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Clay Mineralogy of the Early Permian Warchha Sandstone at Katha Area, Central Salt Range, Pakistan

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Abstract: Eleven samples of Warchha Sandstone exposed at Katha area, Salt Range, Pakistan were collected for their clay mineral studies. Qualitative and semi-quantitative analyses were carried out on less than 2 µ fraction size using X-ray diffraction technique. The studies revealed the occurrence of illite, kaolinite and illite- vermiculite as the most dominant, while smectite, vermiculite, chlorite and chlorite-vermiculite as the minor clay minerals in the studied samples. The clay mineral composition indicates depositional and diagenetic changes from base to top of the Warchha Sandstone. These changes are mainly due to the leaching and warm- humid environment of deposition.

Keywords: Early Permian, Warchha Sandstone, Salt Range

1. INTRODUCTION

The section of Warchha Sandstone exposed in Katha area (Long 72˚ 26' 00"; Lat 32˚ 34' 00") **(Fig. 1)** is selected for the present study. It lies in the Survey of Pakistan toposheet No. 43 D/ 6 and is easily approached by metaled road from Islamabad through Kallar Kahar.

The rocks exposed in study area range in age from Pre-Cambrian to Eocene. The oldest rocks belong to the Salt Range Formation and the youngest to the Kamlial Formation (Table 1). Lithologically, the project area dominantly contains sandstone, claystone, shale and dolomitic limestone. The whole rock sequence is affected by three major stratigraphic breaks. The first major regional unconformity is represented by Tobra Formation of Early Permian age. Rocks of Ordovician, Silurian, Devonian and Early Carboniferous age are missing. The other two major unconformities are at the base of (i) Paleocene marked by the missing of Zaluch group of Permian age and (ii) Late Miocene **(Table 1).** The Formation under study, Warchha Sandstone of Early Permian age is about 118 m thick, nicely exposed on the Katha roadside, Central Salt Range **(Figs. 1 and 2).** It mainly consists of medium to thick bedded sandstone with occasional pebbles and gravels. The sandstone is mainly brown to whitish brown in color and interbedded with shales and clays. The Warchha Sandstone has been studied by earlier workers, especially Ghazi (2009), Ghazi and Mountney (2009), Ghazi and Mountney (2011a, b) from different aspects. However, details regarding its clay mineral composition, which is important to further understand the provenance and especially the diagenetic changes during and after deposition, are largely lacking. For this purpose, eleven samples were collected from base to top of the formation to know about the nature and abundance of their clay minerals.

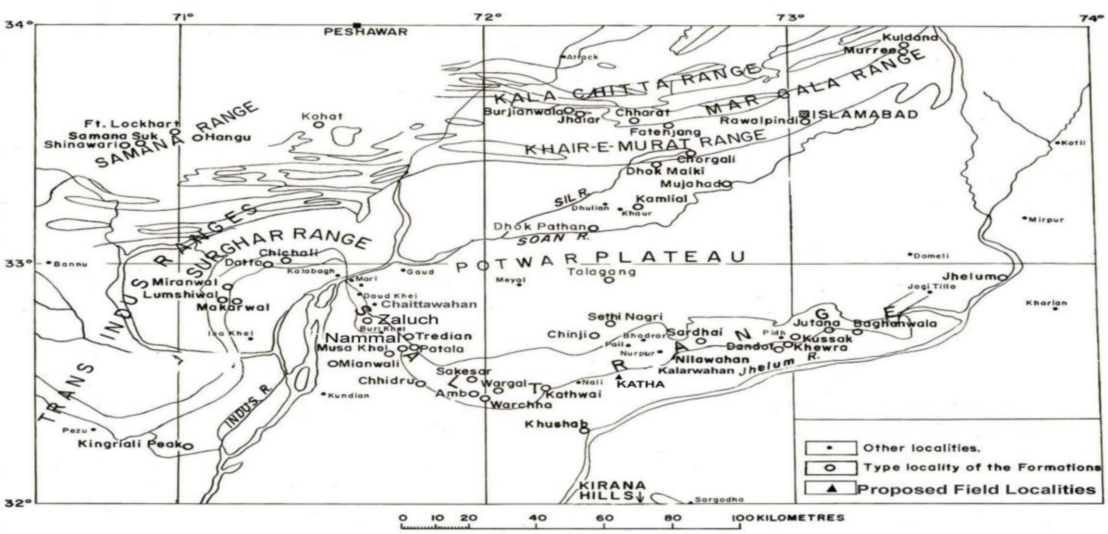

Fig. 1. Location map of study area

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Table 1. Stratigraphy of Katha area, Central Salt Range.

ERA		AGE	GROUP	FORMATION	LITHOLOGY
		Late Miocene		Kamlial Formation	Greenish sandstone, reddish claystone/ mudstone, conglomeritic base.
Major Unconformity					
Cenozoic		Early Eocene	Chharat Group	Chorgali Formation	Olive green shale with bedded limestone
				Sakesar Limestone	Massive & nodular limestone with marl. Chert in upper part
				Nammal Formation	Light grey calcareous shale & limestone
		Paleocene	Makarwal Group	Patala Formation	Green shale with coal seams, thin bedded limestone and marl.
				Lockhart Limestone	Nodular limestone with minor marl
				Hangu Formation	Medium to thick bedded sandstone, laterite at base
Unconformity					
Paleozoic		Early Permian	Nilawahan Group	Sardhai Formation	Dark purple and lavender clays with subordinate sandstone
				Warchha Sandstone	Red and light colored sandstone and grits in part. Clay interbeds
				Dandot Formation	Olive green and gray sandstone. Shale occasionally carbonaceous
				Tobra Formation	Conglomeratic sandstone and shale boulders mainly igneous or metamorphic
Unconformity					
Paleozoic		Middle and early Cambrian		Kussak Formation	Gray and purplish shale and glauconitic sandstone pebble bed at base
				Khewra Sandstone	Massive maroon fine textured shale and flags below

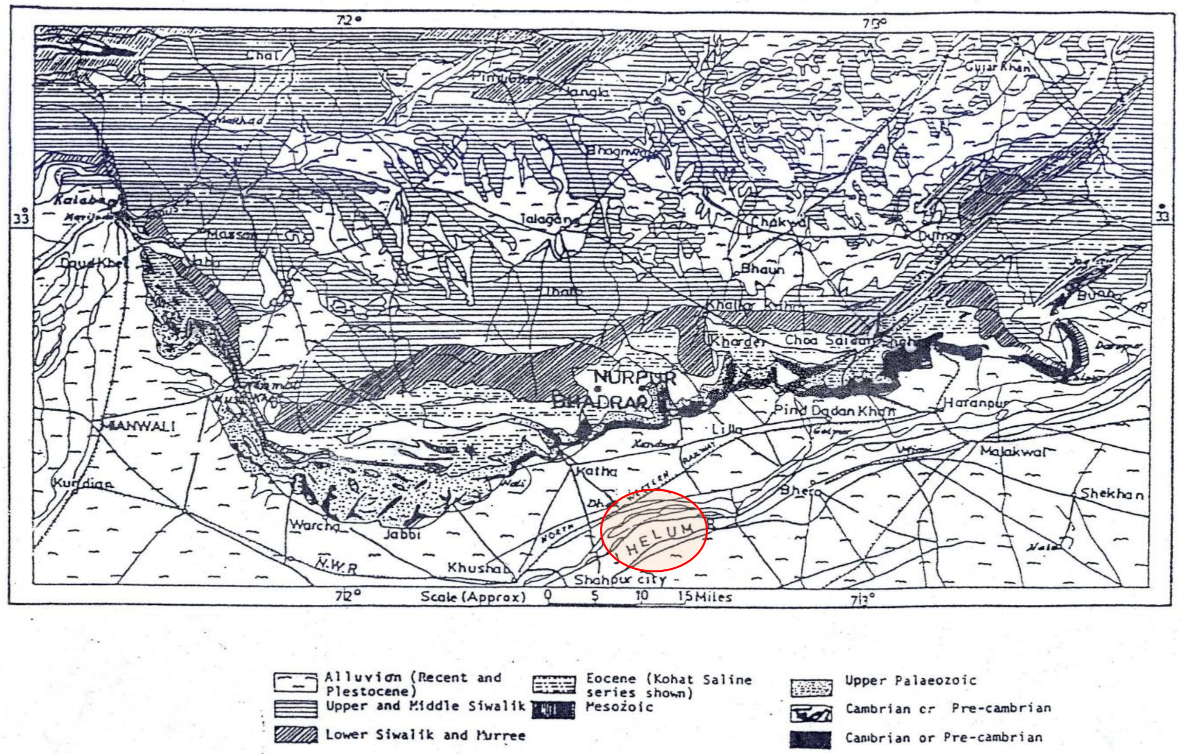

Fig. 2. Geological Map of Salt Range showing location of the study area

Table 2. Percentage distribution of clay minerals in Warchha Sandstone at Katha roadside.

Sample No.	%Illite	% Kaolinite	% Chlorite	%Vermiculite	% Smectite	% Illite-Vermiculite	% Chlorite-Vermiculite
K33	1	3	3	15	66	15	0
K28	18	69	0	0	0	4	9
K25	9	45	0	0	0	23	23
K24	38	32	9	0	0	21	0
K22	42	9	4	5	0	40	0
K18	51	22	8	0	0	19	0
K17	43	44	13	4	0	10	0
K15	18	32	7	9	0	34	0
K13	33	47	7	0	0	13	0
K7	24	18	3	29	0	29	0
K1	35	49	16	0	0	0	0
Average %	28.36	33.64	6.36	5.64	6.00	18.91	2.91

2. PREVIOUS WORK

Proposal as the Warchha Sandstone came from Hussain (1967) for the speckled sandstone of the Waagen (1889-1891), Gee (1945) and for the Warchha Group of Noetling (1901). It has been assigned an early Permian age by Fatmi (1973) and Shah (1977).

Many researchers have carried out research on different dimensions of clay minerals in Paleozoic sediments. These include Grim (1951, 1958), Burst (1959), Weaver (1964, 1967), Deer *et al.* (1966), Dunoyer de Seganzac (1970), Weaver and Polard (1973), Chamley *et al.* (1990), Baqri and Rajpar (1991) and Deconinck *et al.* (1991). Ghazi (2009), Ghazi and Mountney (2009), Ghazi and Mountney (2011a, b) described the sedimentology, fluvial facies and provenance of the Warchha Sandstone.

3. METHODOLOGY

Brown (1961), Baqri (1977, 1978) have provided details of the methods for carrying out semi-quantitative analysis of clay minerals. Selected samples of the Warchha Sandstone were examined for determining their clay mineral composition. About 25-30 gram of each sample was soaked in de-ionized water in a large beaker for several days. Four types of oriented slides were prepared for the purpose of their clay mineral investigation. These four types include natural, glycolated, heated and hydrazine. According to respective treatment the diffractograms were taken on a Philippe X-ray diffractometer using anticathode tube of Fe with the power supply of KV 35 with 12 Am. Speed of the graph paper entering the recording machine was 2cm/ m with an impulse of 4 x 10. Each of the oriented samples (slides) was used to record its X-ray diffraction pattern from 2˚ 2θ to 20˚ 2θ to observe the behavior of the reflection given by different clay minerals. The diffractograms were compared to find out quality and quantities of clay minerals. The mean height peaks of the main reflections of each clay mineral were used to carry out the semi-quantitative analysis as described by Holtzapffel (1985). The clay mineral kaolinite was studied on comparing the peaks at 7A˚. Illite was identified on the basis of its diagnostic reflection at 10A˚. The minerals vermiculite and smectite were recognized due to their 14A˚ and 14-15A˚ reflections respectively. Chlorite was recognized due to its reflection at 14A˚. The mixed layer clay minerals, illite-vermiculite and chlorite-vermiculite, were recognized due to their reflections between 10-12A˚ and 14-12A˚ respectively. **(Fig-3)** provides lithological log and the percentages of various clay minerals plotted against the lithological section of the studied Warchha Sandstone section.

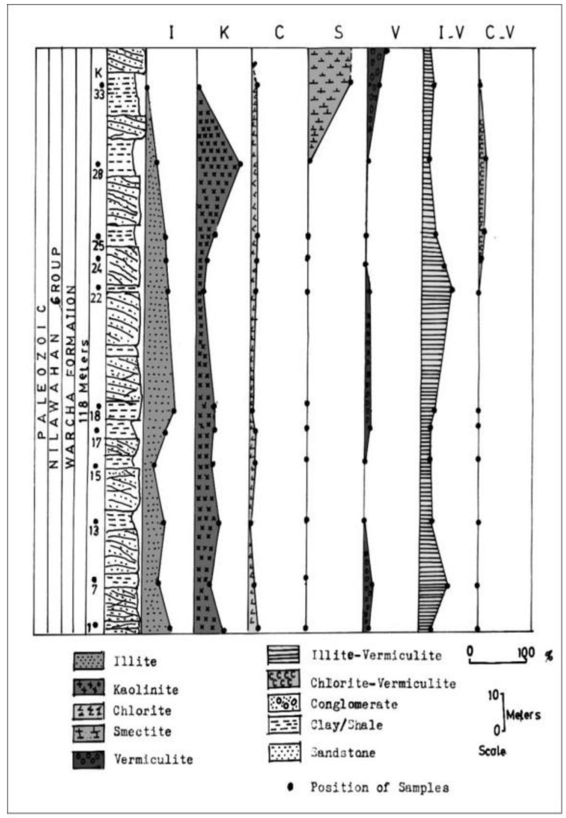

Fig. 3. Distribution of clay minerals from base to top of the Warchha Sandstone exposed at Katha roadside, Central Salt range.

4. RESULTS

Table-2 represents the semi quantitative analysis of the clay minerals found in the studied samples of the Warchha Sandstone. Kaolinite is the dominant clay mineral and was observed with an average percentage of 33.7%. Illite is the second dominant mineral with average percentage of 28.3%. The third dominant is the mixed layer clay mineral identified as illite-vermiculite and was found to be 18.9%. Chlorite was found in most of the samples and its abundance is about 6.3%. Smectite was recognized only in one sample from the top of the Formation and was found to be 6%. Vermiculite was observed in five samples and was observed to be 5.6%. The percentage of mixed layer clay mineral chlorite-vermiculite was about 2.9%. Kaolinite is present in all the samples from bottom to the top in various amounts. It varies from 49% in sample K1 from the base of the formation to the 3% in the sample K33 from the top. The mineral is almost uniformly distributed in the middle part of formation. Chlorite is absent from the upper part but occurs abundantly in the base of the formation. Vermiculite is present mostly in the middle part of the formation.

5. DISCUSSION

The results of the detailed study and interpretative clay mineral analysis of the acquired diffractograms are shown in (F**ig. 4A to 4H)** for all the selected samples in all four conditions (natural, glycolated, heated and hydrazine).

The dominance of kaolinite in most of the samples of the Warchha Sandstone indicates that it most likely formed due to the alteration of the potash feldspar commonly found in the Warchha Sandstone. It is also likely that these minerals were altered diagenetically from feldspar deposits as a result of erosion of igneous rocks. The presence of kaolinite in most of the samples reflects fresh water environment during the deposition of the formation. Kaolinite is the characteristic mineral of low latitude acid tropical soils where leaching is intensive.

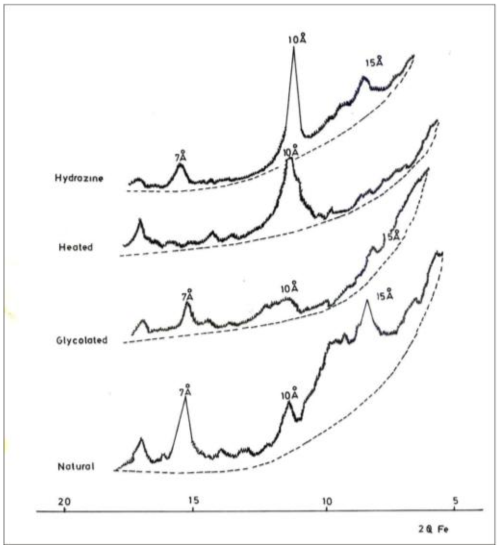

Fig. 4A. Diffractograms of sample K7 (Katha)

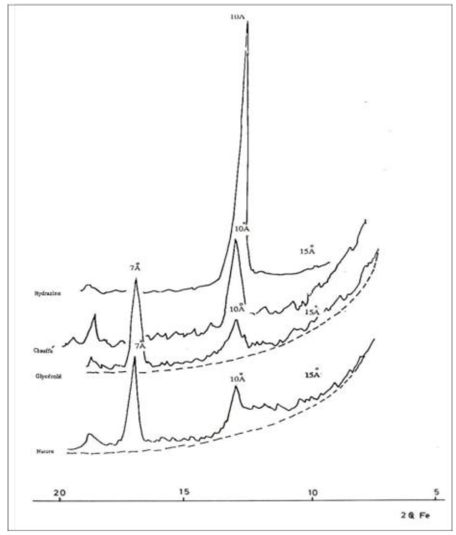

Fig .4B. Diffractograms of sample K13 (Katha)

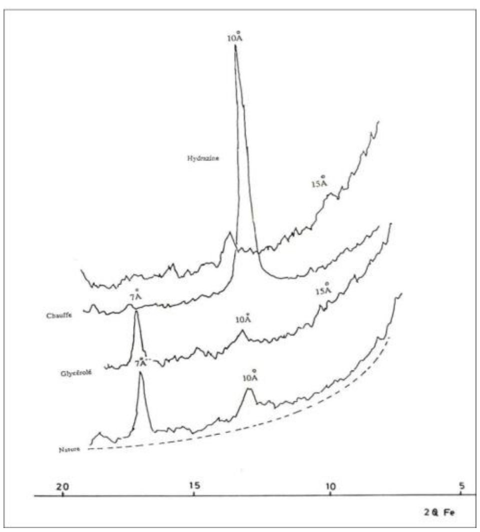

Fig .4C. Diffractograms of sample K17 (Katha)

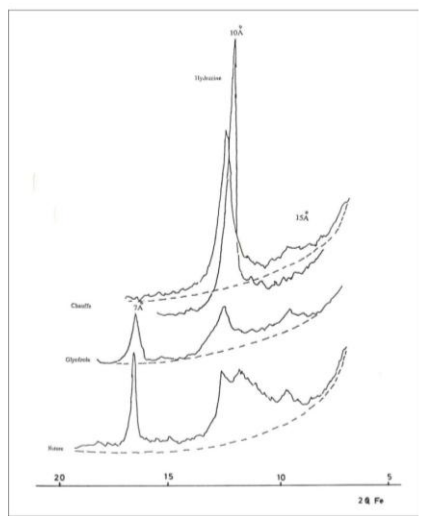

Fig. 4D. Diffractograms of sample K18 (Katha)

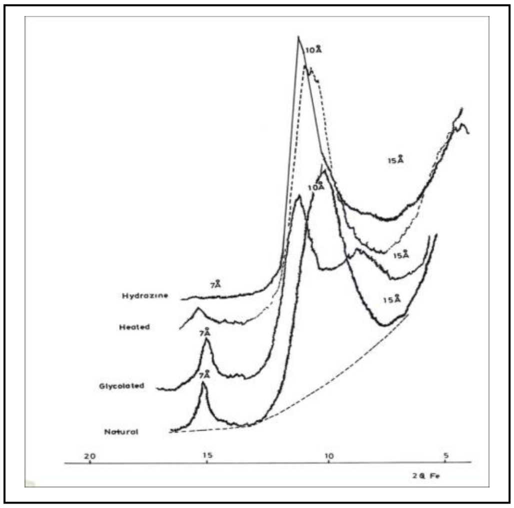

Fig. 4E. Diffractograms of sample K 22 (Katha)

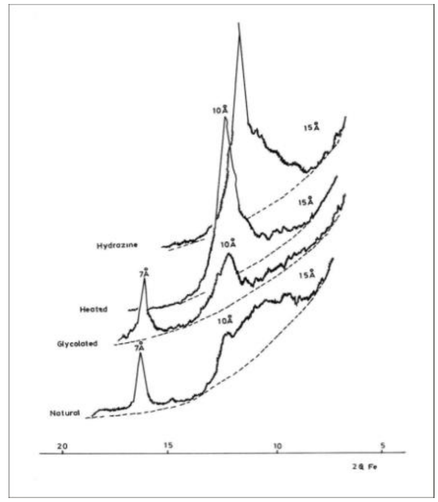

Fig. 4F. Diffractograms of sample K25 (Katha)

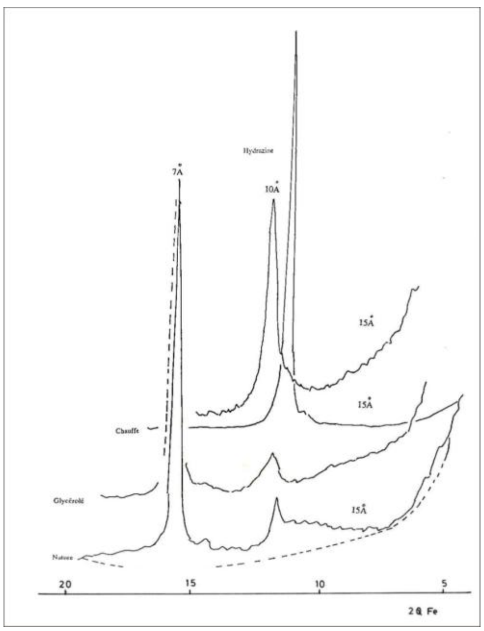

Fig. 4G. Diffractograms of sample K 28 (Katha)

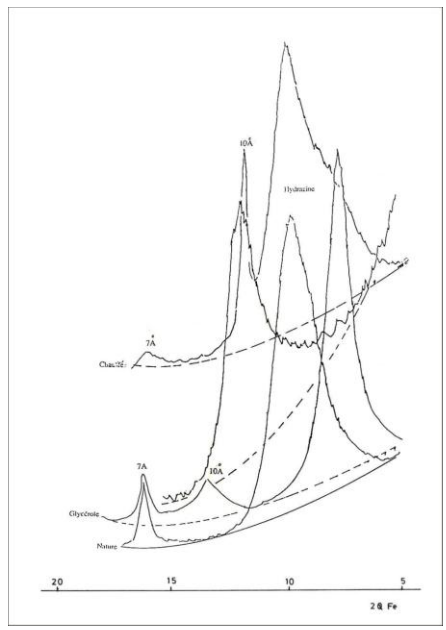

Fig. 4H. Diffractograms of sample K 33(Katha)

Illite is the second dominant mineral in the Warchha Sandstone. Illite is a sheet silicate with two tetrahedral layers and one octahedral layer bounded by potassium. As the potassium-oxygen ionic bonds between the sheets are relatively weak, the mineral cleaves easily along those planes. Illite is formed by weathering of feldspar and mica under alkaline conditions where degree of leaching is minimal. It is also formed in soils of arid regions where chemical processes are limited. Most of the workers, e.g. Weaver (1964, 1967) attribute the presence of illite in Pre-Cambrian to Palaeozoic sediments to continental rather than oceanic origin.

Chlorite consists of two tetrahedral and two octahedral layers. It has a complicated structure involving talc sheet sandwiched between silica sheets with alternate talc sandwich between brucite layers. Magnesium-rich chlorites are stable only in metamorphic rocks while iron rich chlorites may form as an authigenic mineral in sediments. Chamosite (batherine) is an example of iron rich chlorite mineral that is often formed close to the sediments in reducing environments.

Smectite is present in one sample from the top of the Warchha Sandstone reflecting warm-humid paleo-environmental changes during the deposition of Warchha Sandstone. It is formed in low precipitation as the said formation is immediately overlain by Sardhai formation bearing shales of relatively deeper environment. It occurs as an alteration product of volcanic ash and tuffs. The presence of illite and chlorite indicates that these minerals were transported due to erosion of acid igneous and metamorphic rocks.

The mixed layer clay minerals illite-vermiculite and chlorite-vermiculite were observed in several samples. These minerals also appear to be of diagenetic nature close to alteration of illite, vermiculite and chlorite. Vermiculite observation in only five samples reflects comparatively warm conditions for Warchha Sandstone.

Ghazi *et al.* (2011a) stated that the source of Warchha Sandstone is from Indian Shield (Aravalli Range to the southeast and Malani Range to the south of Salt Range). The deposition of detritus from such igneous and metamorphic rocks in the form of Warchha Sandstone has been taken place in the region. After deposition, the diagenesis of K-feldspar and plagioclase in humid-warm environment has converted both feldspars to clays like chlorite, vermiculite, illite and illite-vermiculite as findings of this present study.

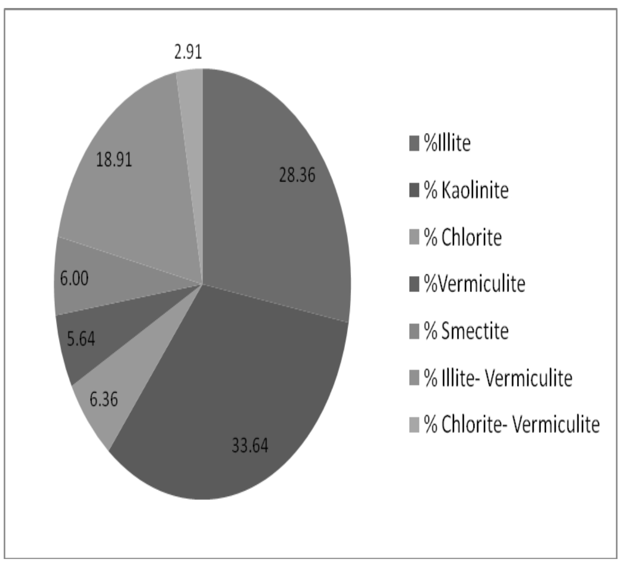

Fig. 5. Average percentage of different clay minerals (Table 2) in Warchha Sandstone at Katha.

6. CONCLUSION

The clay minerals in the Warchha Sandstone exposed at Katha area were identified as kaolinite, illite, chlorite, smectite, vermiculite, the mixed layer clay minerals as illite-vermiculite and the chlorite-vermiculite. The most dominant clay minerals are kaolinite and illite. Origin of these clays belongs to the diagenetic changes in feldspar (K-Feldspar and Plagioclase) derived from the source area.

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