

Mineralogical Characterization Using X-ray Diffraction for Laterites of Swarnagadde Plateau, Western Ghats, Karnataka

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Abstract: Laterites comprising the Swarnagadde plateau of Western Ghats on the south-western margin of peninsular gneissic complex. Laterites generally cap the granitic-gneiss and found plateau and coastal plains of the study area. A thick residual laterite-cappings have been formed during the Tertiary period due to intense and prolonged tropical weathering is the only major geological event of the area. Laterites are the products of intense sub aerial weathering in which Fe and / or Al content is higher and Si content is lower than in merely Kaolinised parent rocks. XRD analyses for identification of different mineral phases taken up and gibbsite, boehmite, kaolinite, goethite, anatase, hematite and other minerals have been identified in most of the laterite and altered rock samples, comprehensive peak data is presented in tables. Gibbsite and anatase show a gradual increase from reddish brown phase to white phase. Goethite and hematite show a decreasing trend from reddish brown to white phases of laterites. Kaolinite remains more or less uniform in all the phases except the clay zone in which it decreases. It increases slightly in laterites and becomes predominant in this saprolite horizon.

Keywords: Gibbsite, Weathering, XRD analysis, Reddish brown, Laterites.

I. INTRODUCTION

XRD is the most essential tool used to characterize crystal structures; evaluation of crystal structure is significant for Nano-scale materials, since material's properties may be affected in the nanometres scale. The principle of powder XRD is based on the well-known Bragg's law. The most generally used database for the identification of crystal structure is the Joint Committee on Powder Diffraction Standards-International Centre for Diffraction Data (JCPDS-ICDD) system. When X-ray beam hits an atom, the electrons around the atom start to oscillate with the same frequency as the incoming beam. In almost all the directions, destructive interference takes place, that is, the combining waves are out of phase and there is no resultant energy leaving the solid sample. However, when the atoms in a crystal are arranged in a regular pattern, and in a few directions, there will be constructive interference. The waves will be in phase and there will be well defined X-ray beams leaving the sample at various directions. Hence, a diffracted beam may be described as a beam composed of a large number of scattered rays mutually reinforcing one another. The orientation and interplanar spacing of parallel planes inside the crystal are defined by the three integers h, k, and l called Miller indices. Laterite/aluminous laterite and altered lose materials, composed of minerals may be studied by various analytical techniques. One such technique, X-ray powder diffraction (XRD), is an instrumental technique that is used in identifying minerals, as well as other crystalline materials. Nomenclature, classification, morphological and analytical characteristics, global distribution, processes of horizon development, environmental conditions of laterites are precisely analyzed by [1, 2, 3, 4, 5, 6, 7, 8 and 9] etc. More importantly, [10, 11, 12, 13, 14, 15, 16, 17 and 18] have investigated various profiles of lateritic deposits in Indian peninsula and tried to solve the problems of origin of Indian laterites. But similar amount of work not exist on the studied in detail and there is paucity of detailed information on these study. Hence the present study deals with Mineralogical characterization using XRD (X-ray diffraction) for Laterites of Swarnagadde Plateau, Western Ghats Karnataka.

II. GEOLOGICAL SETTING OF THE AREA

The study area falls within the longitudes 14° 18' to 14° 24' N and latitudes 74° 24' to 74° 30' E forming part of Survey of India toposheet No.47 J/7 covering an area of 76 km² is situated on the Mangalore-Karwar coastal highway. The study

area lies between the Arabian coast in the west and Western Ghats in the east. Area is conveniently approachable in all seasons by well-connected roads and that reaches up to the top of the plateau.

The investigated area as seen from the valley and nalla sections the rock types which covers the coastal track of Karnataka area. The present study area is characterized by Precambrian crystalline rocks (Granites, Granitic gneisses and Schists), laterites and basic dykes. Granitic gneisses are considered as the oldest rocks of the study area and these are predominantly of tonalite/trondhjemites in nature and are comparable to similar early Precambrian granitic gneisses of other shield areas of the world. Radhakrishna, [19 and 20] have investigated and described the Southern parts of coastal tract of Karnataka and the Northern part has been described by Gupta et al., [22]. The granitic gneiss/granites cover major portion of the coastal tract, which is the North-Western coastal continuation of peninsular gneisses or Northern continuation of South Kanara gneisses/granites. The gneisses form prominent hills and headlands along the coast. However, the occurrences of granites in the study area present as patches within gneissic complex.

Table 1. Lithostratigraphic succession of the study area

Stratigraphic position	Rock formations	Age values determined for the corresponding rock formation in the Geological continuous South Canara Precambrian.
After Balasubrahmanyam, [20 and 21]		
Sub recent to recent	Sand/Soil and Alluvium	-----
Tertiary to sub recent	Laterite.....	-----
Proterozoics	Dolerite Dyke Intrusions	2.2b.y K-Ar age obtained for the younger ENE striking set of dolerites.
	Granites	2.2b.y Rb-Sr age obtained for Canara granites.
Achaean	Granitic Gneiss	3.2-3.6b.y K-Ar, Rb-Sr and Pb-Pb age obtained for Canara gneiss
	Schists	3.2-3.6 b.y

Though, the minor intrusions of doleritic dyke have intruded within the gneisses after a long period of metamorphism/deformation and adequate cooling of the country rock witnessed the close of Precambrian geological events of the era about 2.2 b.y ago; [21]. A thick residual laterite-cappings have been formed during the Tertiary period due to intense and prolonged tropical weathering is the only major geological event of the area.

III. MATERIALS AND METHODS

Some mineralogical samples analyzed by XRD are too fine grained to be identified by petrological microscope. XRD analysis for mineral identification of laterite/aluminous laterite and altered rock samples were carried out in the Laboratory of Physics Department, Gulbarga University, Gulbarga (Karnataka) and IIT, Kanpur (UP) with the help of X-ray Diffractometer (X'Pert Pro of Panalytical). Identification is achieved by comparing the X-ray diffraction pattern or 'diffractogram' obtained from an unknown sample with an internationally recognized database (ICDD) containing reference patterns for more than 70,000 phases. XRD analyses for identification of different mineral phases taken up and gibbsite, boehmite, kaolinite, goethite, anatase, hematite and other minerals have been identified in most of the laterite and altered rock samples, comprehensive peak data given in tables (Table No. 2 to 4). Diffractogram with assigned peak diagram for various laterite and altered rock samples are also presented (Figure No. 1 and 2).

A.1 Experimental setup

The phase composition and crystal structure of the samples are characterized by X-ray diffraction (XRD) measurement at room temperature using monochromatic beam of Cu K α radiation (1.540598 Å). An accelerating voltage of 40 kV and a current of 30 mA with a scan rate of 0.05° s⁻¹ are used. The XRD patterns are recorded in the 2 θ range of 10° - 80° versus intensity with a step size of 0.05°. The values of 2 θ , 'd'-spacing's, relative intensity and FWHM are obtained from the XRD pattern. By comparing the X-ray diffraction pattern obtained from the experiment with the JCPDS (Joint Committee on Powder Diffraction Standards) database phases are identified.

IV. RESULTS AND DISCUSSION

A.1 Aluminium Minerals

Gibbsite- AlH_3O_3 : The basic d-spacing's measured for powder diffraction patterns (Figures 1 and 2) of bulk samples of aluminous laterite/laterite, the separated phases and the loose material of altered granitic gneiss, in all of which gibbsite is the abundant mineral phase, are given in Tables 2 to 4. Gibbsite ($\text{Al H}_3 \text{ O}_3$) has monoclinic symmetry ($a=8.6750 \text{ \AA}$, $b=5.0690 \text{ \AA}$, $c=9.7260 \text{ \AA}$, $\beta=94.550^\circ$) with the space group $p21/n1$, and the unit cell contains eight $\text{Al}(\text{OH})_3$ units. The identified distinctive peaks of the gibbsite are 4.8466, 4.3272, 3.3446, 2.4506, 2.3446, 2.1642, 1.9939, 1.80381 and 1.3165. In figures, the XRD pattern obtained on the as received gibbsite powder shows a good agreement with the reference XRD pattern (33-0018 JCPDS file). The observed strongest three peaks are match well with the monoclinic gibbsite of $\text{Al H}_3\text{O}_3$ (JCPDS, CARD NO. 33-0018). Quantitatively gibbsite occurs in association with kaolinite, boehmite and hematite with very high to medium proportion. Gibbsite also characterized by some shoulder peaks in diffractogram. However, a little shift of the peak has been observed, this shift may be due to the occurrence of water molecule in it. The 'd' spacing's and intensities of the peaks obtained for study area gibbsite match up to very well with those reported in the powder diffraction file data of JCPDS/ICCD PDF File 2, 2018.

Boehmite (Al HO.08O_2): The other most important aluminium mineral identified as boehmite (Al HO.08O_2) has orthorhombic crystal system ($a=3.6930 \text{ \AA}$, $b=12.2210 \text{ \AA}$ and $c=2.8650 \text{ \AA}$) with the space group $A m a m$, and the significant peaks of the boehmite are 6.1148, 3.1668, 2.3446, 1.8594, 1.8415, 1.6635, 1.4494, 1.3816 and 1.3120. However, the intensity of the peaks was found weak in contrast to gibbsite. In a few samples boehmite recorded with a minor shift of the peaks, this is also because of intrusive of the water molecules and quantitatively the boehmite occurs in not as much of gibbsite. The main diffraction peaks could be indexed within experimental error as the orthorhombic phase of boehmite AlOOH (JCPDS CARD NO. 00-021-1307) and as cubic γ - Al O (JCPDS card No. 00-001-1303), respectively (Figures 1 and 2).

A.2 Iron Minerals

Hematite: The XRD pattern of laterites show occurrence of hematite in all zones is marked by distinctive reflection line at 2.6980 with variable intensities. In the samples of aluminous laterite the most prominent line of d-spacing 2.6980 of hematite is with weak intensities. In the ferruginous laterite the intensity of this line is comparatively stronger than clay and altered granitic gneiss (Figures 1 and 2). Hematite has the d-spacing value around 2.5168 with weak intensities. From such variation in intensities of d-spacing values in different zones can be attributed that the amount of hematite is qualitatively more in the zone of ferruginous laterite. In the samples, hematite found as insertion with gibbsite, boehmite and anatase. The occurrence of ferrous minerals causes scattering in diffractogram. The characteristic peaks of the hematite are 2.6980, 3.6828, 2.5168, 2.2898, 2.2054, 1.8415, 1.6945, 1.4859, 1.4537 and 1.3120. The observed peaks match well with the Trigonal (hexagonal axes) hematite of Fe_2O_3 (JCPDS CARD NO. 33-0664).

Goethite: Goethite is found in association with hematite, maghemite and a small amount of lepidocrosite constitute the secondary iron minerals found in laterite profiles of the study area. Though, the colour is not a certain guide to mineralogy or chemistry of samples, but in a general way, it is seen that the yellow iron oxides are more hydrated than the red ones. Goethite is present almost generally, in all localities and in all horizons of lateritic profile, of course its proportion is quite variable (plentiful to traces). It is a dominant mineral phase recognized in the ferruginous laterite of the lateritic duricrust. Laterite and ferruginous/aluminous laterites contain this mineral in moderate amount only (Figures 1 and 2). Goethite is identified by the characteristic X-ray diffraction peaks at 4.9796, 4.1644, 3.3478, 2.6858, 2.57321.9082, 1.6571 and 1.2595.

A.3 Clay Minerals

Kaolinite: Kaolinite is important clay mineral and its occurrence is recorded throughout the lateritic profile, but it is a main mineral phase particularly in the lithomarge clay zone. In the investigated area it is present in most profiles and it forms distinct horizons within the saprolite zone (Figures 1 and 2). In general, there is a gradual increase of kaolinite downward the profile from ferruginous laterite to lithomargic clay. A few duricrust samples also demonstrate minute extent of kaolinite, except aluminous rich laterite zone of the weathering profile contains inadequate quantity of this mineral. The maximum XRD peak intensity is recorded in the lithomarge clay zones of the lateritic profile. According to Gillott [23], the comparative quantity of the different lithomarge clay in a sample could be approximately estimated from the relative intensities of the reflection in XRD pattern which is directly proportional to its concentration. Separated laterite phases at some places also show considerable amount of this mineral, apparently representing material transported

from close by kaolinite horizon. This mineral has been recognized through its characteristic X-ray diffraction peaks at 7.1544, 4.4613, 4.3672, 3.5767, 2.3872, 2.3425, 2.2963, 1.6699, 1.9836, 1.6580 and 1.3086.

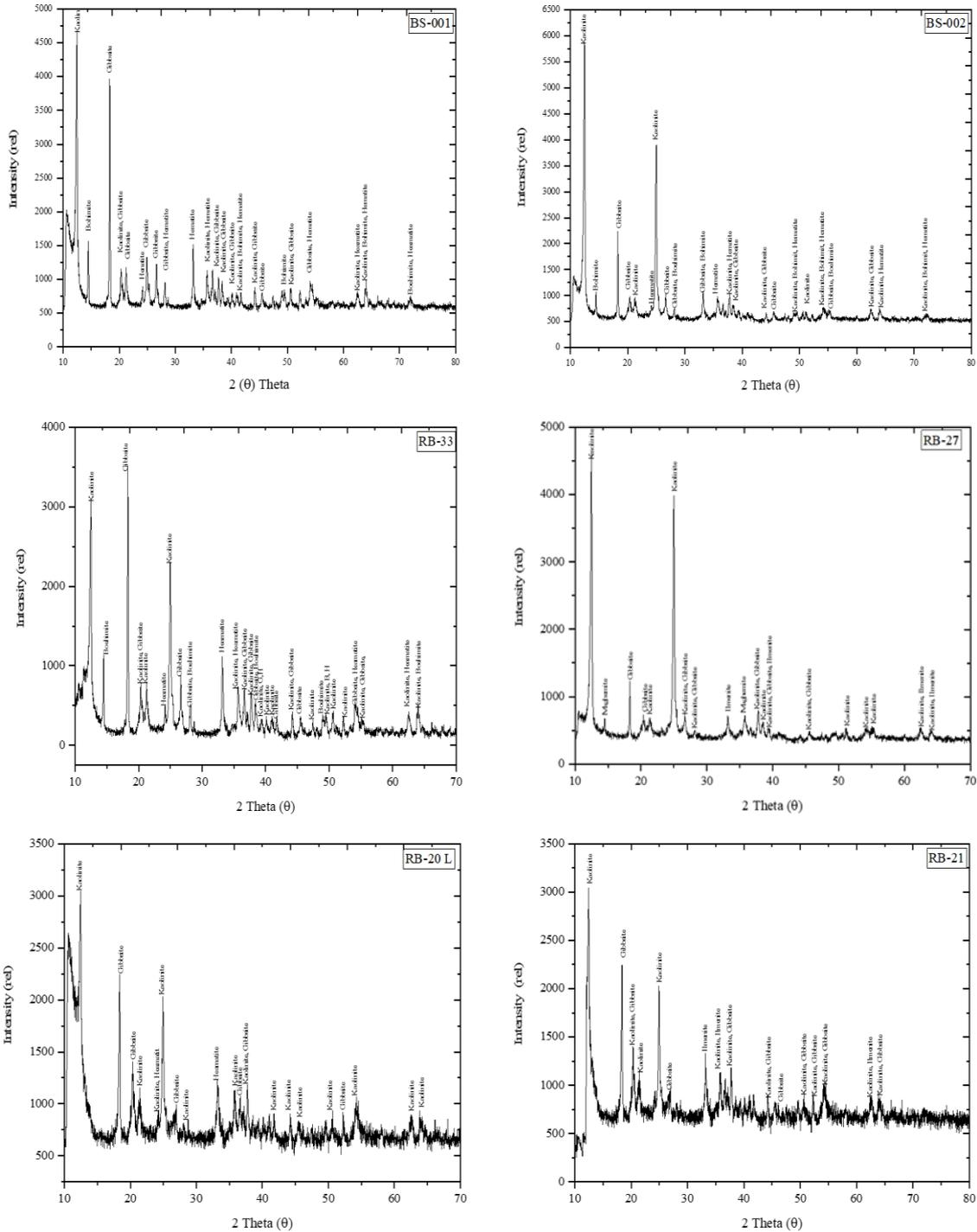


Fig 1: X-RAY Diffraction charts (sample no. BS-001, BS-002, RB-33, RB-27, RB-20L and RB-21)

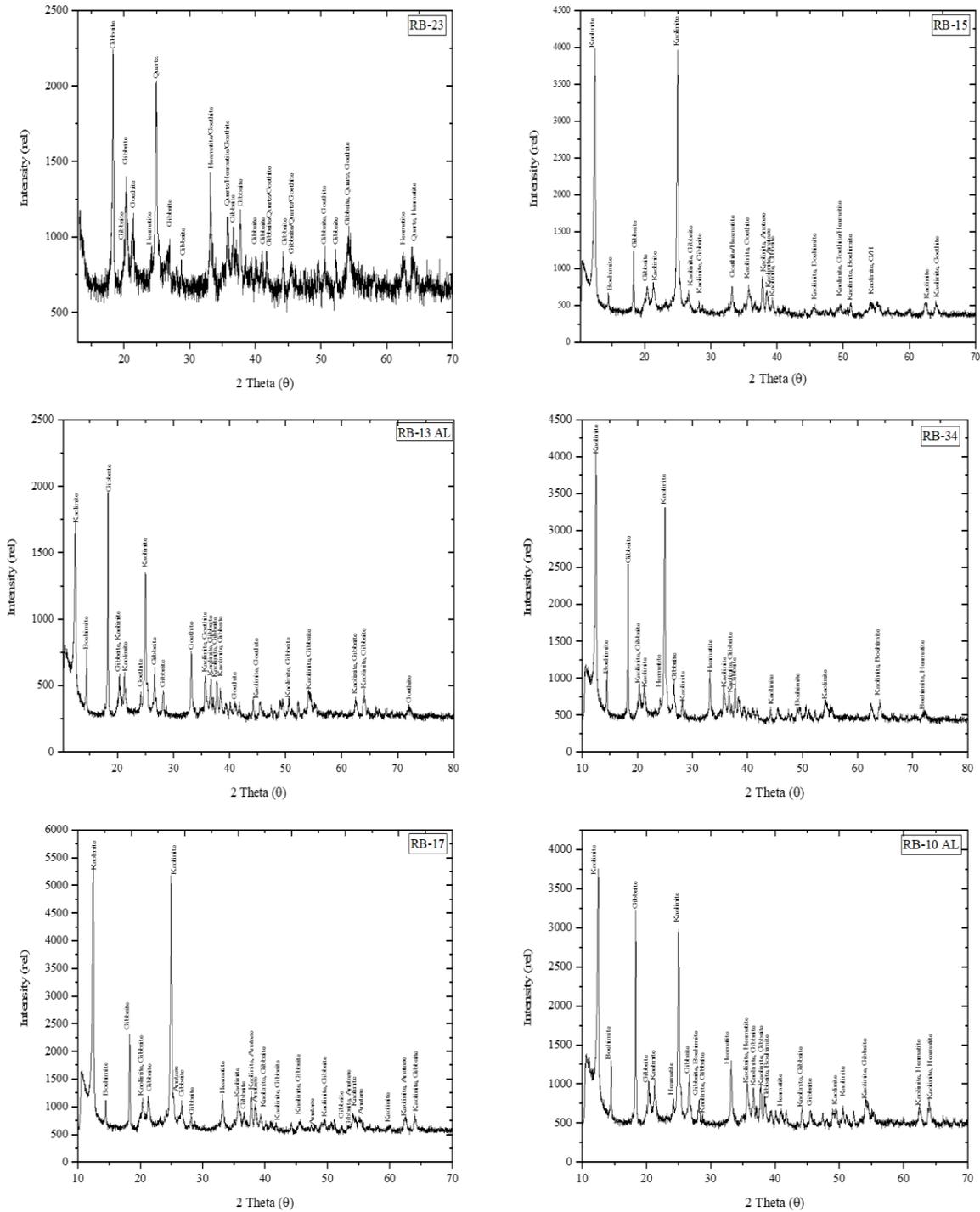


Fig 2: X-RAY Diffraction charts (sample no. RB-23, RB-15, RB-13 AL, RB-34, RB-17 and RB-10 AL)

Table 2. X-Ray Diffraction of Laterite samples from the study area

Sample No. BS-001				Sample No. BS-002			Sample No. RB-33		
Sl. No.	2 Theta (θ)	d-[Å]	Identified	2 Theta (θ)	d-[Å]	Identified	2 Theta (θ)	d-[Å]	Identified
1	12.41	7.127	Kaolinite	12.38	7.144	Kaolinite	12.38	7.142	Kaolinite
2	14.46	6.119	Boehmite	14.41	6.143	Boehmite	14.41	6.144	Boehmite
3	18.29	4.848	Gibbsite	18.23	4.864	Gibbsite	18.23	4.864	Gibbsite
4	20.30	4.372	Kaolinite, Gibbsite	20.26	4.381	Kaolinite, Gibbsite	20.24	4.384	Kaolinite, Gibbsite
5	20.52	4.326	Gibbsite	20.48	4.333	Gibbsite	20.48	4.333	Gibbsite
6	21.22	4.184	Kaolinite	21.38	4.153	Kaolinite	21.16	4.195	Kaolinite
7	24.14	3.684	Heamatite	24.08	3.693	Heamatite	24.08	3.693	Heamatite
8	24.92	3.570	Kaolinite	24.91	3.571	Kaolinite	24.90	3.573	Kaolinite
9	26.61	3.347	Gibbsite	26.57	3.352	Gibbsite	26.56	3.354	Gibbsite
10	26.89	3.313	Gibbsite	28.08	3.175	Gibbsite	26.80	3.323	Gibbsite
11	28.14	3.169	Boehmite	28.64	3.114	Kaolinite, Gibbsite	28.08	3.176	Gibbsite
12	33.17	2.698	Heamatite	33.12	2.703	Heamatite	28.65	3.114	Kaolinite, Gibbsite
13	35.64	2.517	Heamatite	33.78	2.652	Gibbsite	33.11	2.703	Heamatite
14	36.63	2.451	Kaolinite, Gibbsite	35.54	2.524	Heamatite	35.59	2.521	Heamatite
15	37.70	2.384	Kaolinite, Gibbsite	36.57	2.455	Kaolinite, Gibbsite	36.57	2.455	Kaolinite, Gibbsite
16	38.35	2.345	Boehmite	37.60	2.390	Kaolinite, Gibbsite	37.66	2.387	Kaolinite, Gibbsite
17	40.11	2.247	Kaolinite, Gibbsite	38.31	2.347	Gibbsite	38.30	2.349	Gibbsite
18	40.82	2.209	Heamatite	40.78	2.211	Heamatite	40.04	2.250	Kaolinite, Gibbsite
19	41.72	2.163	Gibbsite	41.65	2.167	Gibbsite	40.76	2.212	Heamatite
20	44.18	2.048	Kaolinite, Gibbsite	44.11	2.051	Kaolinite, Gibbsite	41.65	2.167	Gibbsite
21	45.38	1.997	Gibbsite	45.40	1.996	Gibbsite	44.12	2.051	Kaolinite, Gibbsite
22	47.38	1.917	Kaolinite, Gibbsite	47.35	1.918	Kaolinite, Gibbsite	45.32	1.999	Gibbsite
23	48.95	1.859	Boehmite	48.91	1.861	Boehmite	47.33	1.919	Kaolinite, Gibbsite
24	49.46	1.841	Boehmite	50.51	1.805	Kaolinite, Gibbsite	48.89	1.861	Boehmite
25	50.55	1.804	Kaolinite, Gibbsite	51.05	1.788	Kaolinite	50.50	1.806	Kaolinite, Gibbsite
26	52.20	1.751	Kaolinite, Gibbsite	52.15	1.753	Kaolinite, Gibbsite	52.15	1.753	Kaolinite, Gibbsite
27	54.02	1.696	Heamatite	54.00	1.697	Gibbsite	54.01	1.696	Heamatite
28	54.42	1.685	Kaolinite, Gibbsite	54.37	1.686	Kaolinite, Gibbsite	54.37	1.686	Kaolinite, Gibbsite
29	63.99	1.454	Boehmite	55.07	1.666	Kaolinite	62.32	1.489	Heamatite

A.4 Titanium Minerals

Anatase: Anatase as titanium mineral is observed in all the samples during XRD studies and the chemical composition also reflected the higher content of TiO₂ of sample collected from the study area. TiO₂ exists in three forms namely rutile, anatase, and brookite. Rutile is a relatively abundant whereas anatase, and even more so brookite, is rarely found in nature. Anatase is a metastable phase of TiO₂, and its alteration to rutile involves an irreversible collapse of the anatase structure. The distinguishing peaks of the anatase are 3.5265, 2.3872, 2.3425, 1.8799, 1.6635 and 1.4902. The observed three peaks match very well with the tetragonal anatase of TiO₂ (JCPDS CARD NO. 21-1272). Quantitatively, the anatase occurs in association with gibbsite and boehmite with very low proportion. Anatase also characterized by some shoulder peaks in diffractogram (Figures 1 and 2).

Table 3. X-Ray Diffraction of Laterite samples from the study area

Sl. No.	Sample No. RB-27			Sample No. RB-20L			Sample No. RB-21		
	2 Theta (θ)	d-[Å]	Identified	2 Theta (θ)	d-[Å]	Identified	2 Theta (θ)	d-[Å]	Identified
1	12.48	7.088	Kaolinite	12.35	7.160	Kaolinite	12.35	7.160	Kaolinite
2	15.05	5.883	Maghemite	18.28	4.850	Gibbsite	18.28	4.849	Gibbsite
3	18.31	4.843	Gibbsite	19.98	4.440	Kaolinite	19.98	4.440	Kaolinite
4	18.35	4.832	Maghemite	20.26	4.379	Gibbsite	20.26	4.379	Gibbsite
5	20.40	4.350	Gibbsite	20.49	4.330	Gibbsite	20.49	4.330	Gibbsite
6	20.58	4.312	Gibbsite	21.35	4.159	Kaolinite	21.34	4.159	Kaolinite
7	23.15	3.840	Kaolinite	24.12	3.687	Heamatite	24.12	3.687	Heamatite
8	23.89	3.722	Maghemite	24.86	3.578	Kaolinite	24.86	3.578	Kaolinite
9	24.14	3.684	Ilmenite	26.52	3.359	Gibbsite	26.52	3.358	Gibbsite
10	24.99	3.560	Kaolinite	26.85	3.318	Gibbsite	26.85	3.317	Gibbsite
11	26.24	3.393	Goethite	27.90	3.195	Gibbsite	27.97	3.188	Gibbsite
12	32.26	2.773	Maghemite	28.65	3.113	Gibbsite	33.15	2.700	Heamatite
13	32.61	2.744	Kaolinite	32.80	2.728	Kaolinite	35.72	2.512	Kaolinite
14	33.24	2.693	Ilmenite	33.08	2.706	Heamatite	36.36	2.469	Gibbsite
15	33.93	2.640	Gibbsite	35.72	2.512	Heamatite	36.58	2.455	Kaolinite
16	34.94	2.566	Kaolinite	36.36	2.469	Gibbsite	37.04	2.425	Kaolinite
17	35.79	2.507	Maghemite	36.58	2.455	Gibbsite	37.66	2.386	Anatase
18	36.04	2.490	Gibbsite	37.03	2.425	Gibbsite	41.68	2.165	Heamatite
19	39.72	2.267	Kaolinite	37.66	2.386	Gibbsite	44.61	2.030	Gibbsite
20	41.53	2.173	Kaolinite	39.24	2.294	Gibbsite	45.26	2.002	Gibbsite
21	44.20	2.048	Gibbsite	40.05	2.249	Gibbsite	47.34	1.919	Gibbsite
22	47.26	1.922	Kaolinite	40.70	2.215	Kaolinite	47.86	1.899	Kaolinite
23	49.41	1.843	Kaolinite	40.94	2.203	Gibbsite	49.34	1.846	Kaolinite
24	52.28	1.749	Gibbsite	41.68	2.165	Gibbsite	50.51	1.806	Kaolinite
25	54.64	1.679	Kaolinite	44.10	2.052	Kaolinite	51.00	1.789	Kaolinite
26	56.76	1.621	Kaolinite	45.26	2.002	Kaolinite	52.16	1.752	Kaolinite
27	60.94	1.519	Maghemite	47.34	1.919	Kaolinite	53.94	1.699	Heamatite
28	63.81	1.458	Maghemite	50.51	1.806	Kaolinite	54.40	1.685	Kaolinite
29	66.17	1.411	Gibbsite	52.16	1.752	Gibbsite	58.00	1.589	Kaolinite

A.5 Other Minerals-Relic-Minerals

Quartz (SiO₂): Quartz occurs as the major resistant relic mineral in the entire profile of the study area; primarily the minerals of the precursor granitic gneiss are distinguished to occur as intermittent resistant relics in almost the entire lateritic profile. It shows decreasing trend from lithomargic zone upwards into aluminous laterite and slight increase upwards into ferruginous laterite. Laterite and aluminous laterites however show negligible quartz. This mineral phase has been identified by the characteristic X-ray diffraction peaks at 3.584, 2.838, 2.380, 1.980, 1.803, 1.453 and 1.379. The mineral quartz is a ubiquitous mineral present in all the samples recorded and identified by XRD-data (Table 2 to 4 and Fig 1 and 2).

Feldspars: The feldspar minerals occur as small anhedral grains. The optical properties suggest that K-feldspar and plagioclase occur as residual minerals. The XRD patterns obtained for the altered granitic gneiss (Table 2 to 4 and Fig. 1 and 2) have recorded d-spacing value which is for the mineral albite.

Table 4. X-Ray Diffraction of Laterite and Aluminium Laterites samples from the study area

Sl. No.	Sample No. RB-23			Sample No. RB-15			Sample No. RB-13AL		
	2 Theta (θ)	d-[Å]	Identified	2 Theta (θ)	d-[Å]	Identified	2 Theta (θ)	d-[Å]	Identified
1	18.24	4.860	Gibbsite	12.29	7.195	Kaolinite	12.37	7.148	Kaolinite
2	20.22	4.388	Gibbsite	14.44	6.128	Boehmite	18.22	4.866	Gibbsite
3	20.48	4.333	Gibbsite	18.27	4.853	Gibbsite	20.23	4.386	Gibbsite
4	21.31	4.167	Goethite	19.95	4.448	Kaolinite	20.47	4.335	Gibbsite
5	24.07	3.694	Heamatite	20.53	4.323	Gibbsite	21.15	4.197	Kaolinite
6	24.82	3.584	Quartz	21.42	4.146	Kaolinite	24.07	3.694	Heamatite
7	26.81	3.323	Gibbsite	24.46	3.636	Heamatite	24.89	3.574	Kaolinite
8	27.86	3.200	Gibbsite	24.82	3.585	Kaolinite	26.55	3.355	Gibbsite
9	28.61	3.117	Gibbsite	25.30	3.517	Anatase	26.80	3.324	Gibbsite
10	31.50	2.838	Quartz	26.85	3.318	Gibbsite	28.07	3.177	Gibbsite
11	33.10	2.704	Heamatite	29.10	3.066	Boehmite	33.10	2.704	Heamatite
12	33.42	2.679	Goethite	30.20	2.957	Magnetite	35.58	2.521	Heamatite
13	35.68	2.515	Kaolinite	33.74	2.654	Gibbsite	36.56	2.456	Gibbsite
14	36.32	2.472	Goethite	34.75	2.580	Goethite	37.65	2.387	Gibbsite
15	36.54	2.457	Gibbsite	35.12	2.553	Kaolinite	38.29	2.349	Gibbsite
16	36.99	2.428	Kaolinite	35.36	2.536	Kaolinite	40.75	2.213	Heamatite
17	37.62	2.389	Gibbsite	36.92	2.433	Anatase	41.64	2.167	Gibbsite
18	39.20	2.297	Gibbsite	37.58	2.391	Gibbsite	44.11	2.051	Gibbsite
19	40.01	2.252	Gibbsite	38.80	2.319	Goethite	45.04	2.011	Gibbsite
20	40.90	2.205	Heamatite	41.03	2.198	Heamatite	45.31	2.000	Gibbsite
21	44.06	2.054	Gibbsite	41.65	2.167	Gibbsite	54.00	1.697	Heamatite
22	50.47	1.807	Gibbsite	43.26	2.090	Gibbsite	54.36	1.686	Anatase
23	50.97	1.790	Goethite	44.98	2.014	Goethite	62.31	1.489	Heamatite
24	52.12	1.753	Gibbsite	46.81	1.939	Kaolinite	63.92	1.455	Kaolinite
25	53.90	1.700	Magnesite	51.55	1.772	Goethite	64.13	1.451	Kaolinite
26	54.36	1.686	Anatase	52.03	1.756	Gibbsite	71.55	1.318	Gibbsite
27	56.12	1.638	Gibbsite	53.23	1.720	Goethite	71.83	1.313	Heamatite

V. CONCLUSION

XRD investigations of the lateritic profile of the study area divulge the gibbsite is a main mineral phase identified, except the altered granitic gneiss and in lithomargic clay it occur in negligible to scares amount. Gibbsite has a gradual upward increase in the profile with the corresponding decrease of kaolinite clay mineral. Gibbsitization of kaolinite is prominent in laterites and aluminous laterite. However, first generation gibbsite is not clearly seen. Gibbsite occurs throughout as small crystals or grains. These two features indicated fine to medium grained nature of parent rock. Other important aluminium minerals are boehmite and diaspore are found to occur in traces within the aluminous and ferruginous lateritic profile except lithomargic clay zone.

Goethite and hematite are the important iron minerals occurring in good amount in ferruginous laterite and slight amount in aluminous laterite. Average goethite content is less than hematite in aluminous laterite. Kaolinite is a major clay mineral identified in the lithomarge clay horizon and gets depleted in ferruginous laterite. Kaolinite content is generally lowest in the middle part of the profile (aluminous laterite). Anatase and rutile are the titanium bearing mineral phases does not show any marked variation except it is slightly higher in aluminous laterite zone. Quartz shows a decreasing trend from altered loose granitic gneiss materials through lithomargic clay up profile into aluminous laterite and slightly enriched upward into ferruginous laterite zone. There is a marked variation in the contents of gibbsite, goethite, hematite and anatase in the coloured phase of aluminous laterite. Gibbsite and anatase show a gradual increase from reddish brown

phase to white phase. Goethite and hematite show a decreasing trend from reddish brown to white phases of laterites. Kaolinite remains more or less uniform in all the phases except the clay zone in which it decreases. It increases slightly in laterites and becomes predominant in this saprolite horizon.

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