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MINERALOGY AND GENESIS OF BAUXITES OF NAGARDASWADI PLATEAU, KOLHAPUR DISTRICT, MAHARASHTRA STATE (INDIA)

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Abstract

The blanket-type bauxite deposit of the Nagardaswadi Plateau has been studied with reference to its geological setting, mineralogy and genesis. Field relations indicate the following successive stages developed during *in-situ* weathering : basalt (parent rock) → altered basalt → clay → aluminous laterites → bauxite. Gibbsite is the major mineral in the bauxite, with boehmite, leucoxene, "cliachite" and maghemite. The clay mineral has been identified as halloysite, whereas kaolinite is absent. Bauxite in this deposit has been produced directly from basalt via halloysite.

Introduction

Bauxite deposits that form a capping over Deccan trap on the Nagardaswadi Plateau (Fig. 1) (Long. 74° 4′ to 74° 7′; Lat. 16° 0′ to 16° 4′) and other surrounding regions in the Kolhapur District are becoming increasingly important as a source of aluminium ore. They are being mined by manual and mechanical methods and transported to the Indian Aluminium Company's (INDAL) 40,000 ton smelter plant at Belgaum, Mysore State. The plateau, which dominates the region at 3290 feet, is hilly and covered with vegetation; rainfall is about 80″ - 100″ per annum. The deposits are economic, with Al_2O_3 ranging from 50% to 55% and SiO_2 less than 3%. The bauxite capping averages about 4 m in thickness, and contains estimated reserves of 2.85 m long (dry) tons of aluminium ore (Directorate of Geology and Mining, Government of Maharashtra, 1968).

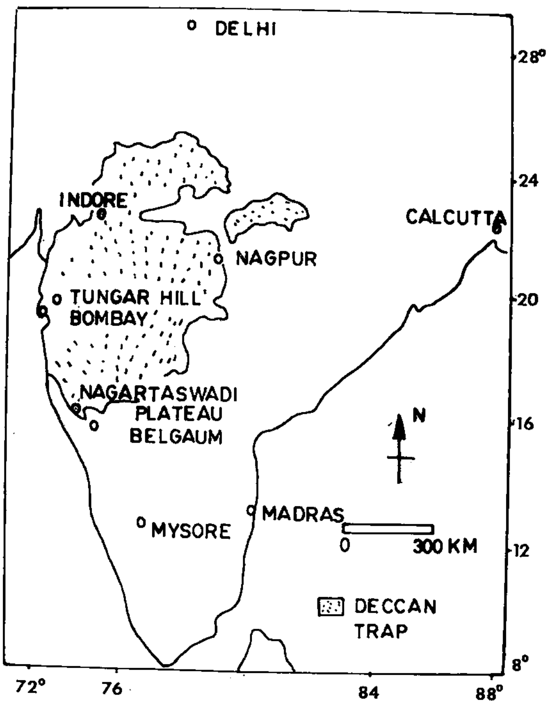


FIG. 1. Map of India showing location of Nagardaswadi Plateau and Deccan trap formations.

Occurrence of Bauxites

A detailed knowledge of the regional morphology is important because it can reveal whether the variations in altitude are attributable to original lithologically - controlled variations, earth movements, or differential post-incision cutting (McFarlane 1971).

The bauxite occurs as thick, uniform capping on Deccan basalts (3290′) on the plateau. The uniform thickness of the capping, well-defined scarps, and marginal nudges give a distinctive feature to the topography. The plateau is about 1 mile in length, 1500 feet in width, and is aligned in a NNE-SSW direction, along the drainage pattern of the region. This type of bauxitic/lateritic capping, generally termed 'pats', is described as 'high-level laterite' by Oldham (1893) and Fox (1923). The classification according to altitude or level is now known to be untenable, although McFarlane (1971) maintains that the laterite on the mesas may be described as high-level laterite by virtue of its topographical position. However, the bauxitic capping positions at Tungar Plateau near Bombay (Balasubramanian 1972) and Nagardaswadi Plateau in Kolhapur District, both in Maharashtra State, suggest a lithological control.

The profile section of the region, given in Figure 2, shows that parent-rock basalt occurs as horizontal flows up to 3290 feet in elevation.

Above this, basalts are altered over a thickness of 8 to 10 feet, and a clay layer about 25 feet thick overlies the altered basalt. Blanketing the clay layer is brownish, aluminous laterite. Deposits of good bauxite ore varying in thickness from 3 to 35 feet, occur within this aluminous laterite; the bauxites are mottled brownish, whitish or grayish, compact, and lack oolitic and pisolitic structures. At places this aluminous laterite is hard and massive and yields good ore although the alumina content is not high enough to name it bauxite. Experience has shown that a rock termed as aluminous laterite in the field may be found to be bauxite upon chemical analysis, or may be rich enough in Al_2O_3 to use as a blending material with high-grade ore.

The profile (Fig. 2) shows that basalt is altered to bauxite via a clay layer. The usual ferruginous layer associated with lateritization is absent, but there are gradual demarcation zones. From the parent rock alumina is gradually enriched, through a lower zone of leaching to an upper zone of concretion, where bauxite is formed. Similar variations due to *'in-situ'* weathering are recorded in other profiles in Deccan trap areas (Sahasrabudhe 1964; Balasubramanian 1970).

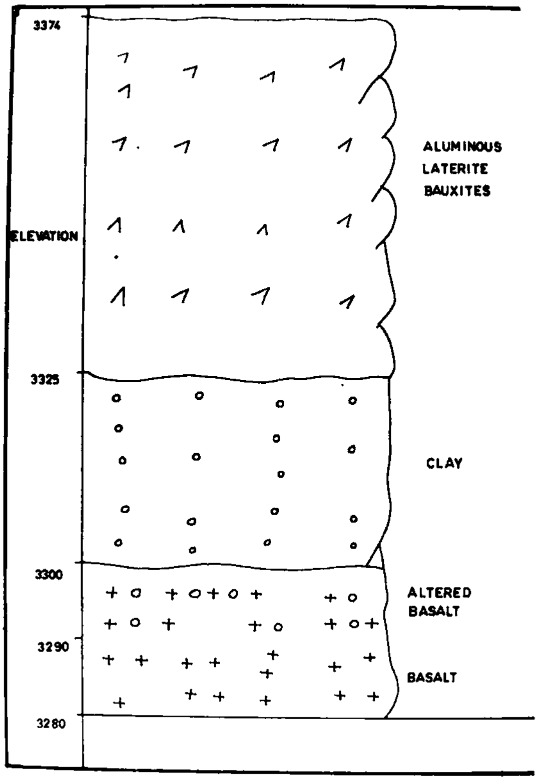


FIG. 2. Profile section of Nagardaswadi Plateau.

EXPERIMENTAL WORK

Representative samples were collected over all the profile by pit sampling, escarpment sampling, stack sampling, grab sampling and also by other methods. Physical properties, pH, petrography, thermal characteristics and minor-element contents of these bauxites have been studied with reference to elevation in the profile. The mineralogy given in Table 1 is based upon the revised classification of Valeton (1972).

Grinding tests were made on a number of representative samples, following the method outlined in the Wealth of India Series (1948). The tests indicate that the bauxite is hard, and contains little clay. Porosity and specific gravity values were obtained by the methods outlined by Zalesskii (1967). Porosity ranges from 5 to 5.5%. The specific gravity of dense brownish-white bauxite is about 2.6, whereas other varieties range from 2.2 to 2.6. A higher specific gravity indicates that ore is higher in Al_2O_3 and lower in silica, so S.G. is a valuable guide for estimating the ore grade. Porosity provides a criterion for estimating the degree of weathering, as it tends to decrease with higher Al_2O_3. This suggests that oolites have been replaced by gibbsite (Balasubramanian 1970).

pH values determined for the various samples in the profile range from 6.5 to 8.

Megascopically, basalt (parent rock) is dark in colour, medium- to coarse-grained, hard and compact. Microsections show the presence of non-pleochroic, brownish augite with $(\gamma - \alpha) = 0.026$, $+2V = 48°$, and long laths of plagioclase feldspar ($An_{60\text{-}65}$). Interstices contain subordinate triangular patches of palagonite and

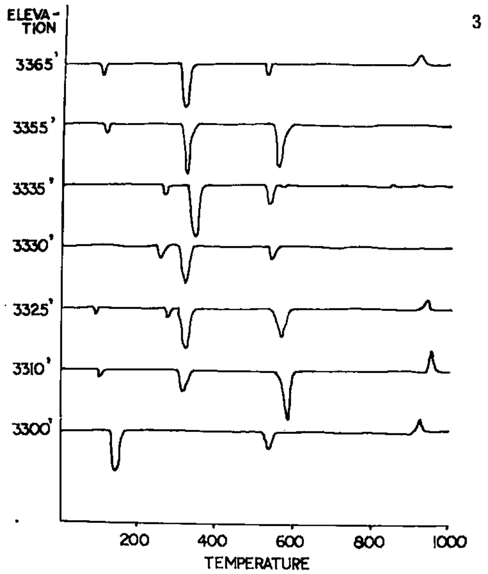
TABLE 1. MINERALOGY OF THE BAUXITE PROFILE OF NAGARDASWADI PLATEAU, MAHARASHTRA STATE

Sample no.	Elevation	Type	Goethite	Gibbsite	Boehmite	Maghemite	Leucoxene	Cliachite	Kaolinite	Halloysite
1	3374 feet	F. bauxite	+	++	-	+	+	-	X	X
2	3360	bauxite	X	++	+	-	+	-	X	-
3	3345	bauxite	X	++	+	-	+	-	X	-
4	3330	bauxite	X	++	+	-	+	-	X	-
5	3325	bauxite	X	++	-	-	+	-	X	+
6	3320	clay	-	+	X	-	-	-	X	++
7	3300	clay	-	-	-	-	-	-	X	++

++ major + minor - trace X absent

celadonite glass. The high percentage of glass (15%) and the characteristic intersertal texture of the rock are probably important factors in effecting bauxitization (Libbey *et al.* 1946). Clots of iron oxides throughout the matrix appear in polished sections to be ilmenite (reflectivity 19%).

Microsections of the altered basalt show clearly the changes that are due to weathering and alteration. Ferromagnesian minerals and feldspars are altered greatly at the initial stage whereas the glasses are not, which shows that there is little de-silicification at this stage. Rims of iron oxide outline the boundaries of original pyroxene grains. Feldspars are altered to gibbsite, not kaolinite, suggesting that direct alteration has occurred (Allen 1948; Gordon & Tracey 1952; Balasubramanian 1972).



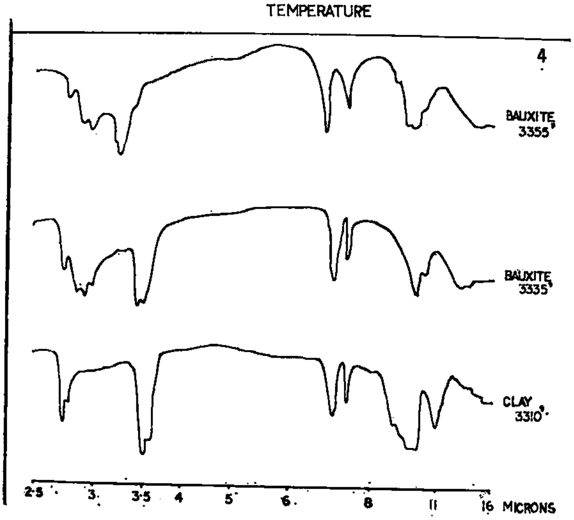


FIG. 3. DTA curves of bauxites and clays of Nagardaswadi Plateau.

FIG. 4. I.R. spectra.

Thin sections of bauxites show the following features. Migration of material in the colloidal state may have occurred in these bauxites. Present at certain places are rhythmic, roughly parallel layers of colloidal iron oxide which might have resulted from a cyclic lowering of pH. Stringers of gibbsite are often associated with cavities, suggesting that the mobilized alumina might have moved through them, deposited, and later developed into fine crystals of gibbsite, some of which show lamellar twinning. In some sections the gibbsite core is surrounded by a ferruginous mantle. Such pisolitic masses, which are translucent to nearly opaque or deep brown, may be termed cliachite (Loughnan 1969). It is very difficult to recognize any altered titanium mineral, hence it is proposed to retain the name leucoxene as suggested by Allen (1952). Small grains of magnetite, hematite, and associated maghemite are disseminated in some pisolites.

DTA curves of the aluminous laterites and bauxites indicate clearly that the gibbsite is the principal mineral, boehmite is always present with it, and kaolinite is absent (Fig. 3). The clay mineral present was identified by DTA as halloysite (Fig. 3). Infra-red spectra also show that kaolinite is absent, and clay yields peaks (Fig. 4) which compare well with those of halloysite (Lyon 1964).

Trace-element analysis show that all elements except Mn have migrated in the bauxite from the parent rock (Table 2). The concentrations of the elements, typically hydrolyzates (Goldschmidt 1954) are low. The migration of trace elements also suggests that *'in-situ'* weathering has occurred.

TABLE 2. RELATIVE VARIATION IN TRACE ELEMENTS IN THE BAUXITE PROFILE

Bauxite (3355')	Cu	Co	Cr	-	Ni	Ti
Bauxite (3335')	Cu	Co	Cr	-	Ni	Ti
Bauxite (3290')	Cu	Co	Cr	Mn	Ni	Ti

GENESIS

Weathering of silicates is mainly a process of hydrolysis. The alteration of potash feldspars is usually shown by the equation:

$$4KAlSi_3O_8 + 22H_2O = 4K^+ + 4OH^- + Al_4Si_4O_{10}(OH)_8, \quad (1)$$

which yields kaolinite. However, Valeton (1972) pointed out that feldspars can also be altered directly to gibbsite:

$$2H^{+} + 6SiO_2Al_2O_3K_2O+14H_2O = 6SiO_4H_4+ 2K^{+}+Al_2O_3 \cdot 3H_2O \quad (2)$$

The above equation indicates that hydrolysis does not take place directly, but may arise from a series of reactions. The Nagardaswadi weathering profile suggests that bauxitization took place in three stages.

The petrographic variations are shown in Figure 5. The first stage is mainly the breaking down of primary silicates, principally augite and feldspars. Calcic feldspar of composition $An_{60\text{-}65}$ is considered to be more stable in the initial stage than $An_{80\text{-}100}$ (Loughnan 1969). In the second stage, glasses have undergone complete desilicification, and in the third stage, leaching of iron and silica has finally resulted in the formation of bauxite. At this stage pH might have been around 7.5, for at this pH alumina alone can precipitate, whereas silica and iron will be leached from the system (Mason 1960). As pointed out earlier, migration of alumina may have taken place in the form of colloids, and gibbsite might have crystallized from them later.

According to Bates (1962) "where leaching is moderate, plagioclase feldspar alters to halloysite whereas the volcanic glass yields allophane, an amorphous hydrated aluminium silicate, together with alumina and silica gels. Gibbsite is produced by

1) removal of silica from halloysite,
2) dehydration of Al gel,

and 3) precipitation from solution.

Although it is possible that the mineral may form directly from feldspar, halloysite is the common crystalline intermediate on both megascopic and microscopic scales. An amorphous transition state probably ranging in composition from allophane to Al-gel exists as the part of the change from halloysite to gibbsite, as evidenced by electron microscope and diffraction work on pseudomorphs after halloysite tubes found in certain samples studied in more detail than others".

Balasubramanian (1972) has drawn the weathering sequence from the mineralogy of the bauxites of the Tungar hill, Bombay, based upon the views of Bates (1962). From the mineralogy it was concluded that the kaolinite stage was not necessary for the formation of bauxite and also in the present study of the Nagardaswadi Plateau kaolinite was not found during any stage of formation, even though a clay layer was observed between parent rock and laterite. The weathering sequence of the parent rock is given in Table 3.

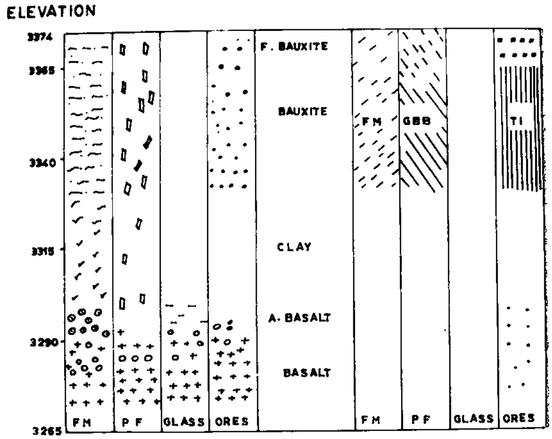


FIG. 5. Petrographic variations of the profile.

TABLE 3. WEATHERING SEQUENCE OF BASALT ON THE NAGARDASWADI PLATEAU*

Plagioclase	Glass	Augite
Gel, Gibbsite, Halloysite	Allophane	FeOH, Gels

Gibbsite (Boehmite) Cliachite ——— Bauxitization

---- moderate leaching
—— prolonged leaching

*Based on the work of Bates (1962) and Balasubramaniam (1972)

The studies made so far on the profiles of laterite that cap the Deccan trap on the Nagardaswadi Plateau, and also on the Tungar Plateau, have shown that a kaolinite stage is not necessary for the genesis of laterite or bauxite. Work is in progress to extend such studies to other laterite profiles in the Deccan trap region.

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