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Flow stratigraphy of Mandu Region, Dhar District, Madhya Pradesh, India

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ABSTRACT

The main aim of the present study is to establish the flow stratigraphy of Mandu Region, Dhar District, Madhya Pradesh. The area of investigation lies towards the western edge of the Malwa Plateau forming about 470 meters thick horizontal sequence of lava flows covering an area of about 200 square kilometers between Mogarba (latitude between 22°20' and 22° 25'; longitude between 75°18' and 75°23') and Lunera (latitude between 22°25' and 22°30'; longitude 75° 22' and 75°30') areas.

Four well-defined formations exposing twenty one lava flows have been identified, which includes "B, "C", "D" and "E" formations. These stratigraphic divisions are mainly based on distinct field characters, phenocrystic assemblages, major physiographic breaks and significant shift or break in elemental abundance and ratios of various elements.

Keywords: Flow stratigraphy, lava flows, marker horizons, Mandu region, Madhya Pradesh

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INTRODUCTION

The Deccan Traps cover an area of 5, 18,000 square kilometers in western and central India erupted in Late Cretaceous to Early Tertiary times. These flows are generally horizontal to sub horizontal showing dips between 0° to 15° (Krishnan 1960; Auden 1949). However, over vast regions the basalts are nearly horizontal, with dips of 1° or less (West 1958; Raja Rao et al. 1978). In general, the Deccan flood province can be arbitrary divided into four sub provinces: the main Deccan proper south of Narmada River, the Malwa Plateau north of the Narmada, the Mandala Lobe in the north east and the Saurastran Plateau in the northwest of Narmada.

STUDY AREA

The area of investigation lies towards the western edge of the Malwa traps forming a part of Dhar District, Madhya Pradesh with 470 meters thick horizontal sequence of the lava flows covering an area of about 200 square kilometers lying between Megara (latitude between 22°20' and 22°25'; longitude between 75°18' and 75°23') and Lunera (latitude between 22°25' and 22°30'; longitude between 75°22' and 75°30') areas covered by survey of India toposheet 46N/7 (Fig. 1).

Physiographically, the study area is dominated by erosional land forms. The topography is characterized by the presence of various land forms like lava plateau, lava hills, mesa, butte and escarpment. The highest point (751 m) of the region is Mogarba while the lowest point (280 m) lies near Badia village. The study area is drained by the Khuj Nadi and Man River flowing towards NE-SW directions.

METHODOLOGY

Detailed fieldwork was carried out to establish the flow stratigraphy of the region. Three hundred fifty samples of fresh basalt flows and dykes were collected from eighteen measured field sections from twenty one lava flows. In general quarries and road cuttings have provided the best sampling sites. Flow contacts were identified by the presence of red/green boles, pipe vesicles, and conspicuous mineralogical and grain-size variations. The location of the flow contacts were marked using an altimeter and survey of India toposheet 46N/7.

Forty six representative rock samples from measured field sections were selected for petrographic and mineralogical investigations covering the entire stratigraphic sequence. The composition of plagioclase and twin laws was determined using extinction angle method (Kennedy 1947). Modal analyses of various mineral phases for representative thin sections covering the entire lava pile were carried out by an automated point counter. Major, trace and rare earth element analysis of twenty two basalt samples and four red bole/green bole samples were carried out using Inductively Coupled Plasma–source Spectrometry (ICP) at Royal Holloway and Bedford New College, University of London by utilizing the techniques developed by Walsh (1979).

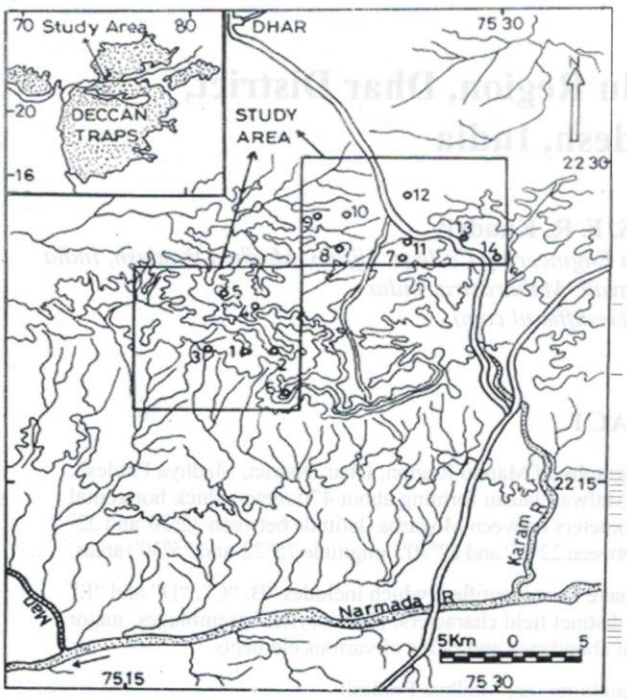

Fig. 1: Loation map of the study area with field traverses

STRATIGRAPHIC NOMENCLATURE

For identifying the individual lava flows and grouping them into recognizable stratigraphic units, the nomenclature described by Bodas et al. (1993) and Khadri et al. (1988) which form a part of the National Science Foundation (USA) sponsored research project on western Deccan traps is followed. The important lithostratigraphic units adopted in the study area include group, sub-group, formation and flow which are in accordance with the classification of the International Sub-commission on Stratigraphic Terminology. The group represents a major lithostratigraphic unit comprising two or more formations showing common lithological characters whereas sub-group indicates formally differentiated assemblages of formations. A mappable sequence of lava flows showing similar field, petrographic and gross chemical feature has been termed as a formation. It is the fundamental unit of lithostratigraphic classification.

A sincere attempt has been made to identify the nature of various flows by field characters, difference in textural features, grain size variations and phenocrytic assemblages. However, the presence of red or green bole beds occurring at flow boundaries displaying vesicular nature with higher concentration of amygdales, occurrence of pipe amygdales at the bottom of the flow along with jointing and weathering pattern are also taken into consideration while identifying various flows.

The formation boundaries can be marked by the presence of distinct break in field appearance or marker horizons (GPB, brecciated horizon and red/green beds) which are traceable over large areas with same stratigraphic level associated with considerable shift in chemical trend from the adjacent flows. Marker horizons are not only identified by their traceability but also by the physiographic expression and lithologic homogeneity.

In the present study, eighteen field traverses were taken considering twenty one lava flows mostly showing wide areal extent in a thick pile of 450 m. In general, lava flows can be classified into aphyric and phyric flows. However, a mix up of these at places is not uncommon. A few flows are characterized by columnar jointing at the bottom of the flows which helps in identifying them in isolated exposure.

1. Aphyric Flow: In general, aphyric flows are characterized by the absence of microphenocrysts with fine-grained nature showing either vesicular or amygdaloidal nature.

2. Phyric Flows: These are characterized by the presence of large phenocrysts of either plagioclase, clinopyroxene, olivine, or a mixture depending upon the nature of phenocystic assemblages. These can be classified into the following five types :

(a) Plagioclase Phyric Flows (Pl. phyric): These flows are characterized by the tabular laths of plagioclase pheonocryst enclosed in a fine- to medium-grained groundmass. The content and the arrangement of plagioclase phenocrysts vary considerably from one flow to another. However, in some cases they are arranged in one specific direction indicating the direction of movement of flow.

(b) Olivine Phyric Flows: In general, these flows contain large phenocrysts of olivine mostly weathered to iddingsite and mafic minerals like clinopyroxene and opaque embedded in coarse to medium grained groundmass. The topography of these flows is more irregular due to the weathering of olivine into iddingsite or serpentine which makes it easier to distinguish them from the other flows.

(c) Mafic Phyric Flows: These flows show variable proportion of pyroxene and olivine phenocrysts in medium- to coarse-grained groundmass. In the field, it is very difficult to identify these mafic minerals separately due to their dark and dense nature with the presence of amygdales.

(d) Picrite Flows: These flows can be identified in the field due to the presence of large pheonocryst of olivine along with their typical weathering pattern forming cliffs and boulders.

(e) Giant Plagioclase Basalt (GPB): These are characterized by the presence of very big phenocrysts of plagioclase sometimes associated with mafics in a coarse-grained groundmass which is either massive or amygdaloidal. In addition to the physiographic and chemical signature, these flows are known as the marker horizons due to their wide occurrence at the formation boundaries and have been effectively used for separating different formation.

FLOW STRATIGRAPHY

Detailed investigations of the lava flows based on eighteen field traverses coupled with petrographic and geochemical investigations have led to identification of 470 m. thick lava pile into four formations namely the B, C, D and E in ascending order comprising of twenty one lava flows (Table 1, Fig. 2). The lowermost "A" Formation reported by Nagar (1993) towards the west of Mogarba seems to have pinched out in the study area.

Formation B

In the study area, this formation is well exposed near Badia field traverse with the thickness of about 135 m. However, the uppermost flows are seen in the Undhakho-Burimandaw and Chikli-Burimandaw traverse. This formation consists of six flows which are characterized by the presence of alternating plagioclase + mafic phyric to plagioclase or aphyric flows showing progressively evolved sequence with GPB at the top (Table 1). The formation shows thickening and thinning of certain flows in different traverses.

Table 1: Detailed stratigraphy of various formations exposed in the study area

Group	Sub-Group	Formation	Thickness(m)	Flow	Characteristic Feature	Phenocrysts			Grain Size	Geochemistry					
						Pl.	Cpx	Ol.		MgO	TiO_2	P_2O_5	Sr	Zr	Y
DECCAN BASALT	MANDU	E	20-35	XXI	Medium grained, Pl phyric basalt with minute amygdales and vesicles	x	x		M						
			25-35	XX	Compact, massive, Pl. phyric basalt	x	x		F	2	2	2	3	3	2
		D	05-10	XIX	Coarse grained, Pl. phyric to GPB with minute amygdales	x	x		C	1	3	3	3	3	3
			20-30	XVIII	Medium grained, Pl. phyric amygdaloidal basalt with mafics	x	x		M	2	3	1	3	3	2
			20-30	XVII	Compact, massive, mafic phyric basalt	x	x	x	M	3	1	2	1	2	1
			15-30	XVI	Pl. mafic phyric minutely amygdaloidal basalt with aphyric bands in between	x	x		M	2	3	3	3	3	2
			25-30	XV	Medium grained, mafic phyric basalt with amygdales and aphyric patches	x	x	x	M	3	2	2	2	2	1
			15-25	XIV	Fine grained, aphyric, amygdaloidal basalt with minute bands of plagioclase	x	x	x	F	2,3	1	1	1,2	1	1
		C	10-20	XIII	Coarse grained, GPB (weathered) with Pl. phyric at places	x	x		C	1	3	3	3	3	3
			20-30	XII	Fine grained, compact, massive, aphyric basalt with minute mafics	x	x		F	2	1	1	1	1	2
			15-20	XI	Medium grained, Pl. phyric basalt with vesicles on the top	x			M	1	3	3	3	3	3
			10-20	X	Compact, massive, Pl. mafic phyric basalt	x	x	x	C	2,3	3	3	3	3	3
			20-25	IX	Fine grained, massive aphyric basalt with minute mafics patches	x	x	x	F	3	1	2	2	1	1
			20-25	VIII	Coarse grained, mafic phyric, amygdaloidal basalt	x			C	3	3	3	3	3	2
			20-25	VII	Medium grained, compact, massive, Pl. phyric basalt	x	x		M	1	3	3	3	3	2
		B	10-15	VI	Coarse grained, GPB	x	x		C	1	3	3	3	3	2
			10-15	V	Compact, massive, Pl. phyric basalt	x	x		M	2	3	3	3	2	2
			10-15	IV	Fine grained, aphyric, amygdaloidal basalt	x	x		F	1	1	1	3	1	1
			30-35	III	Compact, massive, Pl. mafic phyric basalt	x	x	x	M	2,3	2	2,3	3	2	3
			40	II	Medium grained, Pl. phyric minutely amygdaloidal basalt	x	x		M	1	2	2	3	2	1
			20	I	Compact, massive, Pl. mafic phyric basalt	x	x	x	M	2,3	2	2	3	1,2	1,2
		A	Not exposed Base not known												

Index											
	Pl	Plagioclase	Cpx	Clinopyroxene	Ol	Olivine	F	Fine grained	M	Medium grained
	C	Coarse grained	X	Present as pheonocryst/ microphenocryst						

1= MgO: 3.5-5%; TiO_2: 1-1.75%; P_2O_5: 0.14-0.20%; Sr: 125-175ppm; Zr: 75-125ppm; Y: 30-35ppm
2= MgO: >5-6%; TiO_2: >1.75-2.25%; P_2O_5: >0.2-0.25%; Sr: 175-225ppm; Zr: 125-150ppm; Y: 35-40pp

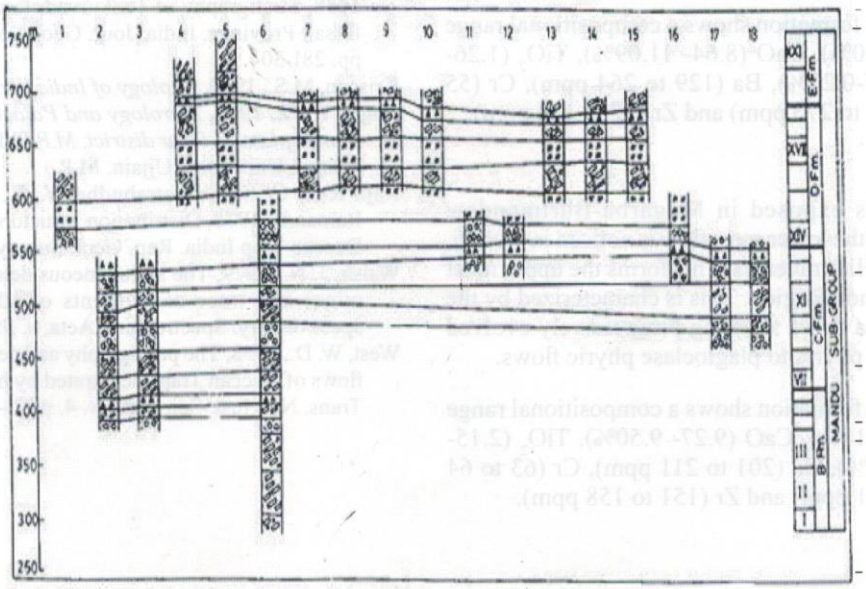

Fig. 2: Detailed flow correclation diagram for various formations exposed in the study area

Chemically, it shows a compositional range of MgO (3.39-6.52%), TiO_2 (1.60-3.03%), P_2O_5 (0.17-0.31%) and CaO (8.05-11.26%). The repeated occurrence of plagioclase + mafic phyric to plagioclase phyric and Giant Plagioclase Basalt at various stratigraphic levels highlights the cyclic nature of these eruptions.

Formation C

This formation rests on highly evolved Giant Plagioclase Basalt characterized by a major physiographic break. In the study area it is well exposed in Badia, Chikli- Burimandaw, Undhakho-Burimandaw field traverses. However, the upper flows of this formation are also exposed in Taliasaray, Jamanghati, Bhilkunda, Shikarpura and Kaliyadeh traverses. It is characterized by alternating plagioclase phyric and plagioclase mafic phyric to aphyric flows with GPB at the top. This formation consists of seven different flows.

Chemically, this formation shows a compositional range of MgO (3.59 to 6.06%), CaO (8.69- 11.37%), TiO_2 (1.65-2.54%), P_2O_5 (0.14-0.30%), Ba (97 to 271 ppm), Cr (33 to 140 ppm), Sr (139 to 258 ppm) and Zr (80 to 181 ppm). This formation represents another cycle of eruption exhibiting more or less similar range of chemical variation in the "B" Formation with slight enrichment in CaO, TiO_2 and depletion in Sr, Zr and Ba contents.

Formation D

The formation D is well exposed in the Mogarba-Burimandaw composite traverse. It rests on the highly evolved Giant Plagioclase Basalt of "C" Formation marking a major physiographic break. This formation is characterized by aphyric and mafic phyric to plagioclase phyric flows showing progressively evolved nature with the occurrence of GPB at the top. In the study area, six flows are exposed which shows variable thickness in different field traverses.

Chemically, this formation shows a compositional range of MgO (4.60 to 7.0%), CaO (8.64- 11.09%), TiO_2 (1.26-2.59%), P_2O_5 (0.17-0.27%), Ba (129 to 264 ppm), Cr (55 to 93 ppm), Sr (141 to 270 ppm) and Zr (82 to 174 ppm).

Formation E

The lithounit is exposed in Mogarba-Burimandaw traverses. However, the lower most flow is noticed in Gungli, Bagrer and Nalcha Hill traverses. This forms the upper most sequence in the Mandu Region. This is characterized by the presence of two lava flows showing progressively evolved plagioclase + mafic phyric to plagioclase phyric flows.

Chemically, this formation shows a compositional range of MgO (5.17 to 5.18%), CaO (9.27- 9.50%), TiO_2 (2.15-2.22%), P_2O_5 (0.24%), Ba (201 to 211 ppm), Cr (63 to 64 ppm), Sr (234 to 241 ppm) and Zr (151 to 158 ppm).

CONCLUSIONS

The study area is characterized by the presence of 470 meters thick lava pile which has been divided into four formations namely B, C, D and E consisting of twenty one lava flows, whereas, towards the east of the Mogarba 525 m. thick lava pile has been grouped into 5 formations (the A, B, C, D and E formations) consisting of twenty eight flows (Nagar1993). Correlation of stratigraphic sequence occurring in the study area and adjoining area demonstrate the traceability of most of the flows with few of them showing pinching and swelling nature.

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REFERENCES

Auden, J. B., 1949, Dykes in Western India- A discussion of their relationship with the Deccan Traps. Trans. Nat. Inst. Sci. India, v. 3, pp. 123-157.

Bodas, M. S., Khadri, S. F. R., and Subbarao, K.V., 1993, Stratigraphy of the Jawahar and Igatpuri Formations, Western Ghat Lava pile. Jour. Geol. Soc., India, Memoir No. 10, pp. 281-304.

Kennedy, G. C., 1947, Charts for correlation of optical properties with chemical composition of some common rock forming minerals. Amer. Min., v. 32, pp. 561.

Khadri, S. F. R., Subbarao, K. V., Hooper, P. R., and Walsh, J. N., 1988, Stratigraphy of Thakurvadi formation, Western Deccan Basalt Province, India. Jour. Geol. Soc. India, Memoir No.10, pp. 281-304.

Krisnan, M.S., 1960, *Geology of India and Burma*. Madras. 604 p.

Nagar, R. G., 1993, *Petrology and Palaeomagnetism of a part of Mandu plateau, Dhar district, M.P.* PhD. Thesis (Unpublished). Vikram University, Ujjain. M.P.

Raja Rao, C. S., Sahastrabudhe, Y. S., Deshmukh, S. S., and Raman,R.,1978, Distribution, structure, and petrography of the Deccan Trap India. Rep. Geol. Survey India. 43 p.

Walsh, J, N., 1979, The simultaneous determination of the major, minor and trace constituents of silicate rocks using ICP spectrometry. Spectrochim. Acta, v. 35B. pp. 107-111.

West, W. D., 1958, The petrography and petrogenesis of forty-eight flows of Deccan Traps penetrated by borings in Western India. Trans. Nat. Inst. Sci. India, v. 4. pp. 1-56.