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A Study of Saturated and Over-Saturated Alkaline Rocks of Rajasthan, India

Dr. Anil Kumar Yadav
Associate Professor
Geology Govt. Dungar Collage, Bikaner Rajasthan

ABSTRACT
Within typical peraluminousMalani rhyolites, peralkaline granites and rhyolites can be found as subvolcanic ring complexes. At Siwana, sodatrachytes, pantellerites, and peralkaline granites are exposed as a ring structure created by cauldron subsidence. The discontinuous, isolated outcrops of arfvedsonite-aegirine granites that make up the ring's periphery show maximal extent in the southwest. Pantellerites and sodatrachytes flows define the ring's northern limit. Peralkaline tuffs and ashes that have been formed in shallow water in the center of the ring exhibit cross-bedding and symmetrical ripple traces. Within the ring, a number of sodatrachyte dykes sliced through the granite and tuffs. The region southwest of Barmer town is characterized by a high prevalence of comendites. In these locations and the area surrounding Jalore, alkali olivine dolerite dykes and small plug-like masses of micro-gabbros are quite common. Some of these fundamental bodies seem to exist as isolated clusters within granites and rhyolites. These bodies exhibit myrmekitic texture expansion and alkali feldspar jacketing of plagioclase in their margins. Therefore, it would seem that this peralkaline episode had been followed by and preceded by a cycle of olivine basalt magmatism.In this paper we studied about the saturated and over saturated rocks of western India.

Keywords-*PeraluminousMalani rhyolites, Peralkaline granites and Rhyolites,Pantellerites and sodatrachytes flows etc.*

I. INTRODUCTION

Alkaline rocks contain higher concentrations of Na and K, are deficient in silica and/or alumina with respect to these alkali elements and contain modal or normative feldspathoids, alkali pyroxenes and alkali amphiboles. Owing to their small volume, and tricky nomenclature – due to a great diversification in their mineralogy – the study of alkaline rocks is challenging compared to that of the most other igneous rocks. Despite this, the study of alkaline rocks remains fascinating to the petrologists owing to their deeper mantle origin and the xenoliths they entrain which constitute the direct proxies of the deeper parts of the continental lithospheric plates. A great deal of economic significance has been attached to the alkaline rocks, as they are significant repositories of precious minerals as well as elements like diamond, gold, copper, rare earth elements (REE), etc. The cratons, the mobile belts and the Large Igneous Provinces (LIPs) from Archaean to Eocene ages in diverse tectonic settings of the Indian shield host a variety of alkaline rocks such as alkali basalt, basanite, carbonatite, ijolite, kimberlite, lamproite, lamprophyre, leucite, melteigite, mugearites, nephelinites, nephelinesyenites, orangeites, alkali pyroxenite, phonolite, and tinguaite rocks . Alkaline magmatism in LIPs has been considered either as precursors to Cood basalt volcanism in the form of early small-scale melting events or mark the culmination of major volcanic episodes .The DLIP represents one of the largest manifestations of the continental Cood basalt magmatism in the world and covers majority of the western and a few parts of the central India . It has an aerial extent of 500,000 km2 and bulk of the volcanic rocks have tholeiiticcompositions .Vast amount of geochronological data on different domains of the DLIP suggest that it encompassed ashort time span of aprox10 Ma as a product of the Reunion plume.The DLIP has also been linked with the (i) large scale plate movements (ii) Cretaceous–Tertiary mass extinction events and (iii) even extra-terrestrial impacts Recent reviews on the DLIPconcern more about the stratigraphy and geochronology of the lava Cows, tholeiitic basalts, and carbonatites than about a wide variety of the associated alkaline rocks. In fact, the alkaline rocks associated with the Deccan LIP, especially from NW India, have been studied over the past century or so. A majority of them have been emplaced in quasi-parallel deep-seated fault systems of mega-scale rifts, such as the Narmada–Son the Cambay, the Kutch and the west coast rifted margin and carry geochemical imprints of the Reunion mantle plume. The previous major reviews addressing the alkaline magmatism associated with the DLIP dates back to almost half a century to three decades and hence a need for an updated review of the studies on these rocks. The objective of this contribution is to provide a comprehensive appraisal on the diverse alkaline rocks associated with the DLIP, based on their time–space distribution, petrology, geochemistry (including isotope geochemistry) and economic significance. Occurrences of different crustal as well as mantle xenoliths entrained in these alkaline rocks have also been emphasized. We also explore their petrogenetic aspects, geodynamic implications, and identify future directions of research.

ALKALINE GRANITEROCKS IN RAJASTHAN

Peralkalinegranites and rhyolites have been reported from various places in the Barmer district of Rajasthan; the prominent occurrences being at Siwana, Jasai, Taratra, Mungeria and Bisala, all in Barmer district. These are 'A-type' granites. They contain arfvedsonite, riebeckite and acgirinebesides accessory fayalite, monazite, zircon and crystalline iron oxides. Perthitic feldspar with exolvedalbite occurring as stringers and veins dominates over plagioclase. It is hyper-solvus type as indicated by the nature of feldspars, presence of soda- amphiboles and soda-pyroxenes and absence of any zoned pegmatites. Though brief mention of the associated peraluminous as well as peralkaline rhyolites has been made by the aforementioned authors who also suggest that the rhyolites (both peraluminous as well as peralkaline) and the high level granites are cogenetic, no details of the peralkalinevolcanics are available. Consequently, greater emphasis has been placed in this paper on silicic volcanics belonging to comendite and pantellerite clans and also the associated sodatrachytes.

In the present paper, the term pantellerite refers to more peralkaline (agpaitic ratio generally more than 1.20) and iron-rich (total iron more than 4%) volcanic group, and comendite to less peralkaline and iron-rich volcanics. But the limits of pantellerite and comendites as suggested are only probable and not absolute. Where deuteric alteration has made the volcanicsperaluminous, the presence of soda-amphibole has been taken as an indicator of their original peralkaline nature. The term sodatrachyte has been used for peraluminoustrachytes and quartz-trachytes.

MODE OF OCCURRENCE

Peralkaline granites and rhyolites occur as subvolcanic ring complexes within normal peraluminousMalani rhyolites. At Siwana, peralkaline granites, pantelle- rites and sodatrachytes are exposed in the form of a ring structure formed due to cauldron subsidence. The periphery of the ring is marked by the discontinuous isolated outcrops of arfvedsonite-aegirine granites which show maximum extension in the southwestern fringe of the ring. The northern boundary of the ring is marked by flows of sodatrachytes and pantellerites. In the centre of the ring, peralkaline tuffs and ashes have been deposited in shallow water, and show cross-bedding and symmetrical ripple marks. A number of sodatrachyte dykes cut the granite and tuffs within the ring. Comendites are very common in the area to the southwest of Barmer town.

Large number of alkali olivine dolerite dykes and small plug-like bodies of micro-gabbros are quite frequent in these areas and also around Jalore. Some of these basic bodies appear to be enclaves within granites and rhyolites. Such bodies in their marginal parts show growth of myrmekitic texture and jacketing of plagioclase by alkali feldspar. Thus, it appears that a cycle of olivine basalt magmatism had not only preceded but also succeeded this peralkaline event.

PETROGRAPHY

Comendites vary from glassy to micro- and crypto-crystalline in shades of ash- grey, pale-blue, greenish-grey and green. They usually contain scattered phenocrysts of alkali feldspar and corroded crystals of quartz in a crypto- to micro-crystalline groundmass. The mafic minerals appear as spongy dyscrystalline aggregate and as finely dispersed wisps in the groundmass. Aegirine and riebeckite are identifiable in many sections. Spherulitic and axiolitic textures are commonly displayed. Pantellerite flows are reddish-brown (due to oxidation of iron), strongly porphyritic with phenocrysts of alkali feldspars and quartz ir a matrix of microcrystalline quartz, feldspar, iron-oxides, wisps and shreds of blue-green amphibole. The mafic minerals are acgirine, arfvedsonite; occasional small grains of katophorite and fayalite have also been noted.

Sodatrachyteflow are dark-coloured, fine-grained with typical trachytic texture, often porphyritic with phenocrysts of orthoclase, rare sanidine in a groundmass of orthoclase laths, aegirine and opaques. Occasional phenocrysts of an aegirine-augite type pyroxene are also seen.

GEOCHEMISTRY

Geophysical investigations in and around alkaline rocks and complexes highlight the presence of magma accumulations, lineaments and thick shield-like crust. A vast variety of entrained mantle and crustal xenoliths/xenocrysts include dunite, spinel lherzolite, websterite, pyroxenite, granulite, feldspar, olivine, quartz, orthoclase, microcline, etc. Xenoliths preserve imprints of cryptic as well modal mantle metasomatism. Average chemical analyses of comendites, pantellerites and sodatrachytes are given in Table-I. It reveal that comendites and pantellerites plot in different fields and in general comendites have higher silica and alumina and lower iron and manganese than pantellerites. The lime content of these rocks is also very low; to a maximum of 1.0% in pantellerites and 0.5% in comendites. All of them have high Na_2O/K_20 and high Na+ K/Ca ratios. These features typify them as ‘A- type’volcanics. In all these rocks there is a complimentary relationship between total iron and lime plus alumina, whereas, amongst normal Malani rhyolites there is covariance between these element pairs. Sr content of these rocks is very low indicating that these are fractionated lavas. Their Zn content is much higher than in the normal Malani rhyolites.

PETROGENESIS

Any petrogenetic model for these peralkaline silicic volcanics should explain the mechanism of their development and their relationship with normal 2-feldspar peraluminousMalani rhyolites, besides the origin of the peralkaline magma. In order to have some idea of the mechanism of their development, correlation analysis of major elements in 155 fresh and unaltered samples of these volcanics, and some of the associated peralkaline granites, was made.

The correlation analysis shows: (1) highly significant negative correlations between silica and total iron, titanium, calcium and magnesium implying that with progressive differentiation the liquid has become impoverished in mafic constituents and enriched in silica; (2) positive correlations between titanium and iron, calcium and magnesium and alumina and calcium, suggesting that low pressure iron oxide,

TABLE I. Average chemical composition of peralkaline silicic volcanics of Barmer and Siwana, southwestern Rajasthan.Major elements as Wt % oxides and trace elements in ppm.

	1	2	3	4	5	6	7
SiO_2	59.87	61.98	74.41	75.78	69.79	72.74	73.33
$TiO_2$0.	78	0.97	0.37	0.33	0.65	0.62	0.39
$A1_2O_3$	14.00	11.79	10.29	10.72	8.42	9.94	10.15
Fe_2O_3	3.84	9.88	1.98	2.22	7.76	3.89	4.44
FeO	0.63	1.15	0.87	0.84	0.93	1.09	0.85
MnO	0.11	0.36	0.07	0.07	0.20	0.11	0.08
MgO	1.23	0.66	0.09	0.10	0.37	0.26	0.26
CaO	5.44	1.41	0.45	0.38	0.96	0.62	0.72
Na_2O	5.83	5.53	4.88	4.33	4.27	4.76	4.03
K_2O	5.36	4.94	4.93	4.11	5.40	5.41	4.67
H_2O^+	0.80	1.00	0.40	0.40	0.80	0.85	0.60
Total	98.44	99.70	98.98	99.31	99.65	100.37	99.53

II. DISCUSSION

In comparison to the peralkaline silicic volcanics, the normal Malani rhyolites have relatively higher CaO and lower Na_2O/K_2O ratio (for 260 normal Malani rhyolites from different parts of the volcanic province the average CaO is 1.12% and the Na_2O/K_2O is 0.60, whereas 155 peralkaline rhyolites, granites and soda trachytes have an average CaO value of 0.79 and Na_2O/K_2O ratio of 0.98) suggesting that they are either 'I or S-type'volcanics, and according to Clemens et al. (1986) the high CaO and late crystallisation of K-feldspar in 'I-Type' and low Na_2O/K_2O in 'S-Type' means that these magmas are unlikely to produce hypersolvus granites. Thus, the contentions of different researchers revealsthat the peralkaline rhyolites and granites are cogenetic with the normal peraluminous rhyolites and represent their late differentiates, are not borne out by the present data. Moreover, the presence of crystalline magnetite in these peralkalinevolcanics indicates that the magma temperature must have exceeded 830°C and from the presence of fayalitic olivine, magnetite and quartz it can be reasonably assumed that the crystallisation took place at an oxygen fugacity at or above that of quartz-fayalite- magnetite (QFM) buffer assemblage. For the Siwana granite, Mookherjee and Roy have shown that arfvedsonite has a field of magmatic crystallisation starting from PH_2O between 3 and 3.5 kb and about 650°C under Ni-NiO buffered oxygen fugacity. Thus the question of these peralkaline liquids being late differentiates of normal peraluminous granitic liquids does not arise.

So far as the question of genesis of 'A-Type' magmas is concerned, several mechanisms have been postulated. The major ideas are:

(1) mantle derived alkaline magmas fractionate to produce residual granitic liquid

(2) mantle derived alkaline magmas react with crustal rocks to produce a syenitic derivative that fractionates to granitic composition. Barth etc. suggested a variant of this scheme in which syenitic magma further reacts with quartzose crustal rocks and eventually forms granitic hybrid;

(3) A-type magmas are due to melting of lower crust under the fluxin influence of mantle derived volatiles .

(4) high temperature partial melting of depleted I-type source in the lower continental crust .

Besides these major ideas liquid immiscibility, liquid-state thermogravitational diffusion and fractional crystallisation of an I-type parent magma have also been suggested as possible modes for genesis of A-type magmas.

The details of the origin of the peralkaline rocks of the present study are still being worked out, but the presence of soda trachytes and abundance of alkali olivine dolerite and plugs in the area favour contamination of mantle-derived magmas to form syenitic liquids that either further react with crustal rocks or fractionate to A-type magmas.

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