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K-rich Titanate from the Jharia Ultrapotassic Rock, Gondwana Coal Fields, Eastern India, and its Petrological Significance

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Abstract: We report a rare accessory groundmass mineral of K-rich titanate, having a composition close to that of potassium triskaidecatitanate ($K_2Ti_{13}O_{27}$), from an underground drill-core sample of ultrapotassic rock from south-western part of the Jharia coal field in the Damodar valley, at the northern margin of the Singhbhum craton, Eastern India. Potassium triskaidecatitanate is regarded as a typomorphic mineral of orangeites (Group II kimberlites) of Kaapvaal craton, southern Africa, and its occurrence in the Jharia ultrapotassic rock is significant since ultrapotassic suite of rocks elsewhere from the Damodar valley have been recently suggested to be peralkaline lamproites based on mineral-genetic classification. The important role played by a unique geodynamic setting (involving a thinned metasomatised lithospheric mantle and inheritance of an Archaean subduction component) at the northern margin of the Singhbhum craton in deciding the petrological diversity of the early Cretaceous ultrapotassic intrusives from the Damodar valley is highlighted in this study.

Keywords: K-titanate, ultrapotassic, Jharia, Damodar Valley, Singhbhum craton.

INTRODUCTION

The Cretaceous ultrapotassic intrusives occurring in the Gondwana coal fields of Jharia, Raniganj, Bokaro, and Karanpura in the Damodar valley, Chhotanagpur Gneissic Terrain, at the northern most margin of the Singhbhum craton in eastern India (Fig.1), have been a subject of petrological interest for more than a century (see Mitchell, 2007). These rocks are widely regarded as "difficult to classify" rocks displaying petrological and geochemical characteristics of orangeites (Group II kimberlites), lamprophyres, and lamproites (Mukherjee, 1961; Middlemost et al. 1988; Rock et al. 1992; Basu et al. 1997; Kent et al. 1998; Jia et al. 2003; Srivastava et al. 2009). Recently, Mitchell and Fareeduddin (2009) carried out a comprehensive mineral-genetic study of two ultrapotassic dykes from the Ranigunj coal field and infer them to be lamproites (*sensu lato*) and place them in the spectrum of such peralkaline rocks (*var. Damodar*) having a common parental magma which was generated from partial melting of the ancient metasomatised lithospheric mantle. The purpose of this note is to report the occurrence of a rare K-titanate mineral from one such ultrapotassic dyke in the Jharia coal field and relate its significance in the context of petrological complexity and nomenclature of the Early Cretaceous peralkaline intrusives from the Damodar valley.

GEOLOGICAL SETUP AND PETROGRAPHY

The Damodar valley, located within the Chhottanagpur Gneissic Complex, at the northern-most edge of the Singhbhum craton, eastern India, is studded with several Gondwana coal fields in disconnected sedimentary basins along the E-W trending fault system (Fig.1A). These coal fields are intruded by swarms of igneous intrusions of mafic and ultramafic composition which occur mostly as dykes and sills but also as rare cylindrical bodies (e.g., Kent et al. 1992; Mukherjee and Ghose, 1999; Paul, 2005). Available age data suggests that the mafic as well as ultramafic magmatism is of ca.114 Ma and is very likely to be related to the interaction between the Kerguelen mantle-plume activity and the Indian lithosphere during the early Cretaceous (Kent et al. 1998).

The borehole sample JH8/BH2 of this study is from Talgoria area, Parbatpura coal block, southwestern part of Jharia coal field (Fig.1B). Geologically the Parbatpura coal block is predominantly occupied by the rocks of Barren Measure Formation and inliers of Barakar Formation. The area is bounded by latitude 23º39'30"N to 23º42'55"N and longitude 86º19'15"E to 86º22'30" E. The Barakar Formation consists of coal beds and is intruded by dolerite, and ultrapotassic dykes and sills. Petrography of the sample JH8/BH2 reveals that it is characterised by

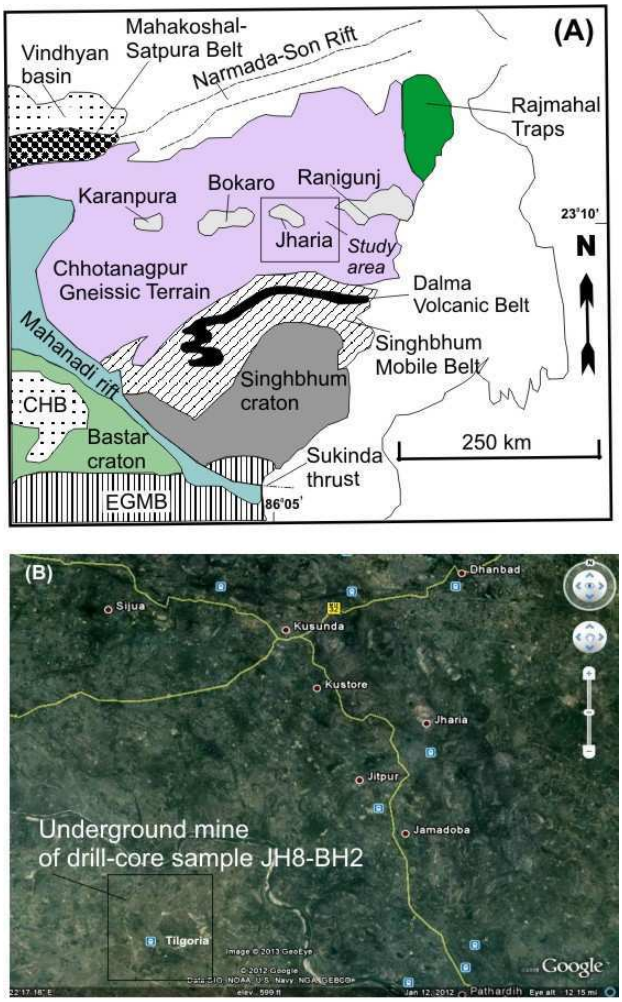

Fig.1. (A) Generalized geological map of the Chhotanagpur Gneissic Terrain showing the disposition of Gondwana coal fields of Ranigunj, Jharia, Bokaro and Karanpura in the Damodar valley (modified from Acharyya, 2003). CHB= Chhattisgarh basin and EGMB= Eastern Ghats Mobile belt. **(B)** GOOGLE EARTH map showing the location of Tilgoria village (in box) at the south-western part of the Jharia coal field (above). The underground mine area from where the drill-core sample of ultrapotassic rock of this study is showed as a box.

inequigranular texture with olivine macrocrysts as well as phenocrysts both of which are entirely pseudomorphosed by secondary phases such as serpentine, talc and carbonate. Phlogopite is the most abundant pristine phase occurring as lath shaped phenocrysts, micro-phenocrysts as well as poikilitic mats in the matrix. Other minerals include K-feldspar, clinopyroxene, apatite, rutile, spinel and carbonates (Fig. 2A). The K-titanate, which is the main subject of this communication, occurs as an accessory phase, opaque in thin section and has been identified by back scattered electron (BSE) imaging. K-titanate essentially occurs as scattered clusters of prismatic crystals of < 50 µm size (Fig.2B).

ANALYTICAL METHODS

A qualitative spectral scan on the K-titanate (Fig. 2C) was first carried out by energy dispersive spectrometry (EDS) using a Princeton Gamma-Tech (PGT) Prism digital spectrometer (model OPE002-1038) attached to CAMECA-SX100 electron microprobe installed at the Mineral Resources, Technical University of Clausthal, Clausthal-Zellerfeld, Germany, to decipher the elements present. A quantitative chemical composition of only such elements was subsequently determined (*see* Table 1) by wave-length energy dispersive spectrometry (WDS). A beam current of 12 nA, an acceleration voltage of 20 kV along with a beam diameter of 1 µm were used and error on the oxides was not greater than ± 1%. PEAK SIGHT online software program developed by CAMECA was used to acquire and process the data and the standards used are the same as discussed in Torab and Lehmann (2007).

RESULTS AND DISCUSSION

The habit of the K-titanate phase is strikingly similar to that of the K-triskaidecatitanate ($K_2Ti_{13}O_{27}$) reported by Mitchell (1995; Figure 2.94, p. 213) from Lace, Sover North and Star orangeites of southern Africa. High titania (TiO_2 up to 83.40 wt.%) coupled with high potassium (K_2O up to 9.94 wt.%) and iron (expressed as Fe_2O_3*= 8.60 wt.%) are the characteristic features of K-titanate of this study. Note that X-ray diffraction data for K-triskaidecatitanate is as yet unavailable (R.H. Mitchell, *pers. commn.*) and therefore its structure is uncertain. Even though there is a deviation from the ideal composition of $K_2Ti_{13}O_{27}$, the average composition of K-titanate of this study ($K_{2.15}Ti_{12.24}O_{27}$ from an average of 13 analyses; Table 1) comes closer to that of K-triskaidecatitanate reported from southern African orangeites ($K_{2.19}Ti_{13.28}O_{27}$ from an average of 8 analyses; see Table 2.32 of Mitchell, 1995), than any other known titanates such as hollandite. This is also illustrated by the similarity in titanium and potassium contents of the K-titanate of this study and those reported from orangeites (Fig.2D). As there is no detectable barium and aluminium in the K-titanate of this study we rule out it being a priderite (K-Ba-Al-titanate). However, minor compositional differences (such as absence of Nb, V and even Ba) from some of the K-triskaidecatitanate reported from southern African orangeites can be explained due either to (i) the composition of the melt or (ii) the crystallisation of rutile, apatite and spinel.

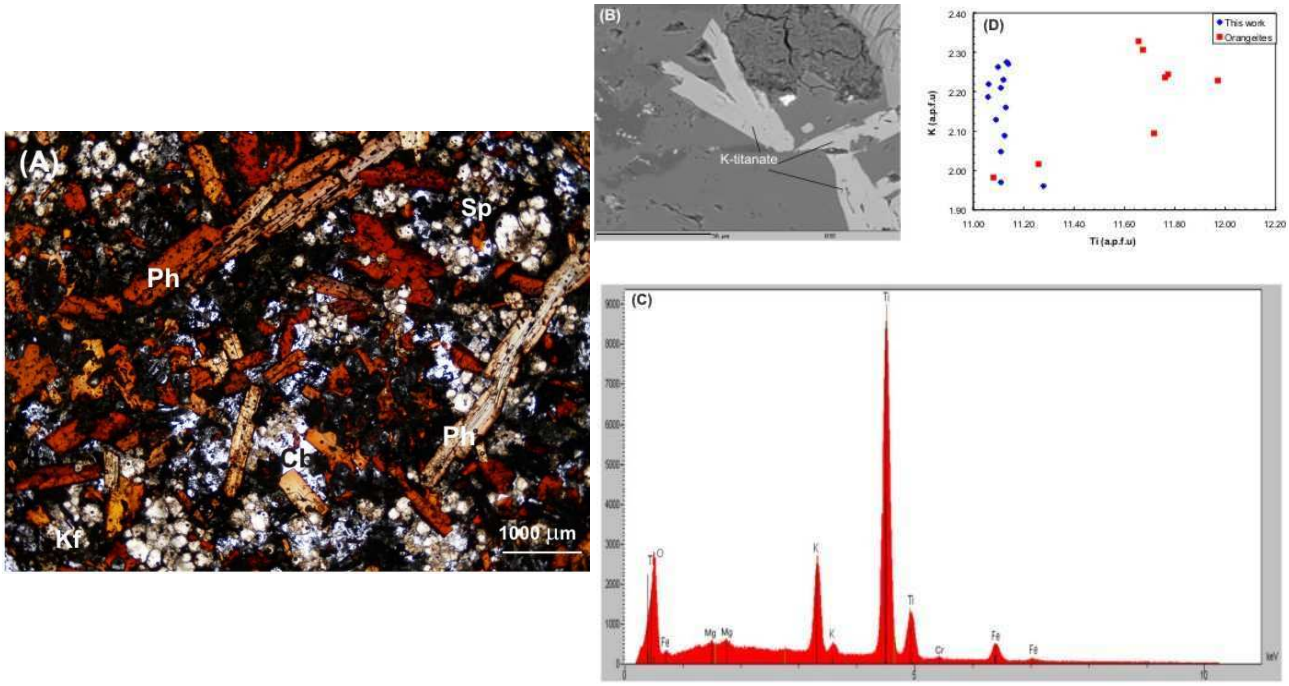

Fig.2. (A) Microphotograph (plane polarised transmitted light) of the JH8/BH2 thin section showing the modal abundance of phlogopite (Ph) in the sample. Other minerals include K-feldspar (Kf), carbonates (Cb) and spinel (Sp). **(B)** A back scattered electron (BSE) image of the K-titanate reported in this study. **(C)** A qualitative EDX elemental scan of the K-titanate (this study). Abscissa is energy in kiloelectronvolts (keV) and ordinate is the elemental count. **(D)** Titanium (atoms per formula unit) versus potassium (atoms per formula unit) compositional variation plot of the K-titanate of this study compared with that of Potassium triskaidecatitanate from southern African orangeites (data from Mitchell, 1995).

Kent et al. (1998) re-interpreted the 'priderite' reported earlier (Gupta et al. 1983; Middlemost et al. 1988; Rock et al. 1992) from Jharia and Ranigunj ultrapotassic rocks as K-triskaidecatitanate and suggested an orangeitic affinity of these rocks. However, Mitchell (2007, p.510) pointed out that their stoichiometry is incompatible with that of $K_2Ti_{13}O_{27}$ and inferred them to belong to hollandite group K-Ba titanates - similar to those that occur in lamproites (*sensu stricto*). Besides, BaO is a conspicuous component (0.8-9.1 wt.%) in their reported chemical composition which distinguishes them from that of the K-titanate of this study. It should be mentioned here that minerals belonging to the K-triskaidecatitanate group are presently considered by the IUGS (Le Maitre, 2002) to be characteristic of the

Table 1. Mineral chemistry (oxide wt%) of the various K-titnate grains from the sample JH8/BH2 of this study. The total iron is expressed as $Fe_2O_3^*$; A = K; B = Ti, Fe, Cr and Mg

Oxide wt%	1	2	3	4	5	6	7	8	9	10	11	12	13
MgO	0.01	0.05	0.04	0.04	0.01	0.00	0.01	0.03	0.01	0.02	0.01	0.04	0.07
K_2O	9.39	9.67	9.52	8.72	9.75	9.82	9.95	9.35	9.6	9.94	9.22	9.04	8.55
TiO_2	82.84	82.5	83.24	83.23	82.3	82.89	82.54	82.6	82.36	82.63	83.23	83.17	83.4
$Fe_2O_3^*$	8.44	8.00	8.08	8.76	8.17	7.50	7.18	8.51	8.75	8.04	7.69	8.6	6.81
Cr_2O_3	0.19	0.25	0.11	0.13	0.52	0.60	0.67	0.14	0.11	0.24	0.76	0.12	0.30
Total	**100.87**	**100.47**	**100.99**	**100.88**	**100.75**	**100.81**	**100.35**	**100.63**	**100.83**	**100.87**	**100.91**	**100.97**	**99.13**
					Structural formula based on 27 oxygens								
Mg	0.001	0.010	0.010	0.010	0.001	0.001	0.002	0.008	0.003	0.004	0.003	0.011	0.020
K	2.270	2.210	2.160	1.970	2.220	2.230	2.275	2.130	2.187	2.263	2.089	2.048	1.960
Ti	11.140	11.110	11.130	11.110	11.060	11.120	11.133	11.091	11.058	11.097	11.124	11.109	11.278
Fe	1.020	1.080	1.080	1.170	1.100	1.020	0.969	1.143	1.176	1.079	1.028	1.149	0.921
Cr	0.030	0.030	0.020	0.020	0.070	0.080	0.094	0.020	0.016	0.034	0.107	0.016	0.042
Total	**14.46**	**14.44**	**14.40**	**14.28**	**14.45**	**14.45**	**14.47**	**14.39**	**14.44**	**14.48**	**14.35**	**14.33**	**14.22**
A	2.27	2.21	2.16	1.97	2.22	2.23	2.28	2.13	2.19	2.26	2.09	2.05	1.96
B	12.19	12.23	12.24	12.31	12.23	12.22	12.20	12.26	12.25	12.21	12.26	12.28	12.26

Group–II kimberlites (orangeites).

Based on bulk-rock incompatible trace element ratios, Srivastava et al. (2009) have recently proposed that a unique geodynamic setting involving (i) metasomatically veined and thinned lithosphere located at the margin of the Singhbhum craton and (ii) the inheritance of ancient (Archaean) subducted component has played a significant role in deciding the diverging petrological and geochemical characters- those of kimberlites (orangeites) and lamproites (cratonic signature) and even those of aillikites (rift-related signature)- displayed by the Jharia potassic rocks. Our report of K-triskaidecatitanate, which is hitherto considered as a typomorphic mineral of orangeites, highlights the petrological divergence (characteristics of orangeites, lamproites and lamprophyres) of ultrapotassic intrusives from the Damodar valley and provide additional support to the geodynamic model proposed by Srivastava et al. (2009) to account their petrological complexity and genesis.

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