.27-1.36% with an average of 0.79%; value of CaO ranges between 1.18-4.57% with an average of 2.98%; value of Na_2O ranges between 2.19-2.68% with an average of 2.46%; value of K_2O ranges between 1.26-3.21% with an average of 2.17%; value of TiO_2 ranges between 0.42-0.75% with an average of 0.56%; value of P_2O_5 ranges between 0.07-0.26% with an average of 0.16%; for the sediments of ChotaTingrai.

7.4.Naharkatiya

The value of SiO_2 ranges between 52.02-58.92% with an average of 54.80%; while the percentage of Al_2O_3 ranges between 11.72-14.29 % with an average of 12.77%; the value of Fe2O3 ranges between 0.15-0.87% with an average of 0.47%; value of MnO ranges between 0.001-0.007% with an average of 0.003%; value of MgO ranges between 0.14-1.62% with an average of 0.72%; value of CaO ranges between 0.01-2.05% with an

average of 0.69%; value of Na_2O ranges between 2.17-2.23% with an average of 2.20%; value of K_2O ranges between 0.96-1.15% with an average of 1.05%; value of TiO_2 ranges between 0.31-0.75% with an average of 0.48%; value of P_2O_5 ranges between 0.01-0.03% with an average of 0.02%; for the sediments of Naharkatiya.

well	Sample no.	SiO_2 in %	Al_2O_3 n %	Fe_2O_3(T in %	MnO in %	MgO in %	Cao n %	Na_2O in %	K_2O n%	TiO_2 n %	P_2O_5 n %	LOI n %	Trace element (Ba) in photapm
NAHARKATIA	NHK#1	54.57	13.76	0.86	0.001	1.61	0.01	2.17	0.96	0.73	0.03	25.26	593
	NHK#2	53.58	11.72	0.15	0.001	0.93	0.61	2.21	1.04	0.31	0.02	29.39	784
	NHK#3	58.92	12.36	0.30	0.001	0.14	0.57	2.21	1.09	0.35	0.03	24.13	840
	NHK#4	52.02	12.39	0.37	0.007	0.49	2.05	2.23	1.01	0.34	0.03	29.05	603
	NHK#5	56.28	12.11	0.28	0.001	0.54	0.87	2.21	1.05	0.40	0.02	26.19	578
	NHK#6	53.44	14.29	0.87	0.005	0.58	0.01	2.19	1.15	0.75	0.01	26.67	921
DHOLA	DHL#1	58.93	10.67	8.04	0.21	4.07	3.97	2.54	3.07	1.26	0.81	6.13	899
	DHL#2	50.39	15.25	4.01	0.10	1.87	5.62	3.13	2.02	0.57	0.25	16.77	684
	DHL#3	49.46	15.12	5.89	0.16	1.54	6.30	2.44	1.94	0.87	0.26	15.62	731
	DHL#4	52.67	14.59	2.99	0.07	1.06	3.68	2.88	1.93	0.43	0.13	19.45	541
	DHL#5	48.25	14.56	3.84	0.08	1.31	4.11	2.40	2.12	0.54	0.17	22.24	538
	DHL#6	49.24	14.09	4.05	0.09	0.48	4.63	2.39	1.81	0.55	0.13	22.90	523
CHOT	CH.TNG#	53.64	14.33	1.85	0.039	1.36	1.18	2.19	1.26	0.75	0.15	23.23	821

	CH.TNG#2	53.31	14.59	3.06	0.071	0.68	4.57	2.62	3.21	0.48	0.26	17.35	691
	CH.TNG#3	56.36	13.36	1.46	0.027	0.27	2.16	2.44	1.89	0.42	0.07	21.64	489
	CH.TNG#4	45.47	13.28	3.40	0.083	0.52	4.47	2.38	2.86	0.66	0.24	26.39	368
	CH.TNG#5	50.39	12.89	1.05	0.022	1.12	2.53	2.68	1.62	0.51	0.07	27.09	685
DUM DUMA	DMA#1	53.77	14.32	1.12	0.001	0.68	0.04	2.17	0.98	0.798	0.03	26.29	969
	DMA#2	48.25	15.07	4.09	0.087	0.60	5.61	2.55	2.36	0.56	0.45	20.35	628
	DMA#3	53.12	12.85	0.62	0.013	0.81	2.43	2.24	1.11	0.34	0.05	26.52	705
	DMA#4	56.72	12.65	0.39	0.004	0.15	1.75	2.22	1.19	0.32	0.02	22.37	706
	DMA#5	55.93	18.06	3.73	0.082	2.24	1.99	2.23	1.94	0.99	0.03	12.75	909
	DMA#6	51.17	12.58	0.89	0.019	1.74	2.60	2.23	1.49	0.43	0.06	26.89	757

Table 3: Chemical Composition of the shallow subsurface sediments of four well

8.Classification Based On Chemical Parameters

The subsurface sediments of the four well viz, Naharkatiya, Dhola, ChotaTingrai and Dum Duma under study have been geochemically classified following Pettijohn(1973). In this geochemical classification the value of $Log(SiO_2/Al_2O_3)$ is plotted against $Log(Na_2O/K_2O)$. Maturity of the sediments can be examined using the SiO_2 to Al_2O_3 ratio. The mature quartz rich sediments have high SiO_2/Al_2O_3 ratios by virtue of the absence of aluminosilicates and in immature sediments the value of ratio SiO_2/Al_2O_3 is lower (pettijohn et al., 1973). The classification differentiates between the mature and immature sediments as those terms are used in both mineralogical and textural classifications.It does so using the ratio of SiO_2 to Al_2O_3 rather than by using either alone.

The average ratio of SiO_2/Al_2O_3 for sediments of Dhola is 3.66, for sediments of Dum Duma is 3.73, for ChotaTingrai is 3.78 and for Naharkatiya it is 4.29. The dominance of Al_2O_3 and K_2O in the present study sediments indicates immature.

9.Observation And Interpretation

The triangular plot of percentage value of Fe_2O_3, MgO and TiO_2 of sediments of four well shows clustering of most of the sample of ChotaTingrai and Dhola in and around the 'Granite and Quartz Monzonite' and 'quartz diorite and granodioritic field' field of Condie, (1967) (Fig. 6). Thus the sediments of ChotaTingrai and Dhola may have probably been derived from quartz diorites and granites.

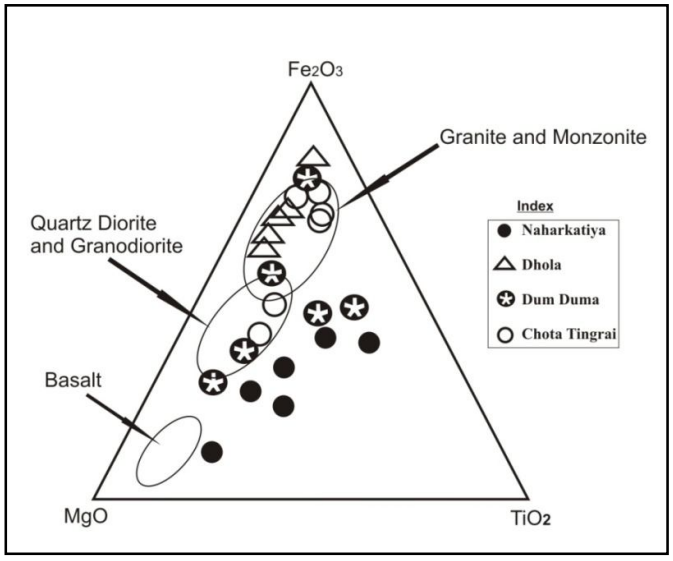

Figure 6: The triangular plot of percentage value of Fe_2O_3- MgO and TiO_2 of sediments of four well indicating their origin(Fields afterCondie, 1967)

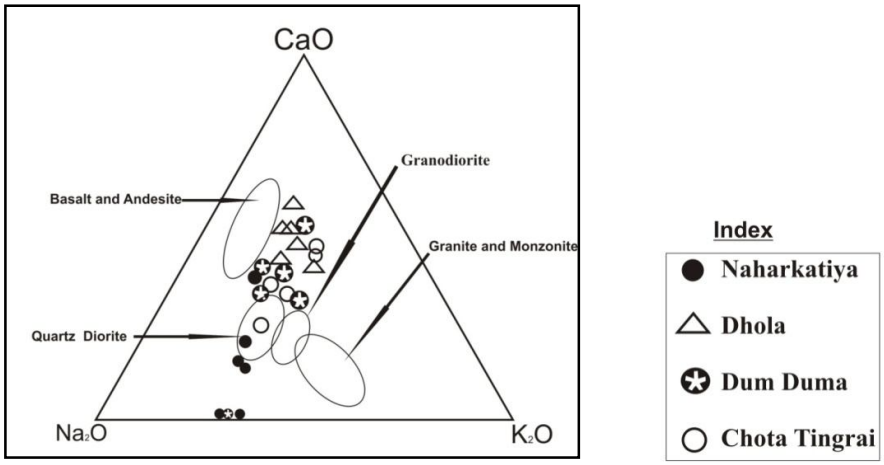

Figure 7: The triangular plot of percentage value of CaO- Na_2O and K_2O of sediments of four well indicating their origin(Fields afterCondie et al.)

Also the triangular plot of CaO-Na_2O-K_2O (Condie et al.) shows that majority of the percentage values of the relevant oxides of the sediments of four well fall in and around 'quartz diorite' and 'basalt and andesite' field. Thus the sediments may have probably been derived from quartz diorites and granites (Fig. 7).

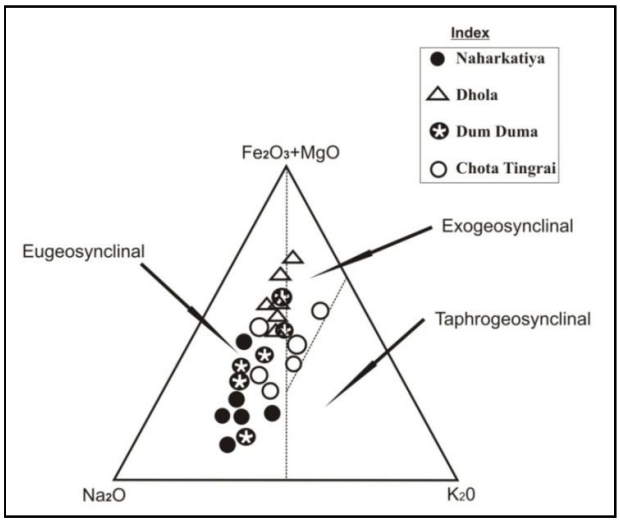

Figure 8: The triangular plot of Fe_2O_3+MgO -Na_2O-K_2O values of the sediments of the four well field (after Schwab,1975 and Blatt et al., 1980)

The triangular plot of Fe_2O_3+MgO -Na_2O-K_2O values of the sediments of the four well shows the clustering of the points 'Eugeosynclinal' field (after Schwab,1975 and Blatt et al., 1980) in (Fig. 8). Thus the sediments were derived from a 'Eugeosynclinal environment'.

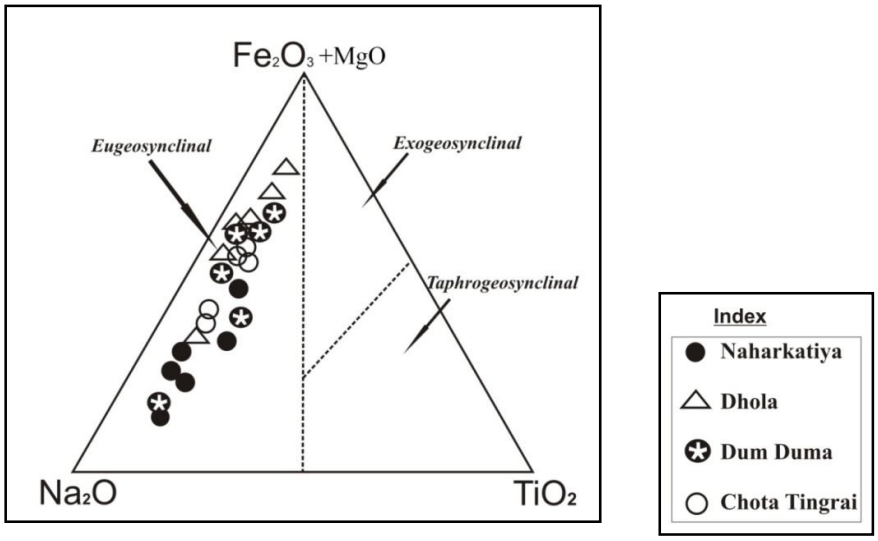

Figure 9. The triangular plot of Fe_2O_3+MgO -Na_2O-TiO_2 values of the sediments of the four well field (after Schwab,1975 and Blatt et al., 1980)

Also the triangular plot of Fe_2O_3+MgO-Na_2O-TiO_2 values of these sediments shows the clustering of the points at within 'Eugeosynclinal fields' (after Schwab, 1975 and Blatt et. al.,1980). The sediments were thus deposited in a eugeosynclinal environment (Fig.9).

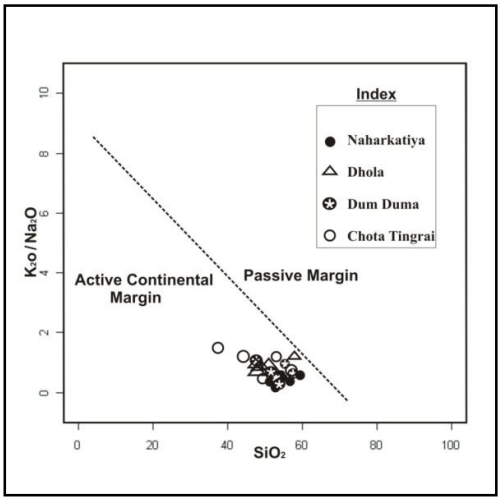

Figure 11: Major element composition plot for tectonic setting discrimination of the sandstones of four sub-surface wells of Upper Assam. All the samples fall in the field of Active Margin tectonic setting (Fields after Roser and Korsch, 1986).

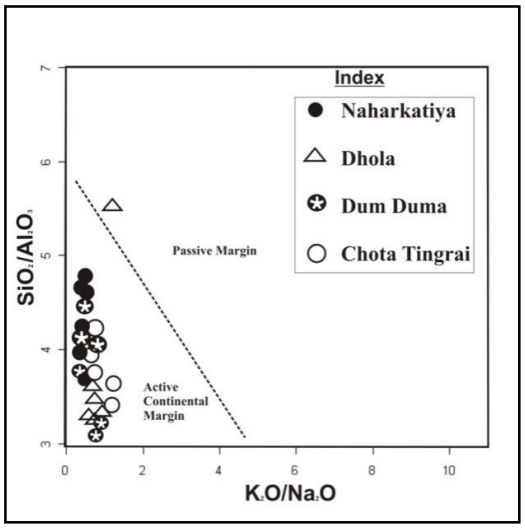

Figure 12: Major element composition plot for tectonic setting discrimination of the sandstones of four sub-surface wells of Upper Assam. Almost all the samples fall in the field of Active Margin tectonic setting(Fields after Roser and Korsch, 1986).

SiO_2 vs. K_2O/Na_2O plot (Fig. 10) of the sediments shows that the sediments of Active Margin tectonic setting (Fields after Roser and Krosch, 1986).Also, the plots of K_2O/Na_2O vs. SiO_2 /Al_2O_3(Fig. 11) indicates that the samples fall within Active Margin tectonic setting(Fields after Roser and Krosch, 1986).

10.Harkar Variation Diagram

Variation of various oxides with respect to SiO_2 is examined and the diagrams are shown in (Fig. 13). The general tendency of the oxides is to concentrate at low SiO_2 value. No clear trend is observed in the distribution of the oxides with respect to the SiO_2 content. For ChotaTingrai, Naharkatiya wells the Fe_2O_3, MgO, Na_2O decreases with increase in SiO_2. Al_2O_3 content is intermediate to low with respect to increase in SiO_2. For most of the wells K_2O and Al_2O_3 contents decrease as SiO_2 increases. However the variation trends of TiO_2 with the increase of SiO_2 are not clear.

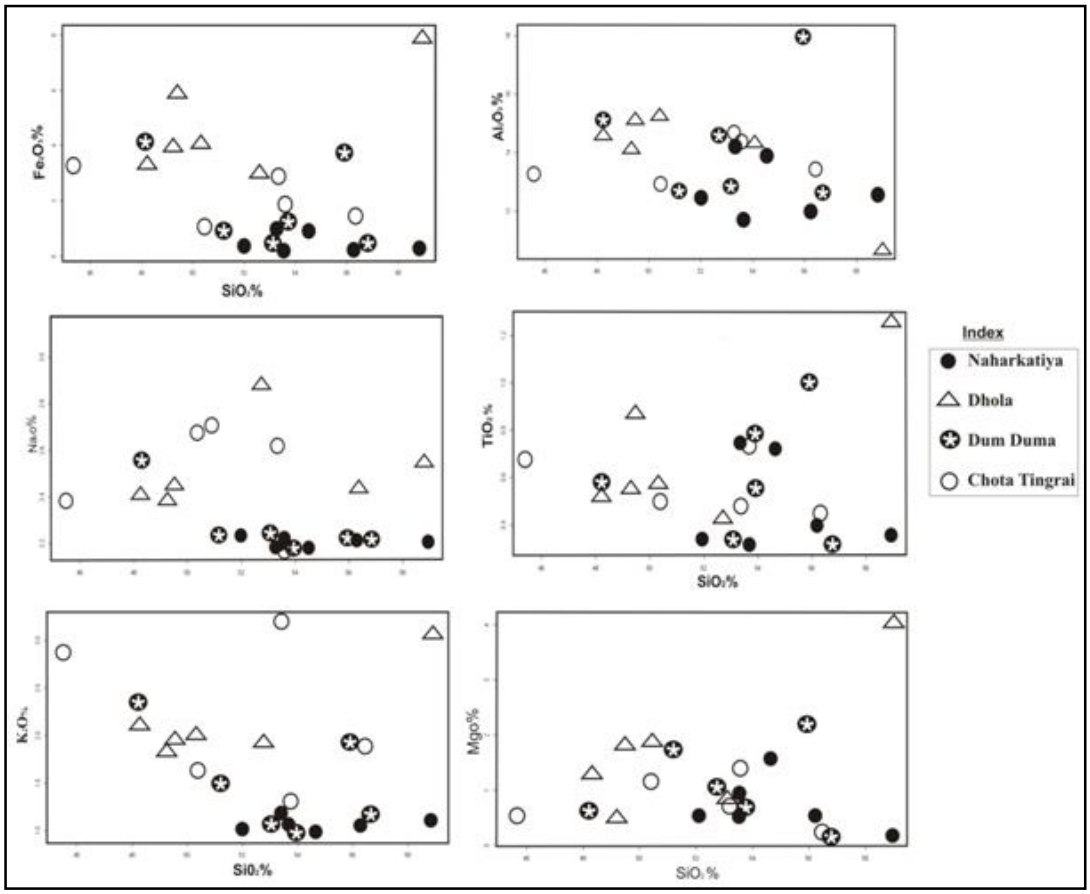

Figure 13: Harker Variation diagram of the various sub- surface wells

11.Conclusions

From the petrography study of the shallow sub-surface sediments of the four wells under study, following conclusions can be drawn-

Diamond diagram of Basu*et al*. (1975) has shown that the sediments of Naharkatiya well were derived mostly from middle and upper rank metamorphic sources. Like that the sediments of Dhola and ChotaTingrai were derived from plutonic, middle and upper rank metamorphic rock but the sediments of Dum Duma were derived from middle and low rank metamorphic. QFL triangular plot indicates that the sediments of the four well viz., Naharkatiya, Dhola, ChotaTingrai and Dum Duma under study were derived from recycled orogenic sources . The Q_mFL_t triangular plot shows that the Naharkatiya seiments under study were mainly of transitional recycled origin , sediments of the Dhola were mainly of quartzose recycled, mixed and transitonal recycled origin however, sediments of ChotaTingrai and Dumduma were mainly of mixed, dissected arc and transitional recycled origin.

From the geochemical study of sediments of four wells, the oxides value shows that CaO dominates over MgO for all the sediments of four wells. The dominance of CaO over MgO indicates that the sediments are of carbonate nature. The value of Na_2O dominates over K_2O indicates the presence of detrital feldspar. The average ratio of SiO_2/Al_2O_3 for sediments of Dhola is 3.66, for sediments of Dum Duma is 3.73, for ChotaTingrai is 3.78 and for Naharkatiya it is 4.29. The dominance of Al_2O_3 and K_2O in the sediments of four well indicates immature sediments.The triangular plot of percentage value of Fe_2O_3, MgO and $TiO_2$of sediments of four well shows clustering of most of the sample of ChotaTingrai and Dhola in and around the 'Granite and Quartz Monzonite' and 'quartz diorite and granodioritic field' field . Thus the sediments of ChotaTingrai and Dhola may have probably been derived from quartz diorites and granites. Triangular plot of $CaO-Na_2O-K_2O$ shows that majority of the percentage values of the relevant oxides of the sediments of four well fall in and around 'quartz diorite' and 'basalt and Andesite' field. Thus the sediments may have probably been derived from quartz diorires and granites. The triangular plot of $Fe_2O_3+MgO -Na_2O-K_2O$ values of the sediments of the four well shows the clustering of the points 'Eugeosynclinal' field . Thus the sediments were derived from a 'Eugeosynclinal environment'. The SiO_2 vs K_2O/Na_2O plot of the sediments shows that the sediments of Active Margin tectonic setting . The plots of K_2O/Na_2O vs. Sio_2 /Al_2O_3 indicates that the samples fall within Active Margin tectonic setting. For ChotaTingrai, Naharkatiya wells the Fe_2O_3, MgO, Na_2O decreases with increase in SiO_2. Al_2O_3 content is

intermediate to low with respect to increase in SiO_2. For most of the wells K_2O and Al_2O_3 contents decrease as SiO_2 increases. However the variation trends of TiO_2 with the increase of SiO_2 are not clear.

12.Acknowledgement:

The authors thank the Head of the Department of Applied Geology of Dibrugarh University for providing laboratory facilities to carry out the research work. Thanks are due to Department of Science and Technology, New Delhi to grant financial assistance to one of the authors (Rupjyoti Hazarika) under Shallow Subsurface Studies programme for the work.

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