

## Is Jammu Bauxite a Reworked Basalt Derived Bauxite?

B. P. SINGH, J. S. PAWAR and MITHILA

Postgraduate Department of Geology, University of Jammu, Jammu - 180 006

Email: bpsingh\_in@yahoo.com

**Abstract:** The sedimentary structures in the bauxite deposits of the Jammu area are suggestive of a reworked bauxite precursor. Trace elements and REE concentrations show that the precursor bauxite originated from the weathering of basalt. It means that the bauxite forms a part of the earliest interval of the Himalayan foreland sedimentary sequences.

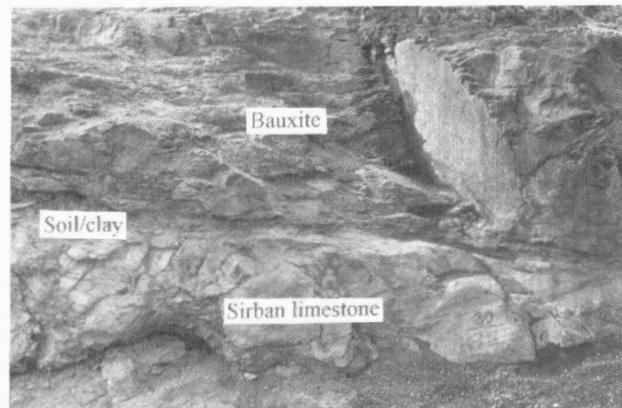
**Keywords:** Bauxite, Reworked basalt, Geochemistry, Sedimentary structures, Jammu area, Jammu and Kashmir.

### Introduction

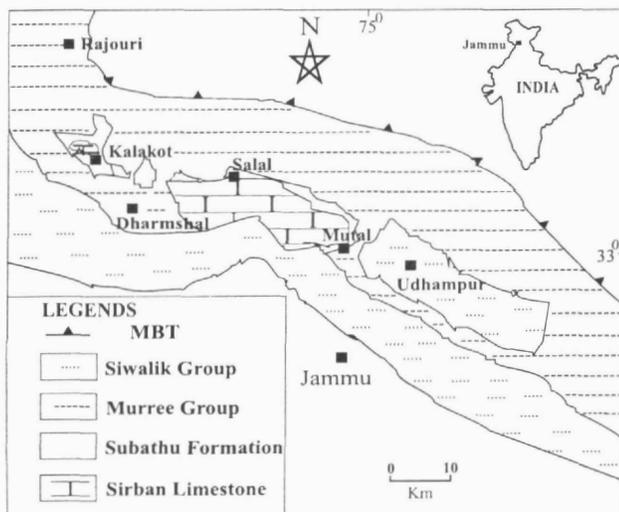
The bauxite deposits of the Jammu area occur as isolated pockets at Salal and Mutal in the Udhampur district (Fig.1). These are interpreted to be of Pre-Eocene age (Middlemiss, 1929; Singh, 1970). A 6-10 cm thick clay/soil horizon occurs just above the Precambrian basement (Sirban Limestone) (Lal et al. 1981). Bardossy (1982) has categorized the Irano-Himalayan bauxite as the karst bauxite. Although the allochthonous and mainly sedimentary characters of several "karst bauxite" deposits are well established, their parent rock has remained largely enigmatic (Ozlu, 1983).

The bauxite shows an erosional contact with the clay/soil horizon (Fig. 2). A 3-4 m thick bauxite occurs at Salal

and about 1.5 m thick bauxite occurs 2 km north of Mutal on Mutal-Jangalgali road (Fig.1). Both the bauxite deposits show sedimentary features with 1 mm to 3 mm thick individual bed/lamina (Fig.3). Elongated and circular aluminous pisolites up to 8 mm length are enclosed in the argillaceous/ferruginous matrix. The bauxites are mainly

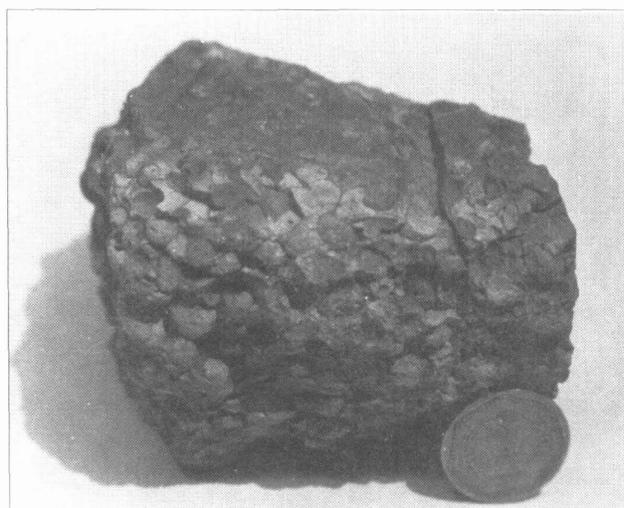


**Fig.2.** Field photograph exhibits Sirban Limestone in the base, overlying soil/clay horizon and bauxite at the top. Note erosional lower contact of the bauxite. *Locality:* Salal, district Udhampur, Jammu and Kashmir.



**Fig.1.** Map shows important locations including Salal and Mutal where the bauxite deposits are exposed in the Jammu area and the geological layout of the area. *Inset:* Location of the Jammu in the outline map of India.

composed of gibbsite, goethite, diaspore, boehmite, kaolinite, hematite and quartz (Singh, 2003). Earlier, Banerjee (1975) inferred the cause of flattening of the pisolites as a result of Himalayan orogenic movements. The origin of these bauxites is inferred as a result of *in situ* residual weathering of shales and clays deposited in local depressions above the Precambrian basement that was subsequently altered to bauxite depending upon the leaching and local drainage conditions (Lal et al. 1981). The present study is based on trace and rare earth elements (REE) determinations.



**Fig.3.** Sample photograph exhibits circular to elongated pisolites encased in the argillaceous/ferruginous matrix and their arrangement in the laminated form. Diameter of the coin is 2.5 cm.

### RESULTS AND DISCUSSION

Nine samples were analyzed for trace and rare earth elements on an inductively coupled plasma mass-spectrometer (ICP-MS) equipped with a multi-channel analyzer. The average concentrations are shown in Table 1, in addition to concentrations of basalt, rhyolite (after Mishra and Rajamani, 1999) and upper continental crust values (after Taylor and McLennan, 1981).

#### Trace Elements

In the bauxite samples of the Jammu area, trace elements present in appreciable concentrations are:  $Zr > Cr > V > Pb > Ba > Zn > Ga > Nb > Th > Sr > Sc > Rb > Cu > Ni > Y > Hf > Co > Cs > U$  (Table 1).

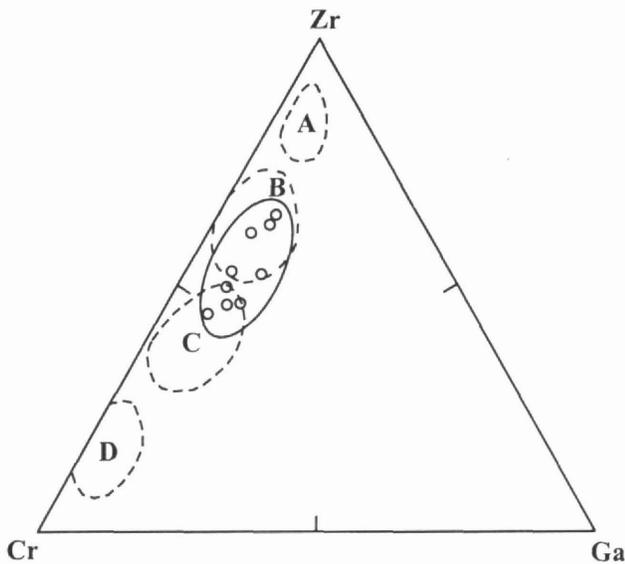
Vanadium and chromium occur in appreciable amounts in the bauxite samples with 190.85ppm and 193.90ppm respectively on an average. Vanadium mostly occurs in magnetite, augite and Ti-bearing minerals in the basalt parent rock (Rao and Krishnamurthy, 1981) and the average value of Cr (193.90ppm) is very close to Indian basalt reported by Mishra and Rajamani (1999). Therefore, these values suggest a possible basic source (basalt). Nb also comes from the decomposition of Ti-bearing minerals, which is the main concentrator of this element (Mordberg et al. 2001). The value of Ba (88.18 ppm) is very close to that of Indian basalt. Zr is derived from the zircon, which is most resistant to weathering and forms appreciable content of the many igneous rocks and occur at highest level in the granites. Although, Hf has close affinity with Zr and both occur together, its concentration is very low (10.33ppm) in

**Table 1.** Relative abundance of trace elements and REE (average values) in bauxite, basalt, rhyolite (Mishra and Rajamani, 1999) and upper continental crust (after Taylor and McLennan, 1981)

Elements	Bauxite (n=9)	Basalt	Rhyolite	UCC
Sc	25.58	—	—	10
V	190.85	—	—	60
Cr	193.30	189.50	42.80	35
Co	8.36	—	—	10
Ni	19.10	231.30	15.60	20
Cu	19.26	—	—	25
Zn	77.32	—	—	52
Ga	59.20	—	—	—
Rb	25.35	—	—	110
Sr	34.32	258.40	114.40	350
Y	15.62	29.89	19.80	22
Zr	302.28	79.10	165.40	240
Ba	88.18	94.40	1030	700
Pb	165.24	—	—	15.0
Th	35.13	—	—	10.50
U	3.79	—	—	2.5
Cr/Ni	10.12	0.82	2.74	1.75
Th/U	9.27	—	—	4.2
Rare earth elements (Chondrite normalized values)				
La	38.13	—	—	122.64
Ce	43.12	52.77	80.29	100.33
Pr	24.91	—	—	73.67
Nd	20.26	36.91	47.96	54.88
Sm	16.10	25.20	26.49	29.22
Eu	9.84	14.46	14.31	15.16
Gd	12.85	18.70	14.23	18.60
Tb	11.72	—	—	17.09
Dy	11.63	13.74	8.72	13.77
Ho	11.26	—	—	14.11
Er	10.82	13.47	7.70	13.86
Tm	10.11	—	—	12.89
Yb	10.47	10.66	5.68	13.33
Lu	9.92	—	—	12.60
(La/Sm) <sub>N</sub>	2.36	—	—	4.20
Eu/Eu*	0.67	0.97	0.74	0.65

the Jammu bauxite. Ternary diagram, prepared by taking the values of Zr, Cr and Ga, suggests that the bauxite samples fall within the basic and intermediate fields (Fig. 4). The presence of Zr in substantial amount (on an average 303.28 ppm) may be because of mixing of the upper continental crust rocks during the reworking of the bauxite precursor.

The substantial amount of Ga in the bauxite samples may be because of its affinity with the aluminium (Smith, 1963) and hence, its presence is justified. As Rb substitutes K in suitable conditions, the low value of Rb in these bauxites is due to low content of K-feldspars in the parent rock. Cu, Co Ni and Y in the rocks are present in the ferromagnesian minerals (Carr and Turekian, 1961). Rao and Krishnamurthy (1981) suggest that ionic potential of



**Fig. 4.** Zr-Cr-Ga, ternary diagram representing bauxite composition in terms of these trace elements. Field A - Granite composition, B - intermediate magmatic rocks, C - basic rocks and D - ultrabasic rocks (after Ozlu, 1983).

$\text{Cu}^{2+}$  is less than 3, hence it passes into ionic solution and it should be depleted in the bauxites. Similarly in the present case also, the depletion of the Cu may be due to its passing in the ionic solution. Another cause for the low values of Cu and Ni may be because of mixing of the upper continental crust (UCC) derived sediments during reworking. Sr substitutes Ca in calcium rich minerals, but very low value of Sr seems related to leaching of calcic minerals during surface weathering in this bauxite. The appreciable concentration of Pb (165.24 ppm on an average) in the bauxite samples (Table 1) may be because of enrichment of this element during weathering as a result of selective leaching of alkaline earth elements and silica from the parent rock.

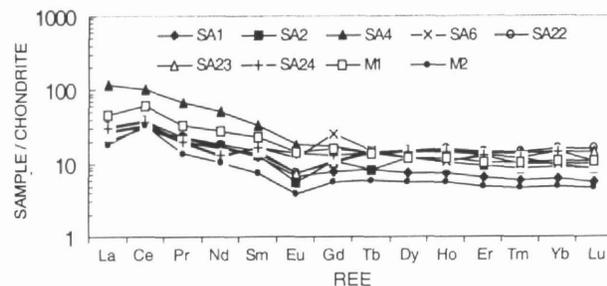
Cr/Ni ratios from 1.2 to 1.6 indicate ultramafic source and higher ratios indicate mafic volcanic source for sediments (Garver and Royee, 1993). The average Cr/Ni ratio of the Jammu bauxite is 10.12 (Table 1) indicating their derivation from mafic volcanic rock.

Another important ratio is Th/U for deciphering the source where the upper crustal rocks have average ratio of 3.5. Lower ratio than that depicts reducing sedimentary environment because of enrichment of U, and high Th/U ratio is correlatable with sedimentary processes and weathering of igneous rocks. Weathering tends to result in oxidation of  $\text{U}^{4+}$  to soluble  $\text{U}^{6+}$  with loss to solution and elevation of Th/U ratios. The Th/U ratio of the Jammu bauxite ranges between 5.77 to 10.73 with average value 9.27 (Table 1) as a consequence of weathering and oxidation

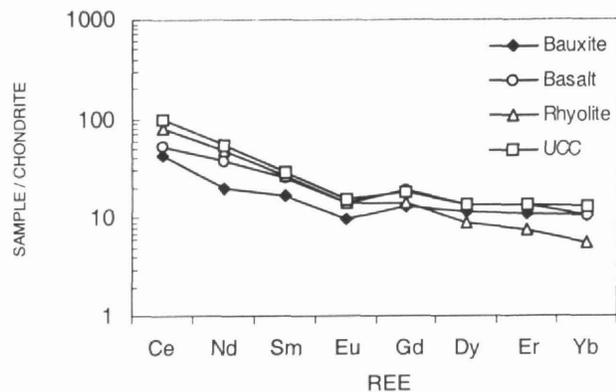
of  $\text{U}^{4+}$  to soluble  $\text{U}^{6+}$  with loss to solution and elevation of Th/U ratios.

#### Rare Earth Elements

The bauxites do not show significant enrichment of  $\Sigma\text{LREE}$  where the chondrite normalized value (on an average) is 155.09 against 88.74 average value of  $\Sigma\text{HREE}$ . The  $(\text{La}/\text{Sm})_N$ , a measure of LREE pattern, is 2.3 on an average (Table 1). Further, the measure of the total REE is within the range of 128.43 to 473.08. Significantly, the REE pattern shows a slight positive Ce anomaly in some of the samples, and a negative Eu anomaly (Fig. 5) with the average  $\text{Eu}/\text{Eu}^*$  value 0.67 (Table 1). The sediments derived from mature continental crust and volcanic arcs built on continental crust are characterized by high  $(\text{La}/\text{Sm})_N$  ratio and high total rare earth elements ( $\Sigma\text{REE}$ ) whereas sediments derived from young, undifferentiated volcanic arc has lower  $(\text{La}/\text{Sm})_N$ , lower  $\Sigma\text{REE}$  and lack a Eu anomaly (Bhatia and Krook, 1986; McLennan and Taylor, 1991; Centeno-garcia et al. 1993; Girty et al 1993). The low  $(\text{La}/\text{Sm})_N$  ratio and the low  $\Sigma\text{REE}$  value in the Jammu bauxites may be as a result of their derivation from the undifferentiated volcanic arc. Also, the REE pattern of these bauxites is similar to the REE pattern of the basalt with slight depletion in LREE (Fig. 6). This may be because of fractionation of LREE



**Fig. 5.** Plot of chondrite normalized REE ratios against respective rare earth elements in the bauxite samples of the Jammu area.



**Fig. 6.** Chondrite normalized REE patterns of bauxite (average ratios), basalt, rhyolite and UCC.

during weathering of the basalt. In sedimentary deposits, the dilution or enrichment in the REE is argued by the mixing of either the continental rocks with the oceanic derived volcanic rocks or vice-versa (Garver and Scott, 1995).

The average Eu/Eu\* value of the bauxite samples is close to the value of the upper continental crust and less than the basalt or rhyolite shown by Mishra and Rajamani (2003). Negative Eu anomaly in them (Fig. 6) may be a result of the mixing of the upper continental crust material during reworking and sedimentation. Alternatively, Eu as a substitution product of Ca must have been depleted due to the removal of Ca from the basalt with the surface weathering (Salil and Shrivastava, 1996). The Ce enrichment observed in the bauxite samples seems to be related to the mixing of the source material in the sedimentary environment and addition of the Ce from the UCC.

Based on trace element and REE geochemistry, it is concluded that the bauxite precursor originated from the weathering of basalt and later on, it was eroded and deposited on the Precambrian limestone basement as a result of sedimentary processes. There was widespread volcanism in the Cretaceous Period (e.g. Deccan basalts) and weathering of basalts gave rise to laterite/bauxite in Paleocene (Babu, 1981). Furthermore, the latitudinal position of the northern tip of India was very close to the equator during Paleocene resulting in warm and humid climate, which aided residual chemical weathering of basalts.

*Acknowledgements:* Authors are grateful to the Department of Science and Technology, New Delhi for the grant in form of a project to BPS. We are thankful to the Officer-in-charge ICP-MS Lab, NGRI, Hyderabad for chemical analyses.

#### References

- BABU, P.V.L.P. (1981) Laterite as an unconformity plane in the evolution of the Indian Peninsula- A synthesis. *In: Anon. (Ed.), Laterisation Processes*, Oxford and IBH Publ. Co., New Delhi, pp.302-307.
- BANERJEE, P.K. (1975) A reconnaissance survey of the distribution of some trace elements in Indian bauxite. *Mineral. Deposita*, v.10, pp.177-188.
- BARDOSSY, G. (1982) Karst bauxites, bauxite deposits on carbonate rocks. *Akademiai Kiado, Budapest*, 441p.
- BHATIA, M.R. and KROOK, K.A.W. (1986) Trace element characteristics of greywackes and tectonic setting discrimination of sedimentary basins. *Contrib. Mineral. Petrol.*, v.92, pp.181-193.
- CARR, M.H. and TUREKIAN, K.K. (1961) The geochemistry of cobalt. *Geochim. et Cosmochim. Acta*, v.23, pp.9-60.
- CENTENO-GARCIA, E., RUIZ, J., CONEY, P.J., PACHETT, P.J. and ORTEGA-GUTHTTEZ, F. (1993) Guerrero terrane of Mexico: its role in southern Cordillera from new geochemical data. *Geology*, v.21, pp.419-422.
- GARVER, J.I. and ROYEE, P.R. (1993) Chromium and nickel in shale of the foreland deposits of the Ordovician Taconic Orogen: Using shale as a provenance indicator for ultramafic rocks. *Geol. Soc. Amer. Program*, v.25, 17p.
- GARVER, J.I. and SCOTT, T.J. (1995) Trace elements in shale as indicators of crustal provenance and terrane accretion in the southern Canadian Cordillera. *Geol. Soc. Amer. Bull.*, v.107(4), pp.440-453.
- GIRTY, G.H., HANSON, A.D., YOSHINOBU, A.S., KNAAK, C. and JOHNSON, D. (1993) Provenance of Paleozoic mudstones in a contact metamorphic aureole determined by rare earth elements, Th and Sc analyses, Sierra Nevada, California. *Geology*, v.21, pp.363-366.
- LAL, M., JAMWAL, J.S. and NANDA, M.M. (1981) Bauxite deposits of Jammu, India. *In: Anon. (Ed.), Laterisation Processes*. Oxford and IBH Publ. Co., New Delhi, pp. 190-192.
- MCLENNAN, S.M. and TAYLOR, S.R. (1991) Sedimentary rocks and crustal evolution: Tectonic setting and secular trends. *Jour. Geology*, v.99, pp.1-21.
- MIDDLEMISS, C.S. (1929) Kalakot, Metka, Mahgola and other coalfields of Jammu Province. *Mineral Survey Report*, Jammu and Kashmir Government, 116p.
- MISHRA, M. and RAJAMANI, V. (1999) Significance of the Archaean bimodal volcanics from the Ramgiri schist belt in the formation of eastern Dharwar Craton. *Jour. Geol. Soc. India*, v.54, pp.563-583.
- MISHRA, M. and RAJAMANI, V. (2003) Geochemistry of the Archaean metasedimentary rocks from the Ramgiri schist belt, eastern Dharwar Craton, India: implications to Crustal evolution. *Jour. Geol. Soc. India*, v.62, pp.717-738.
- MORDBERG, L.E., STANLEY, C.J. and GERMANN, K. (2001) Mineralogy and geochemistry of trace elements in bauxites: the Devonian Schugorsk deposits, Russia. *Mineral. Mag.*, v.65(1), pp.81-101.
- OZLU, N. (1983) Trace element content of "karst bauxites" and their parent rocks in the Mediterranean belt. *Mineral. Deposita*, v.18, pp.469-476.
- RAO, J.J. and KRISHNAMURTHY, C.V. (1981) Some observations on the mineralogy and geochemistry of Hazaridadar and Raktidadar plateaus, Amarkantak area, Madhya Pradesh, India. *In: Anon. (Ed.), Laterisation Processes*, Oxford and IBH Publ. Co., New Delhi, pp. 89-108.
- SALIL, M.S. and SHRIVASTAVA, J.P. (1996) Trace and REE signatures in the Maastrichtian Lameta Beds for the initiation of Deccan volcanism before KT. *Curr. Sci.*, v.70(5), pp.399-401.
- SMITH, F.G. (1963) *Physical Geochemistry*, Addison-Wesley Publishing Company, Inc., London, 624p.
- SINGH, B.P. (2003) Evidence of growth fault and forebulge in the Late Paleocene (57.9-54.7 Ma), western Himalayan foreland basin, India. *Earth and Planet. Sci. Lett.*, v.216, pp.717-724.
- SINGH, P. (1970) Larger foraminifera from Subathus of Bergua-Jangalgali area, J&K. *Jour. Geol. Soc. India*, v.11, pp.34-44.
- TAYLOR, S.R. and MCLENNAN, S.M. (1981) The composition and evolution of the continental crust: rare earth element evidence from sedimentary rocks. *Philos. Trans. Royal Soc. London*, v.A301, pp.381-399.

(Received: 9 March 2004; Revised form accepted: 31 January 2005)