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Petrographic Variations in the Deccan Basalt Lava Flows of Rajura Volcanics, central India: Textural Implications

M. S. Deshmukh*

Post Graduate Department of Geology, R. T. M. Nagpur University, Nagpur (M. S.), India

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Abstract

The present study encompasses petrographic variations in simple Deccan basaltic lava flows of the Rajura volcanics, central India. The Deccan basalt lava flows entirely covered the area and exposed in the form of moderate hillocks. During geological fieldwork, flows are identified and differentiated based on mineral content, relative grain size, presence of phenocrysts, and red bole horizons. Flow mapping reveals three basalt lava flows: mafic plagioclase microphyric basalt, phyric basalt, and plagioclase mafic microphyric basalt. The petrographic study of the lava flows was carried out to understand the mineralogy, textural patterns, crystallization, and genetic significance of the lava flows. The result indicates dominant plagioclase and clinopyroxene minerals with opaques exhibit porphyritic, glameroporphyritic, ophitic, and sub-ophitic textures. The petrographic variations are due to the combination of several factors like gravitational sinking of phenocryst, low viscosity, and slow rate of effusion of lava flows, as described by earlier workers. Plagioclase occurs as phenocrysts and in the groundmass phase, indicating early crystallization of phenocryst followed by crystallization of groundmass. The petrographic studies are further useful to correlate the lava flows exposed in different hillocks of the area.

Keywords: Deccan basalt; Lava flows; Petrography; Textures; Correlation.

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1. Introduction

Basaltic lava flows are ubiquitous in our solar system, observed on terrestrial planets [1]. Similarly, India's Deccan volcanic province (D.V.P.) presently occupies 5,18000 Sq. km area of Western and Central India. It has not been studied in detail regarding volcanic types, morphology, petrography, paleomagnetism, and geochemistry [2,3]. Most of the investigations carried out by previous researchers were confined to the thick lava piles of the Western Ghats [2-9]. Compound flows are extensively developed in the Western part of the Deccan Traps and exhibit remarkable variation in their phenocryst content [10]. Similarly, simple lava flows are composed of vesicular and massive units which differ in petrographic characteristics. Possible reasons for petrographic variations are considered to be due to a combination of several factors like gravitational sinking of phenocrysts aided

* *Corresponding author*: manishdesh40@gmail.com

by low viscosity slow rate of effusion, which allowed enough time for crystallization and sinking of phenocrysts and also transported them during later eruptive stages [10]. The aim of the present research work is to carry out the petrographic aspect of the basalt lava flows, to understand mineralogy, textural patterns, crystallization, genetic significance, petrographic variations, and correlation of the exposed basaltic lava flows of the Rajura area, Amravati district, part of Central India.

2. Study Area

The area under study comprises approximately 10 sq. km area of Amravati district, Maharashtra State, India, and it is covered by the Survey of India topographical map 55H/13 and bounded by 77°48'00"-77°50'14" E longitude and 20°55'32"- 20°57'18" N latitude (Fig. 1).

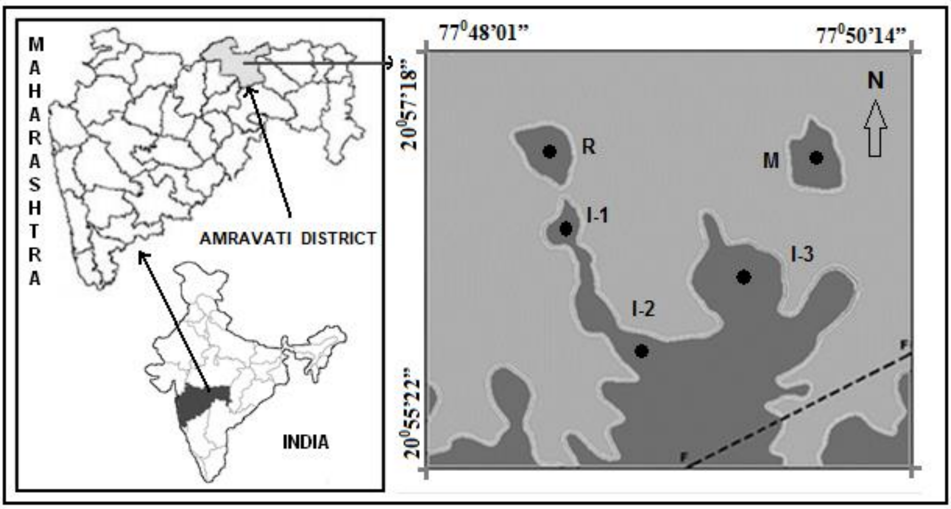

Fig. 1. Location and geological map of the study area (Deccan Basalt Formations, indicated by light grey color (Reverse palaeomagnetic polarity) and dark grey color (Normal palaeomagnetic polarity); field traverses R, M, I-1, I-2 & I-3 [after 2, 14].

3. Material and Methods

The survey of India's topographic map (1:50,000) scale is used as a base map during geological excursions. Five different hillocks were selected, considering the highest to lowest elevation, that they could represent a complete exposed lava pile of 46 meters between an altitude of 390 meters above mean sea level. For the identification of different lava flows and their lithological and petrographic variations, rock samples were collected from different locations (elevations) of the hills. G.P.S. is used to measure the corresponding altitudes. Rock samples were collected from the top of the hill towards the lowest elevation in the area. Accordingly, different lava flows were identified based on differences in grain size, mineral content, presence of phenocrysts, physiographic breaks, and red bole horizons. Thin sections of representative rock samples (collected from different lava flows exposed in different hillocks in the area) were studied at S.G.B. Amravati University, Maharashtra State (India) laboratory, to understand petrographic variations and also to understand crystallization patterns, mineralogical and textural variations and their significance for correlation of the lava flows. The field characteristics of the rock samples and petrographic study in hand specimens are also carried out to support the data.

4. Geological Setup

The lava flows can be classified as simple or compound, with the former consisting of a single lobe [11]. Deccan lavas are largely modeled on the lines of Hawaiian lavas following the initial comparisons by Walker [12]. They were categorized as (i) compound (with multiple units of pāhoehoe type), (ii) simple, or (iii) a'a types [8,10,13]. In the Rajura area, three basalt lava flows are exposed, which are divided into two different formations based on field and palaeomagnetic studies [2,14]. The lava flows exposed in this area are designated as the Karanja Formation (Sahyadri Group) by the Geological Survey of India [15]. The major lineaments of the area are trending $N80^0E$-$S80^0W$ [16]. Sequentially, the exposed flows are lowermost fine-grained, mafic plagioclase microphyric basalt (Flow I), medium to coarse-grained, plagioclase phyric basalt (Flow II), and fine-grained, plagioclase mafic microphyric basalt (Flow III) [2]. The Indla field traverse (I_1), with an exposure of 37 meters, lava pile, comprises two lava flows between 388 to 425 meters altitude above mean sea level. Indla field traverse (I_3) comprises fine-grained, plagioclase phyric basalt (Flow II), overlain by fine-grained, plagioclase mafic microphyric basalt (Flow III) between the altitude of 460 meters to 410 meters. Mardi Field Traverse (M) exposed 38 meters basalt lava pile between altitudes of 390 to 440 meters, comprising medium to coarse-grained, plagioclase phyric basalt (Flow II) at the bottom, overlain by fine-grained, plagioclase mafic microphyric basalt (Flow-III) (Fig. 2).

5. Results and Discussion

5.1. *Petrography of basalt lava Flows*

The petrographic study of rocks is primarily hinged on detail examination, identification of minerals, texture, deformation history, paragenesis, and origin of rocks through macroscopic and microscopic examinations [17]. It envisages crystallography, mineralogy, textural patterns, and genetic significance of the lava flows. Also, the variation in petrographic characteristics of individual lava flows facilitates the correlation of two similar flows exposed at different locations. In thin section, the vesicular-amygdaloidal basalts show an equigranular, porphyritic texture with phenocrysts of plagioclase feldspar in a groundmass, often consisting of glassy material sometimes altered to palagonite. The compact basalt appears fine-grained in thin sections, which exhibit an equigranular, porphyritic texture wherein phenocryst of plagioclase feldspar is embedded in a groundmass of olivine, pyroxene and iddingsite [18].

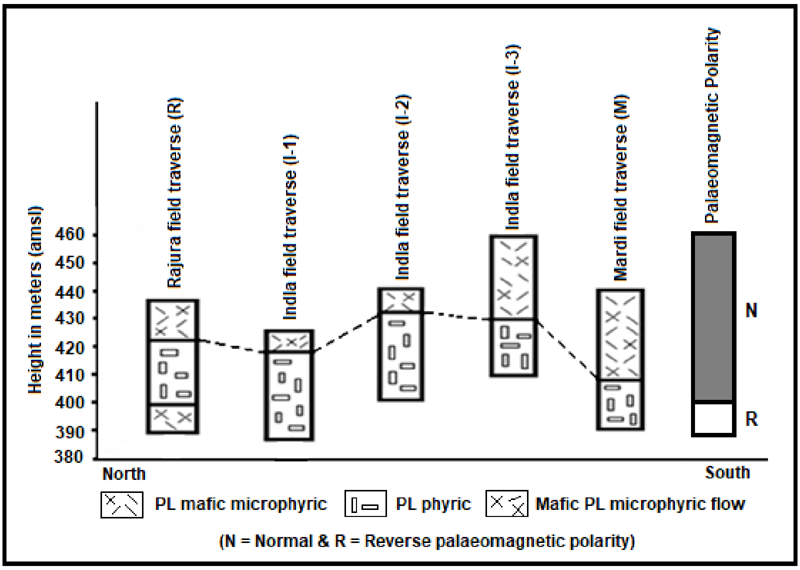

Fig. 2. Flow correlation diagram Rajura volcanic [after 14].

The Rajura volcanic flow mapping results reveal the exposure of three lava flows; the topmost flow is mafic plagioclase microphyric basalt. It is fine to medium-grained with microphenocryst of plagioclase and clinopyroxenes embedded in opaque-rich groundmass. It generally shows ophitic to sub-ophitic texture (Figs. 3a and 3c), with clinopyroxene and plagioclase in the groundmass phase. It also shows microcrystalline texture, where euhedral to subhedral acicular plagioclase crystals are embedded in cryptocrystalline groundmass. The plagioclase phenocryst exhibit albite and Carlsbad twins (Figs. 3a and 3c), where large phenocrysts of plagioclase are embedded in medium to coarse-grained groundmass, composed of plagioclase and clinopyroxene. It exhibits typical porphyritic to glameroporphyritic texture (Figs. 3e and 3f), where plagioclase in the groundmass is euhedral to subhedral in shape. Plagioclase shows albite and carlsbad twinning (Figs. 3a and 3c). In the groundmass phase, aggregates of clinopyroxene are intruded by laths of plagioclase feldspar, indicating sub-ophitic texture. Plagioclase occurs as phenocrysts as well as in the groundmass phase, which indicates earlier crystallization of phenocryst followed by groundmass (Fig. 3d). Opaques are granular, subhedral, and anhedral in shape (Fig. 3h). At the lower part of the hill near Rajura village, plagioclase mafic microphyric basalt is exposed. It is fine to medium-grained, plagioclase mafic micropheric basalt exhibiting ophitic to sub-ophitic texture with granular opaque minerals (Table 1). The common textures observed are porphyritic and sub-ophitic. However, certain fine-grained aphyric flows exhibit microphyric and flow textures. The existence of plagioclase phenocryst and olivine points to a probable derivation of basalts from magma of shallow depth [19]. Plagioclase usually occurs as labradorite and clinopyroxene as augite to sub-calcic augite, with a minor occurrence of pigeonite in the groundmass phase. Olivine occurs as alteration products (iddingsite or serpentine) along the borders, and the cracks of olivine and iron oxides are filled with a solid solution series of titano-magnetite and ilmenite with occasional presence of primary glass. Carlsbad, albite, and cross twins are quite common in plagioclase with occasional Baveno type of twins. Clinopyroxene is prismatic grains showing subhedral forms, whereas magnetite is ilmenite, occurring as irregular laths and in skeletal form. The cavities of amygdalas are filled with various zeolitic minerals like natrolite, stilbite, mesolite, apophyllite, etc. This variation in the textures of individual lava flows is attributed to the difference in the rate of cooling, gravitative settlement, order of crystallization, quantitative mineralogy, volatile constituents, incorporation of foreign material (xenoliths), and effect of the movement of flows during crystallization [7]. The petrographic variations are due to a combination of several factors like gravitational sinking of phenocryst, aided by low viscosity and slow effusion rate, as suggested by earlier workers [20].

Table 1. Field and petrographic characteristics of the basalt lava flows, Rajura volcanic, central India.

Lava Flow	Samp. No.	Sample Elevation in meters (amsl)	Textural characters		Textures	Mineralogy	
			In hand specimen	In thin section		Ground-mass	Opaque
III	M - 3	436	Compact, massive, fine-grained, P.L. mafic microphyric basalt	Fine to medium-grained, P.L. mafic microphyric basalt	Ophitic, sub-ophitic	P.L., C.P.X.	Granular
	I/3 - 4	451	Compact, massive, fine-grained, P.L. mafic microphyric basalt	Fine to medium-grained, P.L. mafic micropheric basalt	Ophitic, sub-ophitic	P.L., C.P.X.	Granular
II	I/1- 13	390	Compact, massive, medium-grained, P.L. phyric basalt	Medium to coarse-grained, P.L. phyric basalt	Glamero-porphyritic	PL, C.P.X.	Granular
	M - 14	403	Compact, massive, medium-grained, P.L. phyric basalt	Medium to coarse-grained, P.L. phyric basalt	Porphyritic, Sub-ophitic	PL, C.P.X.	Granular
I	R - 13	395	Compact, massive, fine-grained, mafic P.L. microphyric basalt	Fine-grained, mafic P.L. microphyric basalt	Sub-ophitic	PL, C.P.X.	Skeletal, Granular

(P.L.: Plagioclase feldspar; C.P.X.:Clino-pyroxene; Opaque: dark magnetic minerals)

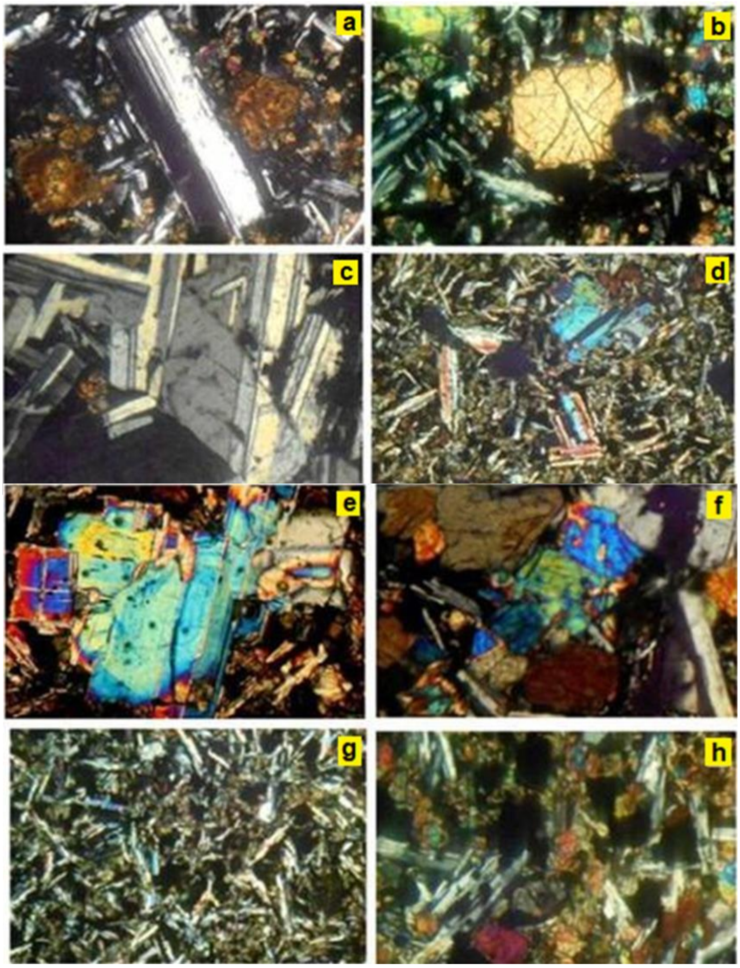

Fig. 3. Photomicrographs of the basalt lava flows (10 x magnification) (a) Phenocrysts of P.L. and C.P.X. embedded in opaque rich groundmass (ophitic to sub-ophitic texture); (b) Microphenocryst of C.P.X. embedded in P.L., C.P.X., and opaque rich groundmass; (c) P.L. exhibit albite and Carlsbad twins in P.L. phyric basalt; (d) Plagioclase occurs as phenocryst as well as in the groundmass phase, indicating earlier crystallization of phenocryst followed by the groundmass; (e & f) P.L. phenocrysts embedded in medium to coarse-grained ground mass comprising P.L. and C.P.X., which exhibit porphyritic and glameroporphyritic texture; (g & h) Microphenocrysts of P.L., C.P.X. and opaques in mafic P.L. microphyric basalt.

6. Conclusion

Individual lava flows are identified and differentiated based on various mineral phases, relative grain size, presence of phenocrysts, mega-phenocrysts, and microphenocrysts), basaltic structures (amygdaloidal and massive nature), break in physiography, and the red bole horizons. The study reveals exposure of three lava flows in the area: mafic plagioclase microphyric basalt, plagioclase phyric basalt, and plagioclase mafic microphyric basalt. The petrographic study envisages mineralogy, textural patterns, crystallization, and genetic significance of the lava flows. The textures are used to understand the interrelationship of various minerals in thin sections. The results indicate that the lava flows exposed are dominantly composed of plagioclase and clinopyroxenes with opaque minerals, exhibiting porphyritic, glameroporphyritic, ophitic, and sub-ophitic textures. Plagioclase occurs as phenocrysts and in the groundmass phase, indicating the earlier crystallization of phenocrysts followed by groundmass crystallization, as earlier workers suggested. The result also indicates a large variation in the textural patterns, which is a mere reflection of the condition of the formation of respective lava flows and the nature of the parental material. The variation in the textures of the individual lava flows is attributed to the difference in the rate of cooling, gravitational settlement, order of crystallization, volatile constituents, and the effect of the movement of flows during crystallization.

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