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Ultra-potassic and ultra-aluminous hybrid volcanic rock in the Proterozoic of Bastar craton, Madhya Pradesh, India

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Late Proterozoic intracratonic Indravati basin of Bastar has been dissected by Silekjhodi–Tirathgarh fault zone marked by deep gullies and escarpments which afford access to an unconformable junction between basement crystallines and the overlying basinal sediments. This junction exposes the presence of fine-grained green coloured volcanic rock in certain locations. The rock is aphanitic with phenocrysts of potash feldspars and leucite(?) set in a groundmass which is pervasively sericitized. The rock displays unique chemical characters in having high K_2O ($\simeq$11.5%) and Al_2O_3 ($\simeq$32%) contents whereas CaO, MgO, TiO_2 and Na_2O contents are low ($\simeq$1%). This ultra-potassic character indicates a deep-seated source for the rock material, whereas its ultra-aluminous character indicates crustal contamination during its ascent.

LATE Proterozoic intracratonic Indravati basin occupies about 9000 km^2 area in the southeastern portion of the Bastar craton in Madhya Pradesh. Jagdalpur, the district headquarter of Bastar, is situated in the midst of the Basin, and is located 300 km south of Raipur. Ultra-potassic rock was detected at the base of Tirathgarh waterfall by Shivkumar and Fahmi[1] and its sporadic presence has now (1994–95) been traced to extend over a 20 km stretch along WNW–ESE trending Silekjhodi–Tirathgarh fault zone (Figure 1). We attempt to report here a unique occurrence of ultra-potassic, ultra-aluminous rock which may have only a few examples in the world. Detailed investigations on the occurrence are under progress and shall be directed to gain insight into its significance in crust–mantle evolutionary processes in the Bastar craton.

Archaean granitic gneisses of Bengpal Group (characterized by dominance of meta-argillites) and younger granitoids of Central Indian Craton form the basement. Quartzite, sandstone, shale and carbonate rock suites display a sort of concentric disposition from margin inwards in Indravati basin. A comprehensive account of the basin and Bastar craton is given by Crookshank[2], Ramakrishnan[3] and Mishra *et al.*[4]. The Indravati basin along with the basement has been traversed by faults (E–W, N–S) which have controlled the disposition of basin margin and also dissected the basin into blocks which bear evidences of vertical movements. The stratigraphic column encountered near the unconformity exposed in the escarpments bordering Silekjhodi–Tirathgarh fault zone is as follows:

Late Proterozoic	Tirathgarh Formation of Indravati group	Quartz vein
		Orthoquartzites
		Laminated shales and siltstones
		Gritty–pebbly sandstone
		Arkosic sandstone
		Ultrapotassic flow
		Regolith
Archaean	Bengpal group	Crushed granites
		Intrusive granite
		Granite gneisses, schists, migmatites and meta-argillites

The rock type of present interest is the ultra-potassic volcanic flow exposed in Tirathgarh, Batkunta, Koikamari and Silekjhodi localities along the fault zone (Figure 1). It occurs at the unconformity overlying the basement granites and just below the sediments of Indravati group (Figure 2). The exposure dimensions vary from 5 m × 2 m (Batkunta) to 200 m × 15 m (Tirathgarh) and it goes under the sedimentary cover. Occurrence of quartz pebbles at the top layer of ultra-potassic rock at Batkunta indicates subaerial nature of volcanism.

The major oxide weight percentage data of the volcanic rock from Bastar craton (Table 1) show very high K_2O ($\simeq$11.5%) and K_2O/Na_2O (> 25) values and confirm its ultra-potassic nature and also indicate their ultra-aluminous ($\simeq$32%) Al_2O_3) character. The table also includes chemical data of ultra-potassic rocks of different continents for comparison. Ultra-potassic rocks of Bastar are rich in K_2O, Al_2O_3 and depleted in total iron, MgO, TiO_2 and CaO. Foley *et al.*[5] have suggested that potassium-rich igneous rock should be termed as 'ultrapotassic' if they contain high contents of K_2O (> 3%) and have high K_2O/Na_2O (> 3) with an additional requirement of MgO content >3%. They have subdivided ultra-potassic rocks into groups I, II, III and IV based on their major element chemistry and tectonic environments. Attempts of plots on discriminant diagram (Al_2O_3 vs CaO, SiO_2 vs K_2O/Al_2O_3 and SiO_2 vs CaO) show that ultra-potassic rock of Bastar cannot be

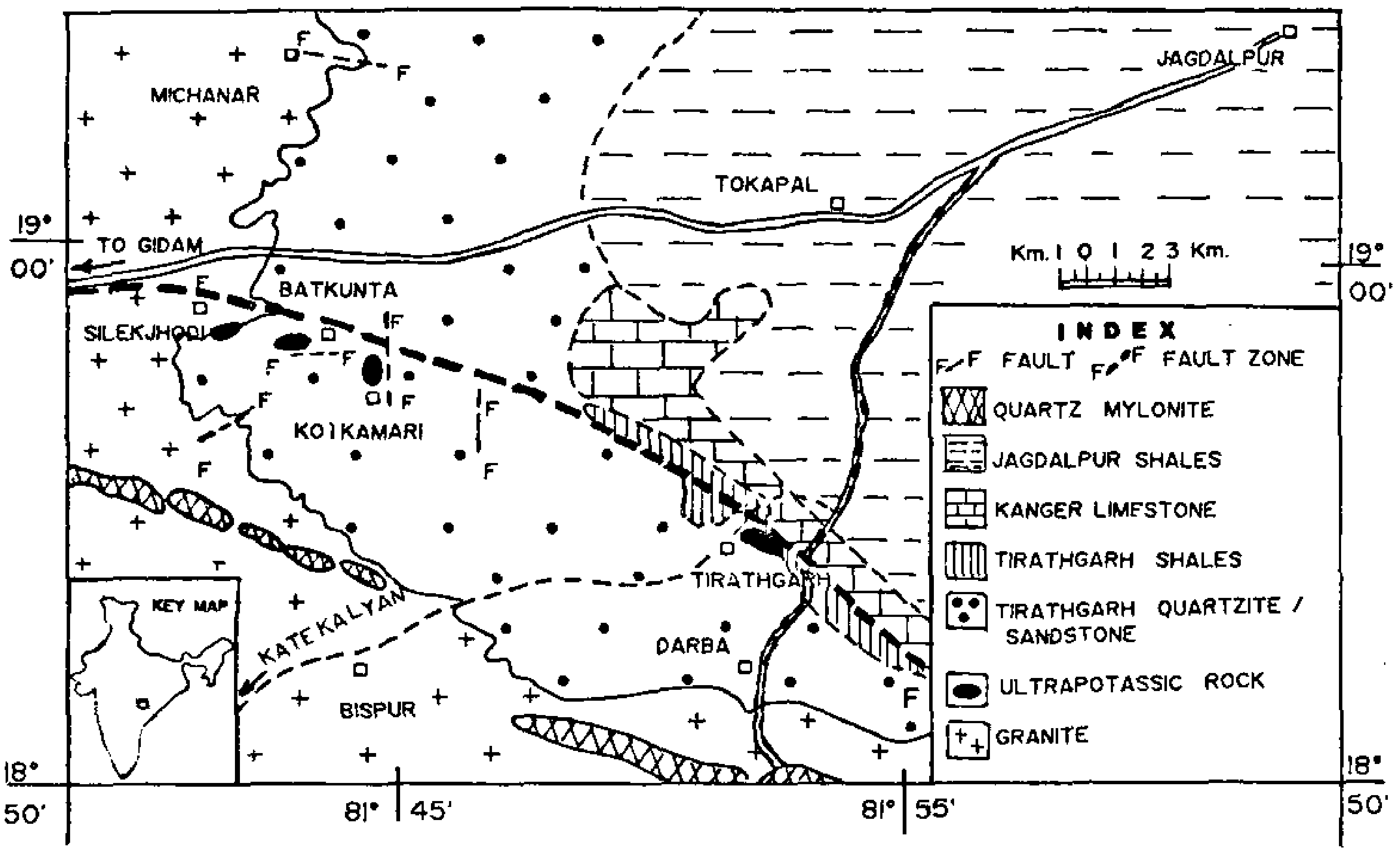

Figure 1. Geological map of south-western margin of Indravati basin showing ultra potassic rock occurrences.

Table 1. Major oxide data of ultrapotassic rock, Indravati basin, Bastar (M.P.)

	TGH/6	TGH/7 Tirathgarh	JDP/95/7	JDP/95/78C Batkunta	JDP/95/78D	JDP/95/82 Silekjhodi	JDP/95/106C Koikamari	East[8] African rift	West[9] Australia	East[10] African Rift	Roman[11] Province
	1	2	3	4	5	6	7	8	9	10	11
SiO_2	45.48	44.56	47.27	47.97	49.70	47.85	47.65	43.22	51.3	39.06	47.12
TiO_2	0.36	0.33	0.19	0.05	0.11	0.05	0.34	4.53	5.1	8.18	0.64
Al_2O_3	33.20	33.88	33.15	31.85	31.70	32.03	32.53	9.98	7.4	4.61	11.84
Fe_2O_3	3.11	3.19	2.93	3.36	2.56	2.76	3.22	12.55*	–	–	3.26
FeO	0.43	0.36	0.05	0.29	0.36	0.29	0.36	–	7.1*	6.47*	4.16
MnO	0.06	0.05	0.01	0.01	0.01	0.01	0.01	0.17	0.09	0.23	0.15
MgO	1.08	2.00	0.39	0.66	0.61	0.50	1.05	8.8	11.7	24.84	12.84
CaO	0.44	0.16	0.05	0.05	0.05	0.05	0.05	11.56	6	8.06	13.88
Na_2O	0.10	0.23	0.45	0.27	0.27	0.27	0.23	2.69	0.5	0.68	1.42
K_2O	11.06	11.38	12.11	11.49	11.14	11.73	11.54	4.77	8.3	3.46	3.29
P_2O_5	0.42	0.43	0.05	0.05	0.10	0.12	0.05	0.55	1.1	–	–
H_2O^+	–	–	2.85	3.17	3.68	3.81	3.55	–	–	1.11	–
H_2O^-	3.87	2.83	0.05	0.05	0.05	0.05	0.05	–	–	0.57	–
Total	99.61	99.40	99.55	99.27	100.34	99.52	100.58	98.82	98.59	96.70	98.60
K_2O/Na_2O	110.60	49.48	26.91	42.56	41.26	43.44	50.17				
Normative values											
q	0.91	–	–	1.62	4.54	0.59	0.53				
c	21.03	21.16	19.28	18.97	19.17	18.85	19.62				
or	65.44	62.77	70.38	67.83	65.89	69.39	68.28				
ab	0.84	–	–	2.10	2.31	2.31	1.94				
lc	–	3.58	1.09	–	–	–	–				
ne	–	1.05	2.00	–	–	–	–				
hy	2.70	–	–	1.70	1.53	1.25	2.63				
ol	–	3.50	0.70	–	–	–	–				
mt	0.35	0.21	–	0.70	0.84	0.79	0.16				
hm	2.86	3.06	2.88	2.88	1.98	2.22	3.10				
il	0.68	0.62	0.10	0.15	0.21	0.09	0.65				
ru	–	–	0.08	–	–	–	–				
ap	1.01	0.34	0.10	0.13	0.10	0.10	0.10				
Total	95.82	96.29	96.61	96.08	96.57	95.59	97.01				

*Total iron; 1–7, Ultrapotassic rock, Bastar, M.P., India; 8, Ultrapotassic lava; 9, Group I – Lamproite; 10, Group II – Kamafugites; 11, Group III – Ultrapotassic rock.

Figure 2. Ultra potassic rock underlying the Indravati sediments at Tirathgarh waterfall.

characterized by the above classification. Similar attempts on igneous rock classification diagram of Cox *et al.*[6] and on modified total alkali–silica (TAS) diagram of Le Bas *et al.*[7] have also failed to specifically assign its position. However, on TAS diagram, the ultrapotassic rock of Bastar indicates a tendency to foidite field. Volcanic rocks with Al_2O_3 content of $\simeq 32\%$ are a rarity. It is contended that this ultra-aluminous character is acquired through assimilation of meta-argillites and their components within the Bengpal gneisses, forming basement of the Indravati basin. The major normative minerals formed in all the samples are orthoclase (62–70%), corundum (18–21%) and haematite (2–3%) with apatite, ilmenite and magnetite as accessories (Table 1). Two samples show undersaturated minerals such as leucite and nepheline, indicating their alkaline character. However samples show sericitization in thin sections, which is a subsequent alteration phenomenon and could be attributed to the formation of normative quartz. From the above discussion, it is obvious that chemically or petrochemically the volcanic rock of Bastar has unique features.

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Dendrochronological reconnaissance of *Pinus wallichiana* to study glacial behaviour in the western Himalaya

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Tree ring analysis of *Pinus wallichiana* growing in the subalpine region of the Kinnaur, north-west Himalaya has been discussed in this paper. A chronology of this species extending from 1621 AD to 1990 AD has shown that tree ring data could be used to study the glacial behaviour in this region. It has been recorded that the annual ring widths of this species are low during the years having positive glacial mass balance recorded from some glaciers of this region and with glacial advances reported during the recent past in the Himalayan and Trans Himalayan region.

RECENT studies reveal that tree ring data derived from either of several annual ring characters, viz. width, density, cell size, isotope contents and others are unique sources of proxy records to deal with the various aspects of environmental studies[1–3]. Using tree ring data, fluctuations of recent glaciers have been analysed from the Alps[4], Mount-Baker[5], Canadian Rockies[6] and others.

In India, a great deal of geomorphological studies in the Himalayan glaciers have been done[7–10]. But, except for two synthesized extrapolated long records based on data from several glaciers[8,9], no studies on the history of glacial fluctuations in terms of absolute time scale are available from the Himalayan region. In the present study, the prospect of tree ring study to understand glacial fluctuations in terms of calendar years from the Western Himalayan Region has been discussed. This study is based on ring width data of *Pinus wallichiana* growing in the dry subalpine regions of Kinnaur, in the Western Himalayas.

Several conifers in the Himalayan region have been found to be a potential source for tree ring studies[11–18]. To extend database from diversified climatic zones, the present study was undertaken on *Pinus wallichiana* growing in subalpine forest at Kinnaur, Himachal Pradesh in western Himalaya. This taxon is widely dis-