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Petrogenetic Implications from the Petrography of Lonar Volcanic Rocks, Deccan Traps

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ABSTRACT: This study presents a detailed petrographically investigation of the Lonar volcanic rocks, which form part of the Deccan Traps—one of the largest continental flood basalt provinces on Earth. The objective is to examine the petrology of the Lonar volcanics through both megascopic and microscopic analyses of basaltic lava flows. Representative rock samples were collected from various stratigraphic levels around the Lonar Lake area. Thin-section observations under a polarizing microscope reveal that the rocks predominantly exhibit porphyritic to sub-ophitic textures, characterized by phenocrysts of plagioclase, clinopyroxene, and olivine set within a fine-grained groundmass. Plagioclase, mainly labradorite, displays albite, Carlsbad, and cross twinning. Clinopyroxene occurs as augite and sub-calcic augite, while olivine is partly altered to iddingsite or serpentine. Opaque minerals such as titanomagnetite and ilmenite are common, whereas primary glass is rarely observed. Amygdaloidal cavities are filled with secondary minerals including zeolites (natrolite, stilbite, apophyllite), quartz, calcite, and chlorite. Petrographic variations among different lava flows, expressed through mineralogical composition, crystallinity, and textural differences, suggest multiple cooling histories and magmatic differentiation processes. These findings provide valuable insights into the petrogenesis and crystallization history of the Lonar volcanic rocks, contributing to a deeper understanding of Deccan Trap magmatism.

The results also highlight the influence of secondary alteration and post-emplacement hydrothermal activity on the mineralogical evolution of these basalts. The observed textural and mineralogical features indicate complex interactions between magmatic and post-magmatic processes. This petrographically characterization can serve as a baseline for geochemical and geochronological studies in the region. Overall, the study enhances our comprehension of the volcanic and tectonic evolution of the Lonar region within the broader framework of the Deccan volcanic province.

KEYWORDS: Lonar volcanics, Deccan Traps, basalt, petrography, plagioclase,

I.INTRODUCTION

The Deccan Trap province, one of the largest continental flood basalt provinces on Earth, comprises basalts that display a broad spectrum of compositions, not only in isotopic ratios but also in major- and trace-element chemistry. According to Mahoney (1988), the ascent of plume-related magma through thick continental crust can generate diverse basaltic compositions through processes such as fractional crystallization, crustal contamination, and phenocryst accumulation (Sen 1986; Lightfoot 1990). The basaltic rocks exposed across the Deccan Plateau are widely regarded as the products of major volcanic episodes in central and western India (Renne et al., 2015).

Several archaeological sites within the Deccan Traps—including the Ellora, Pitalkhora, and Ajanta caves—are internationally renowned cultural heritage locations. These structures, carved directly into massive basaltic sequences, exhibit well-preserved roofs and floors, underscoring the high durability and quality of the host basalts. Compositional variations in these rocks may also reflect mixing between plume-derived melts and magmas sourced from the continental lithospheric mantle (Hooper 1984; Turner and Hawkesworth 1995).

Petrographic studies of Deccan basalts commonly reveal porphyritic textures. Phenocrysts of plagioclase, clinopyroxene, and olivine appear in varying proportions, while the groundmass typically shows sub-ophitic, intergranular, intersertal, and equigranular textures. The presence of silica-bearing minerals in the groundmass has also been reported. Deshmukh (1988) suggested that such minerals may be widespread in Deccan lava flows. These flows generally solidified to form highly crystalline groundmasses.

II.STUDY AREA

The study area includes Lonar Lake, an impact crater located at 19°58′–19°59′ N and 76°31′ E, approximately 1.5 km southwest of Lonar town in the Buldhana district of Maharashtra, along with the surrounding Deccan lava flows. The broader area extends between 19°50′–20°10′ N and 76°20′–76°45′ E (SOI toposheets 56 A/5, 56 A/9, 55 D/8, and 55 D/12). The site is accessible by road from Amravati, Akola, and Washim.The Lonar Crater is a circular, bowl-shaped depression measuring about 1,830 m in diameter and 150 m in depth, with a central lake containing alkaline and saline water (Nandy et al., 1961).

III.METHODOLOGY

Detailed microscopic examination of more than twenty representative samples confirms a systematic vertical variation in mineralogy and texture across the stratigraphic sequence. These variations include transitions from fine-grained aphyric flows to medium- to coarse-grained mafic-phyric basalts, accompanied by glassy patches, red bole horizons, and changes in the degree of amygdaloidal development. The integrated petrographic dataset provides essential insights into flow differentiation, magma evolution, and the petrogenesis of the Lonar volcanic succession.

In this study, comprehensive megascopic and microscopic analyses were conducted on basalt samples from the Lonar volcanic region to identify mineral phases, textural characteristics, and their distribution within and between flows. Petrographic variations across the stratigraphy—reflected in features such as red bole horizons, weathered intervals, and amygdaloidal layers—offer valuable information on the crystallization history and petrogenesis of the lava flows. The observed mineralogical and textural diversity supports the differentiation of individual flows into distinct petrographic groups.

IV.RESULT AND DISCUSSION

Mineralogically, the basalts are composed predominantly of labradorite (Ab_2–An_2) and enstatite–augite (including pigeonite), which together form the major mineral components of the lava flows in Maharashtra. Magnetite is common, and some basaltic varieties also contain appreciable amounts of olivine. In this study, megascopic observations and thin-section analyses were carried out to identify mineral phases, textural attributes, and their spatial distribution. Differences among successive lava flows were interpreted based on distinctive field features, variations in phenocryst assemblages, and the occurrence of giant plagioclase basalt (GPB) horizons.

The Lonar volcanic succession, produced by an asteroid impact during the Pleistocene Epoch, exposes a sequence of basaltic lava flows exhibiting considerable petrographic variability. Each flow is distinguished by its stratigraphic position, physical characteristics, and diagnostic textures such as aphyric, microphyric, porphyritic, ophitic, sub-ophitic, glomeroporphyritic, and equigranular patterns. (Table1)The principal mineral assemblage includes plagioclase (commonly labradorite), clinopyroxene (augite to sub-calcic augite with minor pigeonite), olivine (partly altered to iddingsite or serpentine), and opaque minerals such as titanomagnetite and ilmenite. Plagioclase commonly exhibits albite, Carlsbad, and cross twinning, while clinopyroxene occurs as subhedral prismatic crystals. Magnetite appears as octahedral to anhedral grains, whereas ilmenite occurs in skeletal or lath-like forms. Zeolite minerals—including natrolite, stilbite, and apophyllite—frequently fill cavities, along with quartz, calcite, and chlorite.

The Asola and Lonar formations of the Lonar volcanic province show significant petrographic diversity that aids in distinguishing individual basaltic flows and interpreting their crystallization histories. Petrographically, the Asola Formation comprises six flow types, ranging from aphyric to plagioclase-microphyric basalts, amygdaloidal aphyric basalts, plagioclase–mafic microphyric flows, massive plagioclase-phyric flows, and mafic-phyric basalts. These flows exhibit characteristic textures such as porphyritic, sub-ophitic, ophitic, glomeroporphyritic, and equigranular fabrics. The dominant mineral assemblages include plagioclase, clinopyroxene, olivine, and opaque minerals, with amygdales commonly filled by zeolites, quartz, and calcite.

The Lonar Formation also consists of six petrographic groups, ranging from compact massive aphyric flows to mafic-phyric and vesicular amygdaloidal basalts, including flows containing primary glassy patches. Textural variations include porphyritic, sub-ophitic, glomeroporphyritic, and ophitic fabrics. Plagioclase microphenocrysts, clinopyroxene, and olivine dominate the groundmass, while opaque minerals occur as granular, skeletal, or sporadic grains. (Fig.1)

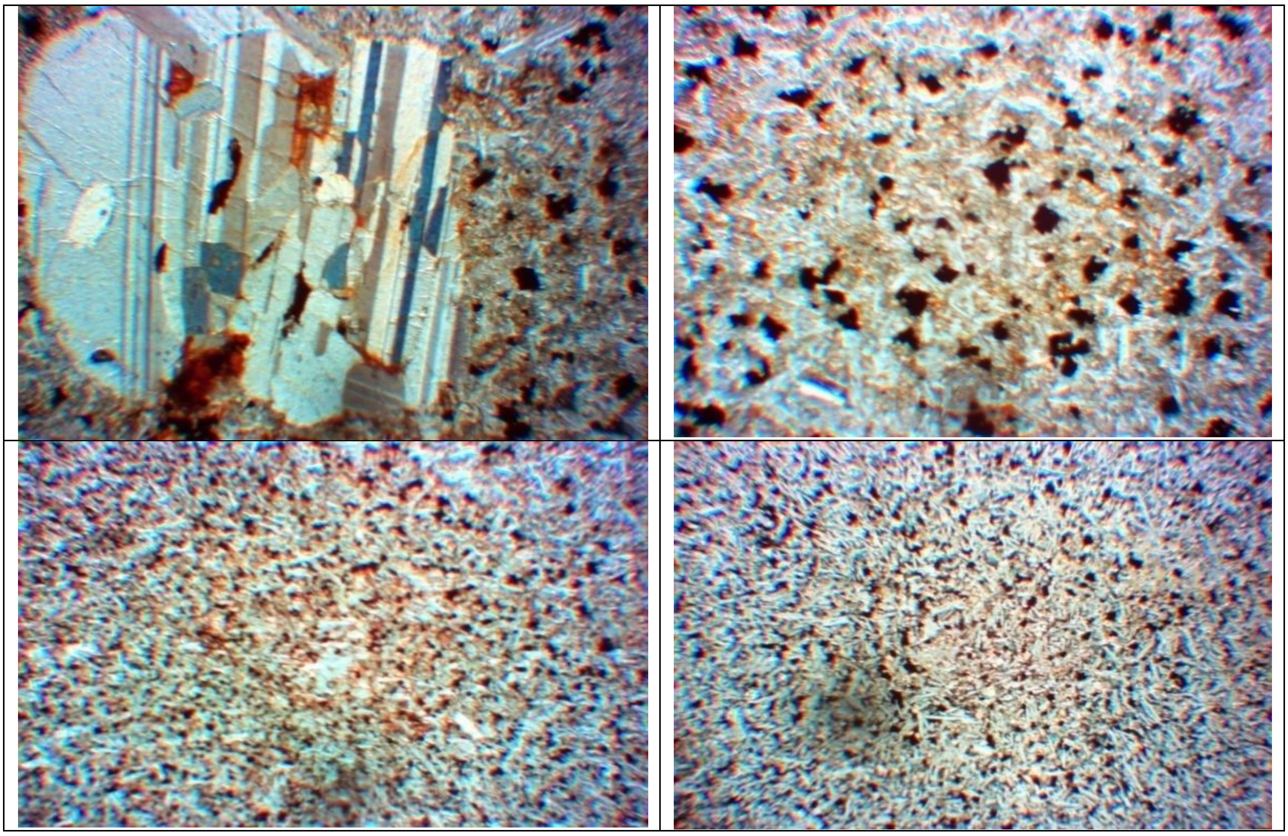

Fig: 1- Microscopic image showing various textures in Basalt.

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Sample	FLOW	CT	Height meters	Textural Character		texture	Mineralogy		
				In hand specimen	In thin section	Subophitic micro Porphyritic	Phenocrysts	Ground mass	Opaque
AS-05	XII	CT_1	626	Fine grained compact massive aphyric basalt.	Fine Grained Compact massive microphyric basalt with glass		Subophitic micro Porphyritic	Pl, cpx	Pl, cpx feo
DT-05	XI	CT_2	604	Fine grained compact massive mafic aphyric basalt	Compact massive medium grained mafic phyric basalt	subophitic	Pl, cpx	Pl, cpxfeo	granular
KG-03	X	CT_3	607	Medium grained compact massive pl mafic phyric amygdaloidal basalt	Medium grained compact massive pl. mafic phyric basalt	porphyritic	Pl	Pl Cpxfeo	granular
TD-05	IX	CT_2	584	Fine grained mafic microphyric basalt with small patches of glass	Compact massive medium grained mafic phyric basalt	subophitic	Micro pl	Pl, cpx, Feo	granular
DT-04	VIII	CT_4	578	Medium grained compact massive pl. phyric basalt	Fine grained compact massive pl. microphyric basalt with minute mafics	Ophitic to subophitic	pl	Pl, cpx	skeletal
AS-02	VIII	CT_4	592	Medium grained compact massive pl. phyric basalt	Fine grained compact massive pl. phyric basalt with minute amygdales	Ophitic to subophitic	Pl, cpx	Pl, cpx, Feo	granular
AS-01	VII	CT_2	586	Fine to medium Grained compact massive mafic. aphyric basalt	Compact massive medium grained mafic phyric basalt	Porphyritic subophitic	Pl, Cpx	Pl,cpx, Feo	granular

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TD-04	VI	CT4	55	Medium grained compact massive pl phyric basalt	Medium grained compact massive pl. microphyric basalt with minute mafics	Ophitic to subophitic	Pl, cpx	Pl,cpx, Feo	granular
KG-02	V	CT2	555	Fine grained compact massive mafic aphyric basalt	Compact massive medium grained mafic phyric basalt	Porphyritic	Pl, Cpx	Pl,cpx,Feo	skeletal
DT-02	V	CT2	551	Fine grained compact massive mafic aphyric basalt	Compact massive medium grained mafic phyric basalt	Porphyritic	Micro pl	Pl,cpx,Feo	granular
TD-03	IV	CT1	538	Fine grained compact massive aphyric basalt	Fine grained compact massive microphyric basalt with mafics	subophitic	Pl,cpx	Pl,cpx,	skeletal
GH-05	IV	CT1	537	Fine grained compact massive aphyric basalt	Fine grained compact massive microphyric basalt with glassy patches in between	subophitic	Pl,cpx	Pl,cpx,	granular
KG-01	III	CT4	531	Mediumgrained compact massive pl phyric basalt	Medium grained compact massive pl. microphyric basalt with minute mafics	Ophitic to subophitic	Pl, cpx	Pl,cpx,Feo	granular
GT-01	III	CT4	526	Mediumgrained compact massive pl phyric basalt	Medium grained compact massive pl. microphyric basalt with minute mafics	Ophitic to subophitic	Pl, Cpx	Pl,cpx, Feo	skeletal
GH-04	III	CT4	518	Mediumgrained compact massive pl phyric basalt	Medium Grained compactmassive pl. microphyric	Ophitic to subophitic	Pl, Cpx	Pl,cpx,Feo	granular

					basalt with minute mafics				
GH-03	II	CT 1	50 7	Fine grained amygdaloidal aphyric basalt	Fine to medium grained compact massive microphyric basalt with mafics	subophitic	Pl, Cpx	Pl,cpx,Feo	granular
DT-01	II	CT 1	50 4	Fine grained amygdaloidal aphyric basalt	Fine to medium grained compact massive microphyric basalt with glass	subophitic	Pl, Cpx	Pl,cpx,Feo	skeletal
TD-01	I	CT 2	492	Compact massive pl mafic aphyric basalt	Compact massive medium grained mafic phyric basalt	sub-ophitic, Porphyritic	Pl, cpx	Cpx Iron oxides	Granular
GH-01	I	CT 2	495	Fine Compact massive pl mafic aphyric basalt	Compact massive medium grained mafic phyric basalt	sub-ophitic, Porphyritic	plagioclase	cpx	granular

Table: 1. Summary of the petrographic data for the various flows exposed in the study area

CONCLUSION

The petrographic diversity documented within the Asola and Lonar formations underscores the complex magmatic, thermal, and post-emplacement histories of the basaltic flows in the Lonar volcanic province. The identification of multiple flow types—ranging from aphyric to strongly phyric varieties, as well as amygdaloidal and glass-bearing flows—demonstrates that the region experienced repeated episodes of lava extrusion under varying physicochemical conditions. Variations in mineral assemblages, such as shifts in the proportions of plagioclase, clinopyroxene, olivine, and opaque minerals, reflect changes in magma composition, degrees of crystallization, and cooling rates during each eruptive phase.

Textural features such as porphyritic, sub-ophitic, ophitic, glomeroporphyritic, and equigranular patterns further reveal contrasting crystallization environments within individual flows. The consistent presence of zeolite-, quartz-, and calcite-filled amygdales points to pervasive secondary alteration processes influenced by circulating fluids after solidification. In the Lonar Formation, the occurrence of primary glassy patches and vesicular layers provides additional evidence for rapid quenching and volatile exsolution during eruption.

Together, these petrographic signatures allow for the clear differentiation of individual lava units and help reconstruct the chronological sequence of volcanic events predating the Lonar impact. They also contribute significantly to understanding the broader petrogenesis of the Deccan basalts, particularly in relation to magma evolution, flow dynamics, and post-eruptive alteration. Ultimately, the integrated petrographic framework developed through this study

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enhances the stratigraphic resolution of the region and offers deeper insight into the geological processes that shaped the Lonar volcanic province.

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