

## **New scope of exploration and techno-economic studies of laterites and bauxites in regions covered with Gondwana sediments**

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### **Abstract**

Lateritic bauxite deposits have been formed from almost every type of rock containing alumina. Distribution and quantity of deposits are related to the type of parent rock. Most bauxite deposits are from sedimentary parent rocks, mostly Arkosic sandstones and siltstones. Naru Hill bauxite deposit is from arenaceous shale or siltstone parent rock, completely altered into laterite/bauxite. Laterite profile appears to rest fresh sandstones which are not the parent rocks, but are hard protecting surface for the deposits. This study is on petrogenesis of Lohardaga bauxite deposit. It was earlier established that the Lohardaga bauxite originated from trap basalts near the sea level during early Tertiary, but recent study changed this view. This study concludes: Bauxite and laterites of the Lohardaga plateau are derived from underlying clayey sediments. Diatoms and sedimentary structures indicate that these sediments were laid down in shallow fresh water and are probably of Upper Gondwana age. Recent studies on Vindhyan bauxite particularly of Satna and Lohardaga leave scope for detailed exploration of laterite and bauxite in regions covered with Gondwana sediments. The bauxite of Satna and Rewa is gibbsite-boehmite and of Lohardaga, gibbsitic. These are metallurgical and high grade refractory bauxites. They can undergo detailed techno-economic studies.

**Keywords:** Lateritic bauxite; Lohardaga deposit; Gondwana sediments; Satna deposit.

### **1. Laterites and bauxites of India**

Laterite is extensively distributed in the Peninsular India. It is common in the greater part of Maharashtra, Madhya Pradesh and Bihar over Deccan Traps. In Madhya Pradesh they lie over Deccan Traps as well as over Vindhyan sandstone and shale. There are several occurrences of lateritic bauxites in Eastern Ghats over Khondalites and charnockites, however they lie over Deccan traps and charnockites of Western Ghat in Maharashtra and Karnataka. Many deposits of bauxite and laterite in Kerala and Goa are also found over gneisses and meta sediments. There are also numerous occurrences of thin crusts of laterite in many other parts of India on rocks of almost every description. Country wide search for bauxites in different lateritic terrains of India was first made by Fox [1]. He first recognized bauxite in India amongst the aluminous laterite of Jabalpur.

The Indian bauxites are mostly of lateritic origin, which occur extensively as blankets or cappings either on the high plateaux and hill ranges of the peninsular India or in certain low-level laterites in the inland areas or coastal tracts of the country.

The smaller isolated areas where plateau laterite and bauxite occur are Kharagpur hills of Bihar; Seoni, Kaimur and Malwa plateaux and Keskai-Bailadila range of Chhatisgarh, Vindhyan plateau bordering Uttar Pradesh and Madhya Pradesh (including Tikar and Naru deposits) and Kumbla in Kerala.

In the Extra peninsular India fairly extensive deposits of high grade diasporic bauxite occur in the Jammu Province of the Jammu and Kashmir state.

A survey of literature on lateritic bauxite occurrences of world shows that lateritic bauxite deposits have been formed from almost every type of rock that contains alumina. It has been also observed that there is a certain

relationship between the distribution and quantity (tonnage) of the deposits, and the type of the parent rock<sup>2</sup>. Table-1 presents the statistical evaluation in this respect.

Among igneous rocks, plutonic and volcanic group of rocks are more prominent from bauxite formation point of view. In plutonic rocks bauxite was mainly derived from granite. The largest granite derived deposits occur in the Darling Range, Australia [3], and at Los pijiguaos, Venezuela. Medium size granite-derived deposits have been found east of Dalat in southern Vietnam and and at Digo - Mokouedou, Ivory Coast. Nepheline syenite and foyalite are the parent rocks of several small to medium size deposits e.g. Arkansas, USA; Los Islands, Guinea etc; In India such deposits are found in Ranchi district Bihar. Volcanic group of rocks is most frequent igneous parent rock group. Within this group, basalt is the most frequently occurring volcanic parent rock. Extensive basalt derived deposits are in southern Vietnam, in Cameroon (Adamaoua) and in Australia (North Kimberely bauxite district).

Prominent Inidan bauxite deposits which have been derived from basalt parent rock are:

- i. Surguja, Phutkapahar, Maikala range and Malwa plateau deposits, Madhya Pradesh.
- ii. Kutch Peninsula, Mewasa-Virpur, Jamnagar district of Gujarat.
- iii. Kolaba, Ratnagiri, Udgiri, Dhargarwadi and Kolhapur district in Maharashtra.

The proportion of the metamorphic rocks is the smallest among the main genetic rock groups, but few major bauxite deposits of India namely East coast bauxite deposits and deposits of Tamilnadu fall within this group of parent rock. Here parent rocks are metamorphic rocks of granulite facies such as Khondalite, Charnockite and leptynite. Chief deposits of this group are:

- i. Nilgiri hills, Palni hills, Shevaroy hills and Kollaimalai hills in Tamilnadu.
- ii. Chintapalli and Anantgiri hills in Andhra Pradesh
- iii. Pottangi, Panchpatmali, Kashipur-Kuturmali Gandhmardan and Sapatla deposits of Orissa.

Table 1 shows that a largest proportion of Bauxite deposits has been derived from sedimentary parent rocks. The most frequent parent rock types of this group are Arkosic sandstones and siltstones. In some locations these arkosic sandstones also contain glauconite.

Next in the series as favourable sedimentary parent rocks are shales and slates of palaeozoic to upper-porterozoic age, well compacted and consolidated. Here the alumina of the bauxite originated mainly from illite-sericite and chlorite type clay minerals. The largest deposits derived from these parent rocks are in Guinea (Boke, Fria, Kindia, Pita-labe) and in the adjacent Boe district of Guinea Bissau. Relatively little bauxite has been formed from kaolinitic sandstone and siltstone e.g. AzZabirah of Saudi Arabia. Even small bauxite deposits had been originated from graywacke e.g. Kibi-Atewa Range in Ghana and Benene in Ivory coast.

**Table 1. The proportion of parent rock types and tonnage of bauxite in the world [2].**

Rock Types	Number of Bauxite Districts	Percentage of Tonnage of Bauxite	Remark
<b>(A) Plutonic Rocks</b>			<b>Plutonic Rocks 15.5%</b>
Granite	10	9.0	
Diorite, Granodiorite	02	1.3	
Monzonite	01	0.7	
Anorthosite	01	0.2	
Lecucogabbro	01	0.1	
Gabbro, Norite	05	3.0	
Syenite	01	0.1	
Nepheline-Syenite, Foyalite	05	0.8	
Dunite, Peridotite	01	0.3	
<b>Total</b>		<b>15.5</b>	
<b>(B) Hypabyssal Rocks</b>			<b>Hypabyssal Rocks 17.3 %</b>
Dolerite	16	17.1	

Pyroxenite	01	0.1	
TinguaiteMetasomasized	01	0.1	
Dolostone	01	0.1	
<b>Total</b>		<b>17.3</b>	
<b>(C) Volcanic Rocks</b>			
<b>Rhyolite</b>	<b>02</b>	<b>0.1</b>	<b>Volcanic Rocks 20.3 %</b>
<b>Trachyte</b>	<b>02</b>	<b>0.1</b>	
<b>Andesite</b>	<b>05</b>	<b>0.9</b>	
<b>Basalt</b>	<b>22</b>	<b>19.0</b>	
<b>Phonolite</b>	<b>02</b>	<b>0.1</b>	
<b>Undifferentiated Volcanic rocks</b>	<b>01</b>	<b>0.1</b>	
<b>Total</b>		<b>20.3</b>	
<b>(D) Metamorphic Rocks</b>			
<b>Metavolcanics (Basic)</b>	<b>02</b>	<b>0.1</b>	<b>Metamorphic Rocks 12.8 %</b>
<b>Greenstone</b>	<b>05</b>	<b>0.1</b>	
<b>Schist (Mainly Sericitic)</b>	<b>10</b>	<b>0.9</b>	
<b>Amphibolite</b>	<b>07</b>	<b>19.0</b>	
<b>Hornfels</b>	<b>03</b>	<b>0.1</b>	
<b>Gneiss, Granite-Gneiss</b>	<b>02</b>	<b>0.1</b>	
<b>Total</b>		<b>12.8</b>	
<b>(C) Sedimentary Rocks</b>			
<b>Kaolinitic Sandy Clay</b>	<b>04</b>	<b>10.6</b>	<b>Sedimentary Rocks 34.1 %</b>
<b>Shale, Slate</b>	<b>10</b>	<b>10.0</b>	
<b>Kaolinitic Siltstone, Sandstone</b>	<b>02</b>	<b>0.4</b>	
<b>Arkosic Sandstone-Siltstone</b>	<b>10</b>	<b>12.9</b>	
<b>Graywacke</b>	<b>02</b>	<b>0.2</b>	
<b>Total</b>		<b>34.1</b>	

In India bauxite deposits derived from sedimentary parent rocks are mainly restricted to Vindhyan formations of Madhya Pradesh and Uttar Pradesh. The bauxite deposits of Banda, Varanasi, and Mirzapur district, Uttar Pradesh and Satna, Rewa area, Madhya Pradesh were considered to have been derived from Vindhyan sandstone/shale [4]. The bauxite deposits of Monghyr, Bihar, and Bhimsen hill, Chandarpur district Maharashtra, have also been derived from shale of proterozoic age and Gondwana age respectively [5, 6].

Thus genetic study of laterite/bauxite deposits i.e. derivation of laterite profile gives us scope for exploration of new laterite and bauxite deposits. The present study discusses the cases of two bauxite deposits, the Naru Plateau of Satna district Madhya Pradesh and Lohardaga bauxite deposit of Jharkhand.

## **2. The study of Naru bauxite deposit, Satna District MP**

### **2.1. Location and approach**

The Naru plateau, locally known as Naru hill lies between longitude 80°59' to 81° and latitude 24°26' to 24° 30'30". The area falls in survey of India toposheet number 63 D/14 and D/15 and belongs to Satna district. Naru plateau can be approached from Satna by all weather Satna-Rewa road for 9 km up to Modhogarh, and then for another 6 km from Madhogarh by fair weather road up to base of the hill. From base of the hill to top, there is a Ghat section of nearly 3 km distance, which is jeepable in dry weather. Nearest railway station is Satna on Bombay-Howrah line from where Naru plateau is located exactly 18 km south-east.

### **2.2. The laterite profile**

At Naru plateau insitu lateritisation can be seen at the level of 540 m and bauxite bearing laterite horizon is mainly confined to 600 m level. The bauxite bearing laterite profile, here rests over fine to medium grained, massive Bhandar sandstone. But this sandstone gradually changes upward in its nature. It also contains shaly intercalations at higher levels. The average thickness of laterite profile is about 60 m. The profile has various zones, sub zones and layers. A generalised laterite profile of Naru plateau is presented in Figure 1.

### **2.3. Petrography/mineralogy of laterite profile**

#### **2.3.1. Bed Rock**

Fresh rock at the base of laterite profile of Naru plateau is upper Bhandar sandstone which is hard, thick- cross bedded to massive and intercalated with shale and siltstone. The fabric of Bhandar sandstone is that of quartz arenite having quartz as the dominant framework constituent. In a few types clay pellets are also present. Grain contacts are numerous, mostly straight to concavo-convex. It appears that there was some compaction and rearrangement of grains. Most of the grains appear to be equant hence there is no preferred shape orientation. The initial cement seems to be silica, later on replaced by iron oxide. The grain size distribution is that of a moderately well sorted fine to medium grained sand. Large number of quartz grains is sub-angular to sub-rounded, but roundness is difficult to estimate in many grains due to overgrowth. In the absence of micas and clay- matrix these sandstones may be placed in the category of sub mature to mature. Quartz is mostly of the monocrystalline type, a few grains show overgrowths, a few chert fragments, nearly rounded are also present. Felspars are insignificant. However in few cases kaolinised fragments are seen which may be originally felspars, but it is not certain that they have been altered in place. A few rock fragments appear to be dominantly argillaceous pellets. There is a possibility that these argillaceous pellets might have been derived from intercalated and underlying shaly beds. Heavy minerals are scarce. However zircon, tourmaline, and a few grains of rutile are present. Opaque heavy minerals are also present.

#### **2.3.2. Shale/Siltstone interbeds**

The upper Bhandar sandstone is underlain by Sirbu shale. At some adjoining hillocks the laterite cappings rest directly over Sirbu shales, e.g. at Bela, Maihar etc; The interbeds of shale and siltstone within upper Bhandar sandstone have almost identical mineralogy with Sirbu shale. These interbeds of shale are either of red, chocolate or green colour. The colour differences reflect only the state of oxidation of the iron. Red coloured shale is because of the presence of finely divided ferric oxide (hematite) and in the green shale iron is largely in the ferrous state. Fineness of grains of interbeds makes identification of the component minerals uncertain. Under the microscope only the larger grains (over 0.01mm) could be identified with certainty. On the assumption that the finer fraction consists of the same mineral as the coarser portions, though in different proportions, it is possible to calculate the probable composition of the shaly interbeds from its chemical analysis. Such calculations show that the finer fraction is richer in the clay minerals, the clay micas, chlorite and the hydroxides of iron. The coarser part, on the other hand contains more quartz and feldspar. Thus the average mineral composition of shaly interbeds can be given as follows:

Mineral	Percentage
Quartz	32
Kaolinite and Clay minerals	12
Clay-mica, Sericite and Chlorite	22
Limonite/Hematite	1
Felspar	4
Titanite and rutile	2
Other minerals	11

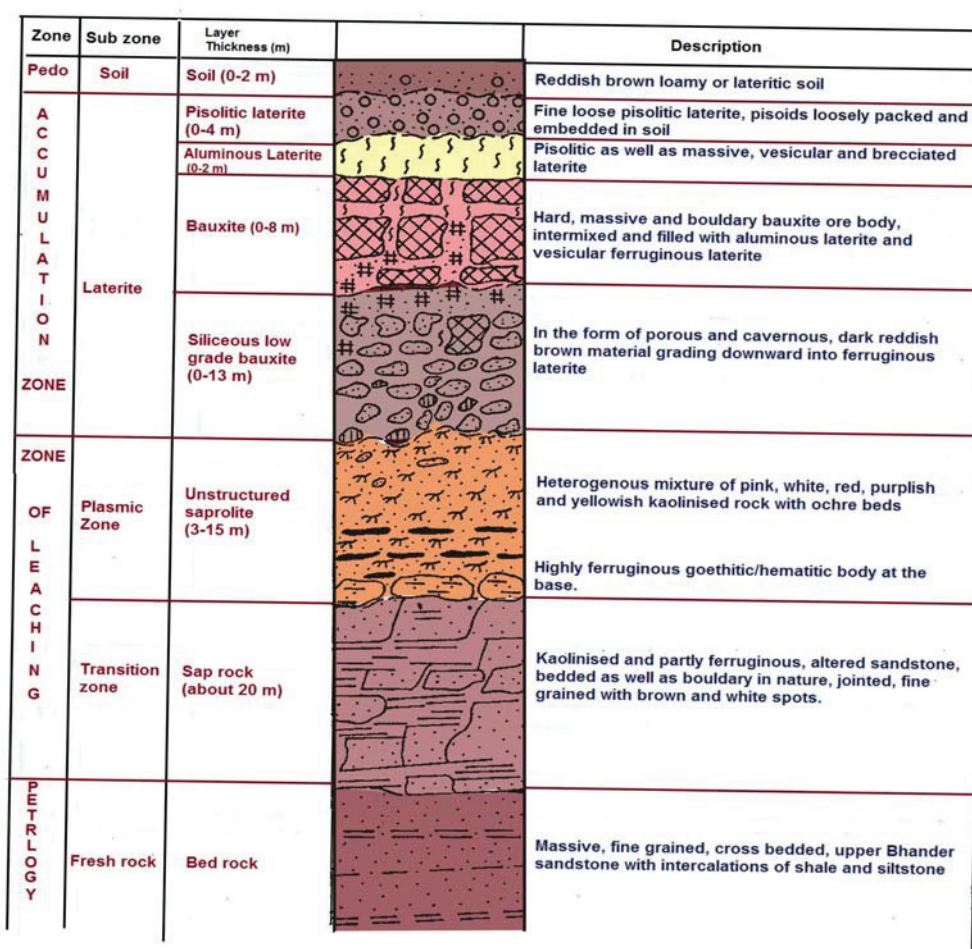


Figure 1. Laterite Profile of Naru Plateau.

This average mineral composition of these shale shows that it consists of about one-third quartz, one third clay minerals and one-third other miscellaneous minerals. Siltstone interbeds are intermediate in character between sandstones and shales. They are richer in silica, poorer in alumina, potash and water than shale, but generally not as rich in silica as are the more mature sands. Mineralogically it contains an abundance of micaeous clay minerals and quartz.

### 2.3.3. Saprolite

The Mineralogy of saprolite horizon of Naru was carried out by XRD method. A few samples of different layers of saprolite horizon from selected locations were run for the XRD. The quantitative mineral phases of different layers of this horizon are given in Table-2. As per mineralogical studies, the saprolite unit can be divided into three distinct layers -

- i. Kaolinite rich white spotted clay with coloured laminations.
- ii. Kaolinite and goethite rich yellow - ochre with pockets of red ochre.
- iii. Highly ferruginous/spongy pockets within the above two members containing mainly hematite, and goethite and other minerals in traces.

### 2.3.4. Laterite/bauxite

Naru bauxite deposits are lateritic bauxite deposits in which gibbsite are the predominant aluminous mineral followed by boehmite and diaspore, like other bauxite deposits of Central India and West Coast. In laterites, goethite and hematite are the chief minerals but their percentage varies with variety of laterite. Kaolinite is main silicate mineral of laterite profile and it is predominant in saprolite/clay horizon. Gibbsite is subordinate in this horizon and occasionally halloysite and montmorillonite is also reported (Table-2). It is also quite significant that quartz is negligible in these laterites and bauxites. Laterites and bauxites of these two areas can be divided into three mineralogically different varieties as follows –

Variety of Ore	Aluminous Minerals	Iron Minerals	Silicate Minerals
Bauxite	60 % to 80 % or more	together up to 20 %	
Aluminous Laterite	50 % to 60 %	0 % to 10 %	20 % to 50 %
Ferruginous Laterite	20 % to 50 %	50 % to 80 %	Up to 10 %

### 2.4. Geochemical behavior of laterite profile

General chemical behaviour of laterite profile of Naru is shown in Table 3. In order to discuss about lateral and vertical variation of different major constituents and chemical changes, profile was studied at three selected locations. Table 3 presents the chemical log with respect to these three locations. The behaviour of major chemical constituents in different units of profile is observed as follows:

(A) **Silica ( SiO<sub>2</sub> )** : At Naru plateau, bed rock contains more than 90 % silica which decreases to 60 % in shale/siltstone interbeds. This decrease is followed by saprolite, laterite and bauxite horizons. The study of chemical log of Naru (Table 5) reveals that SiO<sub>2</sub> increases downward as well as upward from bauxite horizon. In order of increasing silica content, different layers of laterite profile can be arranged as under –

Pisolitic Laterite
Bauxite
Aluminous Laterite
Ferruginous Laterite
Saprolite/Clay
Shale / Siltstone interbeds
Fresh Upper Bhandar Sandstone

**(B)** Silica is mainly contained in clay minerals which are also confirmed by X R D mineralogical analysis (Table 3). Silica present in the form of quartz is occasionally seen in some thin sections. Shale/siltstone interbeds have silica in the form of fine grained quartz and clay minerals. Bed rock i.e. fresh sandstone is purely siliceous containing more than 90 % silica in the form of quartz. Northern and upper half of the middle portion of the plateau is high in silica, as compared to the southern portion of the plateau.

**(C)** Alumina ( $Al_2O_3$ ): General behaviour of alumina in laterite profile of Naru can be seen through Table 3. In fresh Bhandar sandstone and partly kaolinised sandstone the alumina is 1.5 to 7 %, however some exposures of shale and siltstone interbeds within this sandstone, have alumina up to 14 %. This alumina gradually increases up to bauxite horizon. The  $Al_2O_3$  in bauxite samples of Naru varies between 45 to 58 %, but average value as determined from the analysis of samples from different places, is 50 %. As per XRD mineralogical analysis (Table 2), alumina in Naru bauxite is mainly in the form of gibbsite with subordinate amount in the form of boehmite and diasporite.

**(D)** **Iron ( $Fe_2O_3$ ):** Bed rock at Naru contains very less iron (1 % to 2 %), where as it goes up to 10 % - 12 % in shale/siltstone interbeds.  $Fe_2O_3$  in bauxites ranges from minimum 4 % (alumina 58 %) to maximum 19 % (alumina 46 %). Iron gradually increases with depth in profile and reaches to maximum in massive, porous and cavernous ferruginous laterite. But iron movement and deposition is restricted, because of which bauxite is intermixed with laterite. High concentration of iron within saprolite horizon is also noticed in the form of highly ferruginous spongy pockets. Iron is mainly present in the profile as goethite or hematite. Lateral changes in iron are quite diverse and irregular.

**(E)** **Titania ( $TiO_2$ ):**  $TiO_2$  content again is a characteristic feature of Naru bauxite which ranges between 8 - 10 % . It is difficult to explain the  $TiO_2$  content with respect to fresh bed rock i.e. upper Bhandar sandstone, which contains only 0.15 % titanium. However thick shale and siltstone interbeds have titanium upto 1.5 %. With respect to shale interbeds about 7 - 8 times enrichment of  $TiO_2$  is noticed in Naru bauxite. It decreases downward in profile from bauxite to parent rock. Increase or decrease in  $TiO_2$  content with respect to alumina is shown in Table 3.  $TiO_2$  is present mainly in the form of rutile and anatase.

**(F)** **Loss On Ignition (LOI) :** Fresh nature of Bhandar sandstone is confirmed by its LOI content which is 0.5 %. It increases in shale/siltstone interbeds (7 - 8 %) , which proves its weathered nature. Fresh exposures of these interbeds are rarely found around the plateau. LOI values in laterites and bauxites vary between 20 - 27 %.

This behaviour of chemical constituents is shown in Figures 2a and 2b.

Table 2. Quantitative mineralogy of Naru laterite profile.

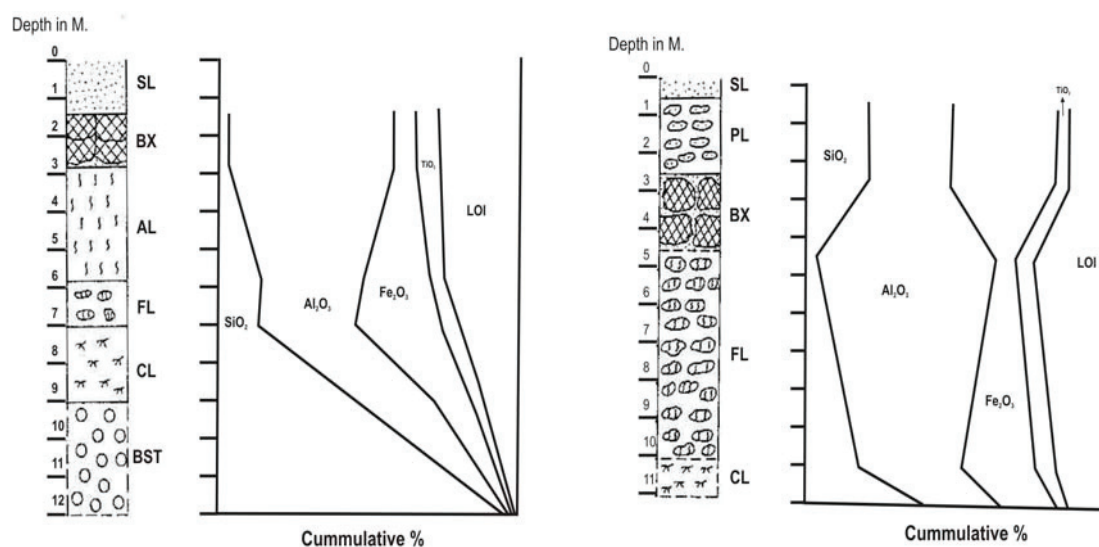
SNo	Horizon	Sample Location	No of samples	GB %	BH %	DI %	AGT %	HM %	KL %	RT %	AN %	CR %	QZ %	HY %	MT %	
1	Ferruginous Pisolitic as well as Massive Aluminous top Laterite	B/P-62	2	22.00	01.00	--	28.00	30.00	13.00	--	01.50	--	02.00	--	--	
		A/P-1	2	31.00	09.00	--	04.00	48.00	06.00	01.00	01.00	--	--	--	--	--
		E/P-18	2	24.00	--	--	30.00	26.00	15.00	--	--	--	--	03.00	--	--
2	Bauxite	E/P-18	2	47.00	08.00	04.00	20.00	05.00	07.00	03.00	04.00	--	--	--	--	--
			2	27.00	--	--	28.00	23.00	16.00	--	--	--	--	03.00	--	--
			2	45.00	10.00	05.00	18.00	08.00	07.00	03.00	03.00	03.00	--	01.50	--	--
3	Fe-rich Laterite	B/P-62	1	65.00	07.50	03.00	04.00	04.00	07.00	02.00	05.00	--	--	--	--	--
		A/P-1	3	80.00	--	--	02.00	05.00	07.00	01.00	01.00	04.00	02.00	--	--	--
		E/P-18	3	76.00	07.00	01.00	04.00	03.00	--	--	01.00	04.00	02.00	--	--	--
4	Saprolite	B/P-62	1	65.00	14.00	--	05.00	02.00	05.00	02.00	03.00	--	--	--	--	06.00
		A/P-1	1	50.00	08.00	--	13.00	10.00	05.50	01.00	01.00	05.00	--	--	--	--
		E/P-18	1	39.00	28.00	02.00	09.00	06.00	04.00	03.00	03.00	07.00	--	--	--	--
5	Sap-Rock	Vg Cl	1	69.00	--	--	16.00	02.00	01.00	03.50	00.50	--	--	02.00	--	--
		Ochre	1	70.00	08.00	04.00	--	02.00	04.00	01.00	01.00	08.00	--	--	--	--
		Wh Cl	1	28.00	--	--	08.00	34.00	--	--	01.00	04.00	--	--	--	06.00
6	Fresh Bhandar Sandstone	Fe-Body	1	25.00	03.00	--	12.00	34.00	20.00	02.00	04.00	--	--	--	--	--
		Down hill	1	28.00	02.00	--	32.00	12.00	19.00	01.00	01.00	02.00	--	--	--	--
		Down hill	1	10.00	--	--	28.00	18.00	38.00	02.00	02.00	02.00	--	02.00	--	--
6	Fresh Bhandar Sandstone		1	05.00	--	--	60.00	--	30.00	--	--	--	05.00	--	--	
			1	05.00	--	--	20.00	--	68.00	--	--	02.00	--	05.00	--	--
			1	--	--	--	10.00	80.00	08.00	--	--	--	--	--	--	--
6	Fresh Bhandar Sandstone	Base	1	--	--	--	08.00	02.00	10.00	01.00	--	--	74.00	--	--	
		Base	2	--	--	--	10.00	02.00	07.00	01.00	01.00	02.00	--	76.00	--	02 .00 ORS
6	Fresh Bhandar Sandstone	Base	1	--	--	--	--	01.00	--	02.00	03.00	--	90.00	--	04.00 ORS	
6	Fresh Bhandar Sandstone	Base	2	--	--	--	--	01.00	--	02.00	03.00	--	91.00	--	03.00 ORS	

**Note:** GB=Gibbsite, BH=Boehmite, DI=Diaspore, AGT=Alumo-Goethite, HE=Hematite, KL=Kaolinite, RT=Rutile, AN=Anatase, CR=Corundum, QZ=Quartz, HY=Halloysite, MT=Montmorillonite, ORS=Other Minerals.

SNo 1 to 5: XRD Study, SNo6: Thin Section Study

**Table 3. General chemical characteristics of laterite profile of Naru.**

SNo	Litho-Units	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub>	LOI
9	Loose Ferruginous Pisolitic Laterite	18.05	28.87	30.16	06.06	17.26
8	Top Aluminous Laterite	06.23	38.12	25.41	06.77	21.42
7	Bauxite	02.95	51.70	11.40	08.53	24.72
6	Lower Fe-rich Laterite / Siliceous low grade bauxite	13.75	39.43	21.31	06.73	23.12
5	Saprolite					
	1. Goethite Zone					
	2. Ochre	05.47	6.25	70.20	03.10	15.67
	3. Variegated Clay	40.06	24.95	17.93	04.08	12.65
4	Shale Interbeds	59.96	15.27	06.43	00.73	04.44
3	Kaolinised Sandstone	88.64	07.16	01.03	00.41	01.89
2	Weathered Siliceous clay	71.30	14.56	08.20	00.18	05.80
1	Fresh Sandstone	96.06	01.35	01.27	00.15	00.53



<p><b>Index</b>                  SL= Soil                  BX= Bauxite                  FL= Ferruginous Laterite                  CL= Clay                  BST= Upper Bhander Sandstone</p>	<p><b>Index</b>                  SL= Soil                  PL= Pisolithic Laterite                  BX= Bauxite                  FL= Ferruginous Laterite                  CL= Clay</p>
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<p><b>Figure 2a.</b> Variation in Chemical Characteristics of Laterite Profile of Naru Plateau                  Location Point: BP-62.</p>	<p><b>Figure 2b.</b> Variation in Chemical Characteristics of Laterite Profile of Naru Plateau                  Location Point: EP-18.</p>
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## 2.5. Genesis of Naru bauxite deposit

Naru bauxite deposit rests over sedimentary rocks (sandstone/shale) of Vindhyan Supergroup. Detailed field observations, mineralogical, petrographical and geochemical studies of laterite profile of Naru plateau discussed above draw attention towards following peculiar features:

2.5.1 The general chemical characteristics of Naru laterite profiles presented in Table- show that Upper Bhander sandstone found at the base of laterite profile of Naru, have more than 90 % silica and very low percentage of titania (about 0.2 %), alumina (less than 2 %) and iron (up to 2 %). The normal principle of enrichment and depletion of elements<sup>7</sup> does not justify these sandstones as parent rocks.

2.5.2 It is important to note that bauxite deposits of the world, originated from sandstone parent rock (Table 2) viz Weipa, Marchinbar (Australia), Ricanau, Onverdacht (Suriname) etc., are characterised by low titanium content of bauxite, derivation of laterite profile from arkosic or felspathic sandstone and appearance of quartz throughout the laterite profile. Absence of these characteristics in laterite profile of Naru makes it improper to consider Bhander sandstone as parent rock.

2.5.3 The TiO<sub>2</sub> content in laterite and bauxite of Naru is as high as in basalt derived bauxites of Central India i.e. Amarkantak bauxite deposits of Madhya Pradesh. Some laterite and bauxite samples of these deposits also show high concentration of Vanadium. But there is no trace of any basic rock or traps around Naru plateau.

2.5.4 Mineralogically fresh sandstones at the base of laterite profiles constitute quartz more than 90 % and feldspar only up to 1 %. Petrographically Bhandar sandstones is quartz arenite [8] and do not indicate pronounced mineral transformation into aluminous mineral. However insitu alteration of kaolinite into gibbsite is seen in many thin sections.

2.5.6 Trace element concentration and their behaviour in Naru laterite profile is quite comparable with trace element concentration in laterite profiles developed on quartz rich parent rocks.

2.5.7 The Upper Bhandar sandstone on which the laterite profile of Naru plateau appears to rest is very hard and massive and has thick intercalations of shale and siltstones. Thin section studies of these interbeds occurring at lower levels, reveal that they are made up of micaceous clay minerals, sericite, chlorite, quartz, kaolinite, other clay minerals, little feldspar, anatase and rutile. Similar type of parent rock was also recognized for Marchinbar (Australia) bauxite deposit [9].

2.5.8 Rocks having identical mineralogy i.e., Sirbu shale has been fully lateritised at many places around Naru, such as at Maihar and at Bela. These laterite cappings directly overlie the Sirbu shale.

2.5.9 The bauxite deposit of Naru plateau crudely shows preservation of some type of sedimentary structure i.e. intercalated nature of shale and sandstone.

2.5.10 Table 1 shows that bauxite deposits of the world like Boke, Fria and Kindia of Guinea, Bhimsen hill and Monghyr of India which have been derived from clay/shale have higher percentage of titanium than bauxite deposits derived from feldspathic sandstones [10].

## **2.6. Model proposed for genesis of Naru bauxite deposit**

Unfavourable chemical composition of fresh bed rock (Table 3) and presence of altered shale and siltstone exposures around the plateaux suggest a strong possibility of complete alteration of actual parent rock into laterite and bauxite. Similar phenomena were also observed at Weipa, Marchinbar-Australia [9, 11]. From above discussion it is concluded that thick shale-siltstone interbeds, occurring within Bhandar sandstone might have served as parent rock for the bauxite deposit of Naru Plateau. It appears that the same has completely lateritised, leaving practically not much evidence of original rock. Hard massive sandstone here also has served as a shield or as host rock for preservation of lateritic Bauxite. It may also be suggested that, shale bed under the influence of excess water, at water table fluctuation zone has given rise to clay/ochre beds, at Naru. These ochre beds directly overlie the Bhandar sandstone at some places. They have a knife edge sharp contact with sandstone and overlying laterite. This gives a false impression that they have deposited as original sediments [12]. These clay/ochre beds are certainly not original sediment, but these are residual product resulting from weathering of parent rock rich in iron minerals. The downward movement of iron solution during lateritization first affected the sandstone in contact, thus forming a top ferruginous sandstone layer. After further degradation of this ferruginous sandstone layer a clay rich residuum has formed which has given rise to an ochre bed. At places where iron has segregated, a highly ferruginous spongy body is seen particularly at the base of saprolite horizon.

## **3. Study of Lohardaga bauxite deposit [13]**

From genesis and new scope of exploration of bauxite point of view, the salient features of the study of Bagru-Bhusarpat Bauxite Deposit [13] are presented here.

### **3.1. Location**

The Bagru-Bhusarpat in Lohardaga district lies between the Latitudes 23°28'30"E to 23°30'00"E and the Longitudes 84°35'00"N to 84°36'00"N in the Survey of India Topographical sheet No. 73-A/10, 73-A/11.

### 3.2. Laterite profile:

Profile	Thickness (m)	Properties
Soil & Murrum	10 - 12	Various shades of reddish, brownish lateritic virgin soil
Laterite	6 - 8	Aluminous & ferruginous
Bauxite	8 - 10	Gibbsitic types predominate over the boehmite.
Lithomarge	2 - 4	Brown to various shades brownish, reddish etc
China-Clay (Kaolin)	8 - 10	Pink, pinkish, whitish colour with yellowish ting, kaolinisation process is to be there.

### 3.3 Genesis

The study [13] leads to the conclusion that the bauxite and the laterites of the Lohardaga plateaus are derived from the underlying clayey sediments. The fact that the clayey beds, which underlie the bauxite and overlie the peneplained surface of the Chhotanagpur granite-gneiss, are of sedimentary origin is confirmed in field, by their distinct bedded nature like a typical sedimentary formation, observation of numerous primary sedimentary structures and other characteristic features of sediments. It is further established by laboratory studies as well, Ga, Th and U contents are negligible, little V, low Ni and Mn contents and their sympathetic behaviour with Fe are prominent. The recovery of fossil spores and diatoms from these beds gives clear evidences in favour of sedimentary origin of this bauxite. Besides, a fossil leaf-impression on the surface of ferruginous shale from Mandupat adds to the evidences in support of the sedimentary origin of these clayey beds. The presence of diatoms and sedimentary structures like primary current lineations, current bedding and the clay galls etc, provide definite indications that these sediments were laid down in a shallow fresh-water environment and are most probably of Upper Gondwana age.

The bauxite deposits of Jharkhand were previously [14, 15] considered to be derived from Deccan Traps, but recent study totally differs. Another strong point against the so-called trap theory of Bauxitisation in this area is the abundance of quartz, both in the clayey beds (observed megascopically in the field and also in hand specimens) and in the bauxites. Rarely, quartz crystals are also found as core of the pisolites in the bauxite in the lower (aluminous) laterite. The ubiquitous presence of quartz in these bauxites and laterites indicate a definite non-trap parentage.

## 4. Scope of exploration of bauxite in Vindhyan and Gondwana formations

**4.1** The above mentioned studies clearly indicate that Arkosic sandstones, Sandstones with Shale interbeds of Vindhyan and Gondwana formations are suitable parent rock for development of laterite profile and laterite/bauxite deposits. It is suggestive to pursue a more comprehensive geological mapping and exploration programme particularly in Vindhyan basin (MP, UP and Bihar) and Gondwana regions (Damodar valley, Narmada Valley, Mahanadi Valley, Godavari Valley and Satpura Region) with the help of recent technology like Remote Sensing and GIS. The ASTER image mapping technique can be applied to demarcate favorable lithological members in these regions

**4.2** Apart from suitable parent rock, favorable geomorphic conditions are necessary for development of laterite/bauxite, therefore in suitable lithological areas, plateaus with favorable slopes can be further demarcated.

**4.3** In third stage ASTER (Advanced Space borne Thermal Emission and Reflection Radiometer) can be used to delineate bauxite rich pockets within the laterites. In this regard, spectral signatures of lateritic

bauxite samples are analyzed in the laboratory with reference to the spectral features of gibbsite (main mineral constituent of bauxite) and goethite (main mineral constituent of laterite) in VNIR–SWIR (visible-near infrared and short wave infrared) electromagnetic domain [16]. The analysis of spectral signatures of lateritic bauxite samples helps in understanding the differences in the spectral features of bauxites and laterites. Based on these differences; ASTER data based relative band depth and simple ratio images are derived for spatial mapping of the bauxites developed within the lateritic province.

**4.4** Most of the laterites are of ferruginous nature and color of the rock varies from red to various shades of pink with pisolitic texture. Bauxite formation process is an extreme case in the lateritization process where silica and iron oxides are progressively leached out from the host rock and enriching the host rock in alumina. The enrichment of alumina and selective leaching of iron from laterite is essential to localize the bauxite within laterite and this is achievable by low Eh condition as both Al and Fe are soluble in the similar pH condition. Minor depression on the relatively flat terrain (where the presence of humus is significant and can provide low Eh condition) is suitable for bauxite segregation. Moreover, it is also observed from the vertical profile of lateritic bauxite that the bauxites are concentrated below the laterite and are capped by iron-oxide residue. Therefore surface exposures of bauxite only can be expected in the deeply incised geological section with undulating surface [16] (where erosion has removed the top lateritic cover and exposed the underlying bauxite).

## **5. Techno-economic evaluation of bauxite, derived from sedimentary parent rock:**

Bauxite quality is good at Naru, for alumina production. Bauxite supplied for alumina production has average 48 % Al<sub>2</sub>O<sub>3</sub> and 2 – 3 % SiO<sub>2</sub>. In order to determine the different commercial utility of bauxite the ore has been categorised into Grade-A (SiO<sub>2</sub>:Al<sub>2</sub>O<sub>3</sub> ranges between 19.68 to 45.77) and Grade-B (SiO<sub>2</sub>:Al<sub>2</sub>O<sub>3</sub> ranges between 11.54 to 45.77). As per the report of Directorate Geology and Mining, the total in-situ ore reserves of 'A' and 'B' grade are of the order of 4.52 and 3.23 million tonnes respectively. The mineable reserves of bauxite of 'A' and 'B' grade are 2.17 and 1.53 million tonnes respectively. Similar types of laterite cappings are available in nearby areas and they need systematic investigation. Reserves of these deposits are very low therefore they cannot sustain greenfield alumina plant based on these deposits. These deposits can regularly supply ore to BALCO's Korba plant and HINDALCO's Renukoot alumina plant. Scope of detail techno-economic study lies in following areas:

**5.1** A very high alumina - low iron bauxite can be selectively mined, which can be used for refractory/abrasive purposes as practiced in ACC's Katni Bauxite mine.

**5.2** Low grade ferruginous laterites produced during the mining of metallurgical grade bauxite can be supplied to steel or cement plants. Bauxite can be beneficiated to reduce iron and/or silica content to use them in refractory or abrasive industries.

**5.3** As per chemico-mineralogical characteristics, bauxites of Naru plateau are **boehmitic titanium rich**. These characteristics require high pressure digestion technology (240 - 250 °C) i.e. European Bayer process, which is being used at BALCO's Korba and HINDALCO's Renukoot plants of India.

**5.4** Complex utilization of ore is required in such type of deposits in order to conserve the bauxite resources.

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