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Infrared spectroscopic study of charnockite hosted bauxite and associated litho-units from Salem district, Tamil Nadu

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Abstract: Bauxite developed over charnockite at Shivaroy Hills, Salem district, Tamil Nadu was studied using the FTIR technique. The results were substantiated by XRD study. In a normal profile, the bauxite zone is underlain by the saprolite zone and unaltered host rock and overlain by a laterite zone. In the present set-up, various litho-units such as saprolite zone (Partially Lateritised Charnockite (PLC) and lithomarge), bauxite zone, and laterite zone are encountered in the profile. The FTIR study of each litho-unit was undertaken and the dominance of gibbsite was observed from the bauxite zone. In addition, a minor amount of boehmite and diaspore are present which was otherwise not recognised from its corresponding XRD pattern. The saprolite zone is enriched in litho-relicts derived from the parent rock and its partial alteration product like kaolinite. The laterite zone is dominated by goethite, and kaolinite with minor hematite. The above findings demonstrate that the FTIR technique can be successfully employed to unravel the mineralogical differentiation in a bauxite profile and can be a marquee tool in bauxite characterization study.
Keywords: FTIR, Bauxite, Shivaroy Hills.

Introduction

A plethora of rocks at the surface or near the surface, containing more than 15% Al_2O_3 can be converted to bauxite through residual concentration under tropical to sub-tropical climatic conditions. In India, bauxite has developed over almost all kinds of rocks, for example (1) Khondalite (East Coast bauxite, Odisha, Andhra Pradesh), (2) Deccan Traps (Madhya Pradesh, Maharashtra and Gujarat), (3) Charnockite (Tamil Nadu), (4) Crystalline rocks (Kerala and Karnataka), (5) Vindhyan sandstone/shale (Chhattisgarh), (6) Iron ore volcanics (Koira, Odisha), (7) Limestone (Jammu and Kasmir), etc. Several workers (Raman, 1978; Subramaniam and Mani, 1979; Mohapatra et al. 1989; Jadav et al., 2012; Reddy et al., 2015, Sahoo et al., 2017 and 2020) have studied the geology, mineralogy, geochemistry, and utilization prospects of bauxite deposits from different parts of India. But the characterization of bauxite through Infrared Spectroscopy has been attempted by a few workers only (Bardossy and Aleva 1990, Sahoo et al., 2020). When minerals are exposed to infrared spectra, absorption takes place due to the vibration of its atoms and the vibration frequency depends on the mass of the atom, forces on bonds, and structure of the molecules. This acts as a fingerprint and helps in the identification of the functional group of the mineral (Farmer, 1968). Bellamy (1958), Colthup et al. (1964), and Nakomoto (1963) interpreted the infrared spectra of organic and inorganic compounds respectively. Several workers have successfully used IR spectra in the study of clay, bauxite, and soil (Lyon, 1964; Joe, 1971, 1972; Vandermarcel and Butelspachra, 1976; Balasubramaniam and Gopinath, 1979). The bauxite ore along with its associated litho-units developed over charnockite in the Shivaroy Hills, Salem district, Tamil Nadu was studied using both FTIR and XRD techniques, and the results are reported in this paper.

Materials and methods

Representative samples from the bauxite zone and its associated litho-zones developed over charnockite in the Shivaroy Hills was collected for the present study. Different techniques used for mineralogical analysis are FTIR (Thermo Scientific, Nicolet Is5) and XRD (Rigaku, Ultima IV) were used. For the FTIR study, the sample <200-micron size, dispersed in KBr in the ratio (1:200) was pressed into discs. The sample was then scanned and the spectrum was recorded over the range from 4000 to 400 cm-1 using a spectrometer. The transmittances vs. wave number (cm-1) plots are interpreted for mineral identification. The acceleration voltage in XRD was kept at 40kV, current at 40mA and the scan speed was kept at 20/ minute.

The bauxite profiles

The basement rock of bauxite in Shivaroy Hills is made up of charnockite affected by varying degrees of alteration. Thick laterite capping is observed on flat and gently rolling surfaces on the hill-tops. Generally, a thick bauxite blanket of 10 to 15m (up to 20m in exceptional cases) occurs below the laterite capping at an altitude of nearly 800m above the mean sea level. Below this laterite-bauxite zone is the weathered parent rock mostly composed of lithomarge and partially lateritised charnockite followed by charnockite. Individual litho-unit shows gradational contact with its adjacent unit. The schematic diagram of the entire profile is shown in Figure 1.

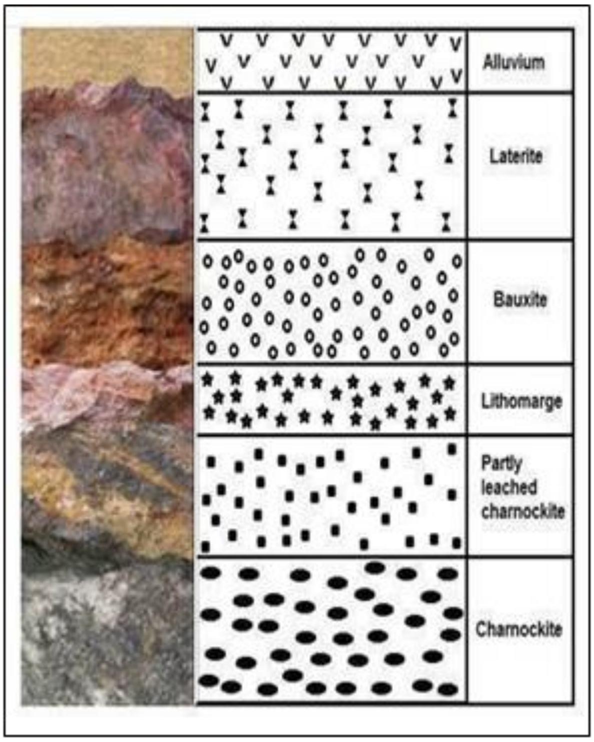

Fig. 1. The bauxite profile developed over charnockite.

Results and Discussion

XRD studies

The result of the XRD analysis is shown in Fig. 2 and Table 1. The partially lateritised charnockite contains orthoclase, enstatite, albite and minor quartz derived from the underlying parent charnockite which has been variably altered. The lithomarge is rich in kaolinite indicating the advanced stage of weathering, where all the primary silicate minerals are substituted by kaolinite. A minor amount of hematite and goethite are probably derived from the breaking down of Fe-bearing minerals in the parent rock and precipitated in the interstices of kaolinite. The bauxite zone is dominated by only gibbsite, having formed from an advanced stage of lateritisation/bauxitisation process. The laterite capping is dominated by hematite, goethite, and limonite in association with kaolinite and minor gibbsite. The iron released from the alteration of Fe-minerals has migrated upwards as colloidal solutions and precipitated along the fractures and interstices of other minerals.

Table 1. XRD analysis of different litho-units of bauxite.

Litho-type	Al-mineral	Silicate mineral	Fe-mineral
Laterite	Gibbsite	Kaolinite	Hematite, goethite
Bauxite	Gibbsite	-	Goethite
Lithomarge	-	Kaolinite	Hematite, goethite
PLC	Orthoclase, enstatite, albite, quartz	-	-

FTIR studies

The minerals identified from the FTIR spectra for the four litho-units viz. partially lateritised Charnockite (PLC), Lithomarge, Bauxite, and Laterite are given in Figure 3 and the results are discussed below.

PLC: Orthoclase, an essential constituent of the host charnockite, is reported from the PLC through FTIR from its characteristic absorbance peaks at 1010 cm^{-1}, 620 cm^{-1} and 584 cm^{-1}. The PLC also constitutes kaolinite and minor magnetite. Minor amount of gibbsite is attributed to broad but weak absorbance peak at 1022 cm^{-1}. So this indicates that the formation of the gibbsite is initiated right from the PLC stage.

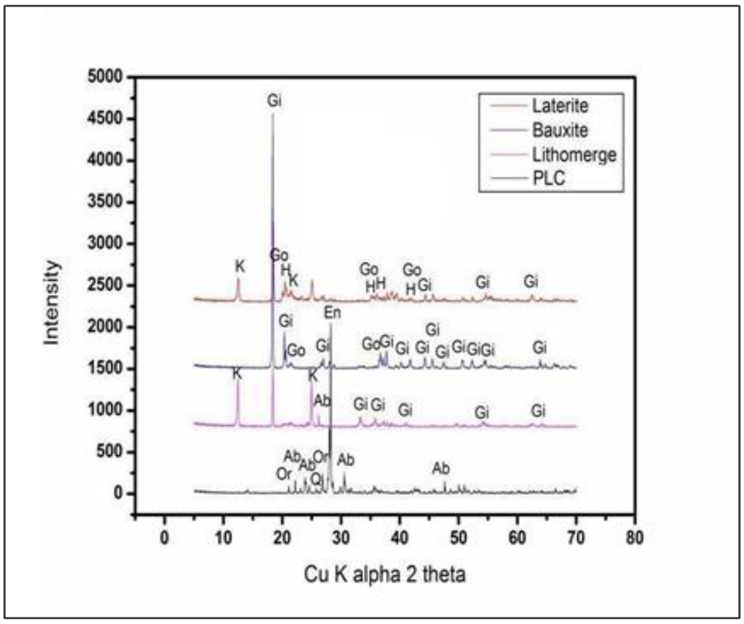

Fig. 2. Composite XRD pattern of bauxite and associated litho-units.

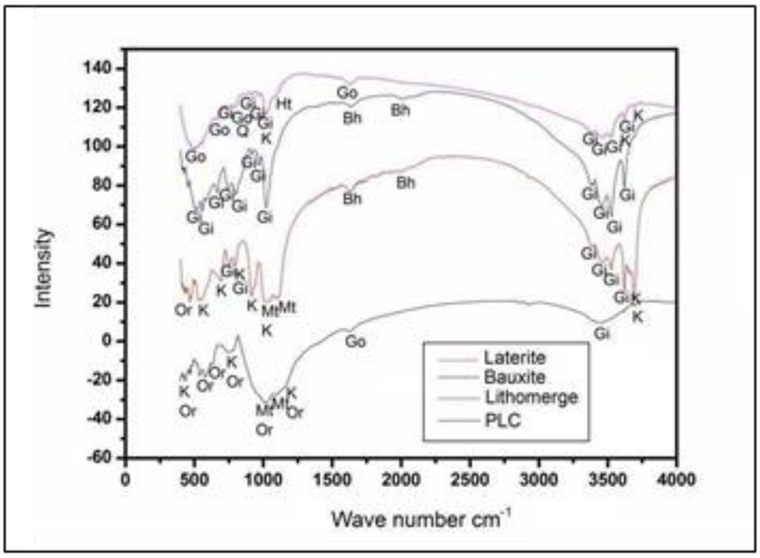

Fig. 3. Composite FTIR pattern of bauxite and associated litho-units.

Lithomarge: With an increasing degree of lateritisation or bauxitisation the feldspar group minerals undergo alteration to produce gibbsite directly or through kaolinite. The absence of feldspar/orthoclase indicates the effect of chemical leaching in lithomarge. Kaolinite is the most dominant mineral in lithomarge with minor gibbsite. Kaolinite is identified from its characteristic peaks at 3695 cm^{-1}, 3620 cm^{-1}, 752 cm^{-1}, 695 cm^{-1}, 549 cm^{-1}, 470 cm^{-1}. The gibbsite content in lithomarge increases in comparison to the PLC, as evident from the appearance of a stronger peak at 1020 cm^{-1} along with 915 cm^{-1}. A very small shoulder at 2000 cm^{-1} may be attributed to boehmite. Traces of magnetite (1105 cm^{-1} and 1012 cm^{-1}) and goethite (800 cm^{-1}) are also reported in lithomarge.

Bauxite: The studied bauxite is primarily gibbsitic in nature. Though gibbsite first appears in the PLC and continues through lithomarge, the gibbsite content only gains prominence in the bauxite zone identified by sharper peaks at 3620 cm^{-1}, 3520 cm^{-1}, 3456 cm^{-1}, 3380 cm^{-1}, 970 cm^{-1}, 915 cm^{-1}, 747 cm-

^{1}, 664 cm^{-1}, 578 cm^{-1}, 557 cm^{-1}, 513 cm^{-1} and 452 cm^{-1}. The boehmite which shows a broad peak at 2000 cm-1in lithomarge becomes more prominent in the case of bauxite indicating its gradual development. A minor amount of goethite (800 cm^{-1}) is noticed in bauxite.

Laterite: The gibbsite peaks become weaker as one approaches the laterite capping. As the process of lateritisation continues, iron minerals are gradually removed from the host into solution and finally get precipitated in the laterite cap. A minor amount of goethite are mostly reported from laterite. The absorbance peak at 800 cm^{-1} is characteristic of goethite. Hematite is reported only from the laterite as is recognised from its diagnostic peak at 1088 cm^{-1}.

Conclusions

The FTIR spectroscopic study of bauxite and the associated litho-units developed over charnockite in the Shivaroy hills, Salem district, Tamil Nadu has established the mineral assemblages that have formed during the lateritisation/bauxitisation process. The findings are in sound conformity with the observations made through XRD studies. Some additional peaks indicating some minerals like boehmite and magnetite are reported from FTIR studies which could not be ascertained through XRD. So, it may be surmised that the infrared spectroscopy technique can be suitably employed to find out the mineralogy of bauxite either solely or in combination with other techniques, which may find profound application in the fields of mineral processing and metal recovery.

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