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### RESEARCH ARTICLE

#### DECCAN VOLCANIC OF MALWA, STRATIGRAPHY AND CORRELATION OF BASALTIC LAVA FLOWS USING MEGACRYST BEARING HORIZON AS TOOL, PARTS OF WESTERN M.P. INDIA

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#### Abstract

A review of earlier studies of the Deccan Trap occurrences of parts of Ratlam, Mandsaur, Jhabua, Dhar, Khargone, Indore, Ujjain and Shajapur districts of Madhya Pradesh, India was carried out of the area falling between latitudes  $22^{\circ} 00' 00''$  to  $24^{\circ} 00' 00''$ N and longitudes  $74^{\circ} 00' 00''$  to  $76^{\circ} 00' 00''$  in Survey of India Quadrangle sheet Nos. 46I, 46J, 46M and 46N. The main objectives of the study were to synthesize the data on the Deccan Trap basaltic lava flows, their types, their diagnostic characteristics with special emphasis on delineating and identifying the various megacryst horizons, their levels with specific elevation above m.s.l. to build up the litho-stratigraphy for regional correlation. Broadly the area exhibits the Proterozoic Aravalli Supergroup, the Cretaceous, Bagh and Lameta Groups and the Deccan basaltic lava flows with intruded dykes and sills. The Aravalli Supergroup is represented by the Udaipur, Lunavada and Champaner Groups. The Udaipur Group consists mainly of hornblende gneiss, marble and calc-silicate, carbonaceous phyllites and chlorite schist. The Lunavada Group comprises dolomitic limestone (Phosphate bearing), quartzite, muscovite quartzite, quartz muscovite schist, feldspathised quartzite, gneissic feldspathic rock and biotitic gneiss. The Champaner Group is represented by dolomite, phyllite, slates and basic intrusives. The Aravalli Super group of rocks is also intruded by serpentinite, pyroxinite, granite and basic rocks. The Aravalli Supergroup of rocks is unconformably overlain by Cretaceous marine sedimentary deposits of Bagh Group. It includes Lower arenaceous and Upper calcareous units and occurs as discontinuous outcrops. These are almost horizontally to sub horizontally disposed. The Bagh Group is represented by three units / Formations i.e. Nimar sandstone overlain by nodular limestone and subsequently by coralline limestone. The Lameta Group of rocks is noticed in the area east and South East of Bagh exposures, overlying the Nimar sandstones. These rocks predominantly consist of limestone, gritty sandstone and conglomerate and generally exhibit hummocky topography and sometimes display solution channels. These are mostly horizontally to sub-horizontally disposed with an average thickness of 5- 6 m. The Deccan Trap has occupied a very long stretch of area which consists of a sequence of 121 basaltic lava flows with a cumulative thickness of about 610 m. These flows represent a sequence of cyclic lava eruptions with fine to medium grained aphyric to

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sparsely / moderately / highly / mega porphyritic lava. About two third of the total flows exhibit Aa characters and the rest are compound and simple Pahoehoe. Some of these flows consist of megacryst units containing feldspar laths varying in size round two to five cm. These megacryst horizons have been identified at different elevations in Quadrangles 46I, J, M, N and on the basis of these horizons, various flows have been grouped into six Formations which have specific nomenclatures and stratigraphic status. These formations are in the order of antiquity 1) Mandleshwar formation, 2) Choral formation, 3) Dhar formations 4) Indore Formation 5) Bargonda Formation and 6) Singarchori Formation. Full sequence is exposed only in quadrangle 46N whereas the Quadrangles 46I, J, M do not exhibit Bargonda and Singarchori Formations. An attempt has been made to correlate the various Formations in degree sheets 46 I, J, M, N with the surroundings Geological Quadrangles. The Megacryst bearing lava- flows act as marker horizons for this purpose. A large number of dykes and dyke swamps of basaltic as well as doleritic compositions have been marked around the Narmada River. The intensity of the dykes is more in the oldest Mandleshwar Formations and it gradually decreases in increasing order of antiquity towards the younger Bargonda and Singarchori Formations. The general trend of these dykes varies from East North East – West South West to E-W running sub parallel to the Narmada lineament, besides a few dykes also cut across this lineament trend and oriented along NNW-SSE to N-S direction. The Length of these dykes varies from about 200 m to 20 Km with width varying from a few meters to as much as 200 m. The possibility exists that these dykes may have been actually feeders through which periodic eruptions of tholiitic basaltic lava took place resulting in formation of such a thick pile of lava flows. Besides as many as seven Intertapean fossiliferous sedimentary horizons have been recognized within the basal part of the flows. These demonstrate episodic nature of volcanic activity, long periods of quiescence and resilience. The overall study of various lava flow s and their interrelations their relative dispositions thinning /swelling and pinching nature. Their relative elevations, occurrence of marker megacryst units, change in lava characters, overall gradient of lava flows and their relation to preexisting topography and slope elements reveals that the sources of lava eruptions of Older Formations are situated somewhere in the west and south west whereas those of Younger Formations are located in the Eastern part of Mhow of the area studied.

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## ..... **Introduction:-**

The geological studies of Deccan Trap Basaltic lava flows of parts of western Madhya Pradesh of the area bounded by latitude 22°00'00" to 24°00'00" N and longitudes 74°00 '00" to 76°00 '00" E of parts quadrangle sheets 46/I, J,M,& N were carried out with the help of available geological maps and reports, supplemented by study of satellite imagery TM, MSS & FCC data in parts of Ratlam, Mandsaur, Jhabua, Dhar, Khargone, Indore, Ujjain and Shajapur districts of Madhya Pradesh.

The objective of study is to compile the data acquired in course of study of the area investigated, study of available geological reports, geological maps bore hole data and other published material on Malwa Group of Deccan Trap Basaltic lava flows of the area. It also includes detailed study of their volcanic diagnostic characters salient features and nature of lava flows for the purpose of correction and building up a common stratigraphic framework for the volcanic sequence for regional correlation. It also includes study of bore hole data, litho logs, rock cores to conceive the regional model of surface and subsurface geology. Kaila (1988)

### Location And Communication

The area forms part of Ratlam, Mandsaur, Jhabua, Dhar, Khargone, Indore and Ujjain districts of M.P. These names also denote the towns which are districts headquarters and are connected by tar road. The National Highway No. 3 (Bombay-Agra road) passes through south-eastern part of the area, Dhar Indore, Jhabua Khargone, Ratlam Shajapur and Ujjain are connected with meter gauge railway line which passes through north-western part of the area. The broad gauge Delhi-Bombay railway line passes through north –western part of the area and connects Barichera Kalana - Ratlam and Dahod in the area. All weather roads connect Indore, Dhar and Jhabua, besides metal roads and network of cart tracts connect the interior parts of 46/I, 46/J, 46/M and 46/N.

### Present Work

The present work includes geological studies of Deccan Trap Basaltic lava flows of parts of western Madhya Pradesh of the area bounded by latitude 22°00'00" to 24°00'00" N and longitudes 74°00'00" to 76°00'00" E of parts quadrangle sheets 46/I, J,M,& N were carried out with the help of available geological maps and reports bore hole data, stratigraphic columns and section supplemented by study of satellite imagery TM, MSS & FCC data in parts of Ratlam, Mandsaur, Jhabua, Dhar, Khargone, Indore, Ujjain and Shajapur districts Deccan volcanic of Malwa Group of western Madhya Pradesh .

### Geology of Deccan Volcanic.

The area studied is mainly occupied by Deccan basaltic lava flows. These lava sheets form E-W trending chain of hill ranges in the areas south of Narmada, NW-SE trending ranges in southern part of Malwa plateau. In the north—east these flows constitute plateaux with steep scarp faces with several isolated hills in form of mesa and butte. The highest elevation in the area is 830 m in the southern part and the lowest is 150 m along Narmada river course in the southeast.

A sequence of 171 basaltic flows between elevation 340—613 m (46I), 47 basaltic flows between altitude 220 m to 750 m (46J), 27 flows between elevation 440 to 550 m (46M) and 56 flows between 275 to 830 m (46N) has been studied and identified. These flows represent a composite sequence of cyclic eruptions with fine to medium grained, sparse to moderately and highly porphyritic Aa and .simple/compound pahoehoe flows having megaporphyritic units at the top. The megaporphyritic units consist of 2-3 cm megaphenocrysts of feldspar, which are identified at elevations of 275 m, 440 m, 520 m, 520 m, 610 m, 790 m, and 830 m in the type area of 46N. Khan et. al (1985) & (1994-95)

### Deccan Volcanics Of Quadrangle 46I

The area of 46I quadrangle (M.P) part includes Survey of India sheets No. 461/8, 10, 11, 12, 13, 14, 15 & 16. It is bounded by Latitudes 23.00.00 and 24.00.00 N and Longitudes 74.00.00 and 75.00.00 E covering parts of Ratlam, Mandsaur and Jhabua districts of Madhya Pradesh..

The area comprises mainly the rocks belonging to the Aravalli Supergroup, the Bagh Group, Deccan basaltic lava flows and laterite.

The south-eastern and eastern part of quadrangle sheet 46I (M.P.) part is occupied by Deccan Trap basaltic flows. The area consists of 21 lava flows between elevation of 340 m and 613 m. The exposed thickness of these flows is about 273 m. These flows are both 'Aa' and compound pahoehoe types which contain phenocryst of feldspar megacryst unit at the top. On the basis of various diagnostic volcanic features and elements of the lava flows of Deccan basalt have been divided into four sub group / formations named as: (i) Mandleshwar formation, (ii) Kalisindh formation, (iii) Kankariya-Pirukheri formation, and (iv) Indore formation in increasing antiquity. Thickness of lava flows in these formations varies from 60 m to 113 m. These flows have been correlated with those of the adjoining area of Quadrangle Sheet No. 46M and 46J on the basis of, elevations, flow gradients and other diagnostic features. (Table No 1 & 6)

### Deccan Volcanics Of Quadrangle 46J

The area of 46J quadrangle studied includes Survey of India sheet No. 463/2. 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 & 16 and bounded by latitude 22°00'00" N and longitudes 74°00'00" to 75°00'00" E covering parts of Jhabua, Dhar and Ratlam districts of Madhya Pradesh.

Geologically the area mainly comprises rocks belonging to the Aravalli Super group, the Bag Group and Deccan

Trap.

In quadrangle degree sheet 46J, the southern, eastern and north-eastern part is occupied by Deccan basaltic Lava flows. These lava sheets form E-W trending chain of hill ranges in the south. NW-SE trending southern part of Malwa plateau in the north-east has steep scarp faces exposed towards south-west with several isolated hills in the form of mesa and butte. The highest elevation in the area is 750 in the southern part and the lowest is 220 m along Narmada river course in the south-east.

The area exhibits a sequence of 47 basaltic flows of Deccan Trap with cumulative thickness of 530 in between altitude 220 in and 750 m. The flows represent a sequence of cyclic eruptions with fine medium grained, sparse to moderately and highly porphyritic basal having Aa and compound pahoehoe characters and megaporphyritic units at the top. The megaporphyritic units are identified in six horizons elevations of 220 m, 430 in, 550 in, 610 in, 720 m and 750 m. Amid these the uppermost level is identified at 750 m above m.s.l. in the area. The flows constitute six groups which are correlated with Mandleshwar, Kalisindh, Kankariya-Pirukheri, Indore, Barsonda and Singarchori formations.

### **Intrusives**

The Deccan Trap and the Bag Group of rocks in the southern part, especially in the vicinity of the Narmada River, are intruded by a number of ultra basic, basic and carbonate dykes and few basic to ultra basic sills. The trend of the dykes is ENE—WSW and is parallel to the trend of the Narmada river occurring in en-echelon pattern. This apparent parallelism may have some relation with the Narmada lineament tectonics.

Among the ultra basic dykes, one dyke occurring NE of Tindari (46J 3&4) is a lamprophyre and the rest are olivine pyroxene bearing ultra basic dykes of pyrites-basalt affinity. The lamprophyre is black, hard, compact, equigranular, porphyritic and has high specific gravity. The pyroxene olivine bearing dyke rocks are black colored, hard, compact and have high specific gravity. On surface they show pitted weathering. Under microscope they are seen to be porphyritic containing abundant phenocrysts of clinopyroxene and agate. The groundmass is composed of clinopyroxene olivine, plagioclase feldspathoids and opaque minerals.

The basic dykes range in composition from gabbros to dolerite. The length of the dykes vary from a few meters to as long as 7.5 km as found near Biswani village with width ranging from 2 m to 15 m. These have non-porphyritic to highly porphyritic, intersertal to intergranular and polytic to sub-ophitic textures. All dykes show chilled margins at the contact with the country rock.

The sills range in composition from ultra basic to basic which intrude Deccan Trap and the Bagh Group. The ultra basic sills are found near Undai (44J/4) and Althawa (46J/6) while basic sills are found near Undala (46J/12) and Sondwa (46J/8).

The carbonate dykes are found to be intruded within the Deccan Traps and their length varies from several meters to about 10 km with width from less than a meter to 30 m. At places these dykes contain xenoliths of basalt and sandstone. These carbonate dykes follow the fractures and fault planes. These ranges in composition from hybrid carbonate rock to calcite/dolomite rock and are found to contain silica in the form of quartz, chert and chalcedony. Khan et. Al (1994-95) (Table No 2 &7)

### **Deccan Volcanics of Quadrangle 46 M**

The area of 46M quadrangle include Survey of India top sheet 46M/1 to 16 between latitudes 23° 00' and 24° 00' N and longitude 75° 00' and 76° 00' E, comprise six districts of Madhya Pradesh and one district of Rajasthan. It covers major part of Ujjain district and small portions of Dewas, Dhar, Indore, Jabalpur, Mandla, Shajapur of Madhya Pradesh and a small portion of Jhalawar district of Rajasthan.

The area occupied by quadrangle 46 M is called Sondwaha plateau forming the western part of the well-known Malwa plateau. The terrain is uneven to undulating and exhibits a terraced topography with more or less horizontal surfaces. The general elevation is 440 m to 550 m above m.s.l. The vast expanse of lava landscape overlies a pre-Cretaceous surface. The extensive erosion during the quaternary period has carved the level across the pile of lavas over which the Chambal, Kalisindh and Mahi rivers flow with undulating divides. Small part of the fossil landscape has been exhausted in the northern part where the Lower Vindhyan Quartzites are found in juxtaposition with the

trap in an irregular fashion indicating that the lava flows poured out upon uneven surface of pre-Cretaceous age. There are number of isolated rounded or linear mesa of the traps occurs in the southern part of the area indicating former level of erosion cycle..

The south-western part is a highly broken rugged land form with little soil cover and more rock exposures giving a relict type of topography. The central part of the area shows a series of flat topped elongated plateau surfaces between 460 and 520 m levels. The development of 5 to 15 m thick laterite capping over these plateau has been noticed between 490 m and 540 m in the north-eastern part. The typical step like terraces with sporadic isolated hillocks over the plateaux is the common features in the central and southern parts of the area.

The general elevation of the area is about 500 m above m.s.l in the major part and the relief varies from 148 m to 216 m.

The low lying plains are restricted to the courses of the major rivers in the northern parts. The rise in the elevations from these low lying tracts is very gradual. The flat surfaces of the terraces often represent the contact of the volcanic flows, the linear rocky and undulating surfaces concealed under moderate to thick soil cover exhibit a north easterly to northwesterly gradient in the central and eastern parts. The prominent break in slopes at the contact of the flows are seen at 440 m, 460 m, 480 m, 510 m, 520 m from north to south. The typical trap topography has resulted due to the disposition and composition of the flows where the relatively soft, easily eroded vesicular zone in the upper part renders a horizontal retreat of scarp slopes.

The area is drained by the Chambal River and its tributaries Sipra, Choti Kalisindh Kure nadi and Bageri nedi. Sipra river and its tributary Gambhir nadi drains the central and the eastern part of the area. All the northerly flowing rivers have a slightly meandering course with asymmetrical to symmetrical river terraces on either bank. The terraces varying in thickness from couple of meters to 15 m comprise mainly of loam.

The gently meandering courses of the major rivers indicate their nearly graded nature of confluence of the minor ephemeral streams with the major ones and general medium to coarse dendritic drainage pattern do not suggest a structural control over the drainage. However, relatively straight courses locally observed along the Chambal river west of Nagda (46M/7) and Sapra river southwest of Jhanda and Choti Kalisindh river in general might be due to concealed fracture. The area is comprised mainly of Deccan Trap and Vindhyan rocks.

The area comprises layered basaltic lava flows with two inliers of the Vindhyan in the north. These lava flows are commonly termed as 'Malwa Traps'. In a vertical column between 440 m and 550 m elevations 17 flows have been delineated, out of which, three flows pinch out in the north-easterly direction. The lava flows in the area are of simple pahoehoe and 'Aa' except middle sequence in the southwestern part which shows compound pahoehoe characters.

The lava sequence of 17 flows has been divided into three formations on the basis of the megacryst horizons identified at 440, 525 m and 550 m elevation. Khan et. al (1994-95) ( Table No.8 )

**Table No.10:-** Megacryst Horizons of 46M.

	Formation	— No of- flows	Megacryst Size horizon located at an elevation of	cm
III	Indore Formation	7	550 m above	1—5
II	Kankaria Pirukheri Formation	6	Top flow .525	2—4

I	Kalisindh Formation	4	Top flow 440 m	1—4
Base not exposed				

The lava flows are horizontally disposed and constitute three distinct stacks which are correlatable with Kalisindh, Kankariya, Pirukheri and Indore formations in the south (46N) and (461) in the West.

#### **Kalisindh Formation**

This comprises four - 'As' flows exposed in the low lying tracts of Chambal river, Sipra river and Choti Kalisindh river the exposed thickness of these flows is about 40 m. The base of these lava flows is not exposed where as the upper contact with the overlying formation is at 440 m level. The upper part of the flow is characterized by a vesicular zone with irnpersistent patches of red bole traversed by carbonate veins. In the south-western part along the Mahi river the thickness of these flow is more and this' group comprises two prominent 'Aa' flows. The lava flows are fine grained, sparsely porphyritic and moderately compact with well developed columnar joints having diameters of 40 cm to 1m in the lower massive part. The upper flow is fine-grained, dark grey, moderately porphyritic with phenocrysts of pyroxene and plagioclase.

#### **Kankariya Pirukheri Formation**

This formation comprises six 'Aa' flows are well exposed along the low lying tracts of Chambal and Sipra river section between elevations of 460 m and 525 meters. The lower lava flow is dark grey, fine grained, compact, aphyric to sparsely porphyritic with distinct basal clinkers and has a baked contact with the lower flows. The middle flows are marked by a palaeo weathered, adulatory and vesicular zone of 2 to 4 m and are dark grey, very compact, massive, and fine grained and moderately porphyritic containing plagioclase feldspar phenocrysts. The upper flow is grey to dark grey, compact, massive and fine with a megacryst unit at the top containing feldspar of 2-4 cm size.

#### **Indore Formation**

The formation consists of seven flows between elevation 525 m and 550 m. The lower three flows are fine grained, compact, hard, massive porphyritic to sparsely porphyritic which are separated by overlying lava sheet by impersistent red bole. The thickness of these flows varies from 5-10 m. The middle part of this formation is represented by three lava flows, which exhibit pahoehoe characters. These flows are fine-grained massive and porphyritic in nature and occurs as butte and mesa in the area 540 m above m.s.l.

The top flow is an Aa' flow confined between altitudes of 545 m and 550 m and is exposed in north of Bhikwa. The flow is fine grained, dark grey and compact basalt. It is sparsely porphyritic and the top of the flow is not exposed

#### **Craterlets:**

A few craterlets have been reported from the area near Kukido Magra (not traceable in top sheet 46M/2 1:50,000) and at the base of the hill east of Jethana (23° 40' 40": 75° 00'40"). These craterlets are oval to perfectly circular. Their diameter varies from 1 to 10 m. with a wall or a rim rising 3 to 9 m above the surrounding surface. These rims show 30° to 40° inclination towards center. There are 46 such craterlets near Kukido Magra and 10 in the hill east of Jethana. These craterlets are within flow no 7 & 8. A calcite body of radiating nature has also been recorded in one of the craterlets at the base of hill east of Jethana. (Table No 3) Khan et. al (1994-95)

#### **Deccan Volvanics Of Quadrangle 46N**

The studied area of quadrangle 46N consisting of Survey of India top sheet 46N/1 to 16, it is bounded by latitudes 22° to 23° north and longitudes 75° to 76° east. The area forms parts of Dhar, Indore, Khargone, Dewas, Ujjain and Jhabua districts of Madhya Pradesh. This quadrangle as a whole forms the southwestern part of Malwa plateau and the fringing plains; the part of Malwa plateau known as Indore-Mhow plateau lies in the north-eastern part of the quadrangle. The area has east-west trending chain of hill ranges with several mesa and butte typo geomorphic features in the central part and a southerly facing scarp and the Narmada plain in the south. The highest elevation in the area is 881 m in the northeast and the lowest is 150 in along Narmada River on the southwest. The drainage

pattern in the area is predominantly of dendritic type. The southern part is drained by westerly flowing Narmada River and its tributaries while the northern part is drained by several northerly flowing rivers like Sipra, Gambhir, Chambal and Mahi.

The area is extensively covered by Deccan Trap lava flows having a few small inliers of Archaean, Bijawar, Bagh and Lameta Group of rocks in the south-western part; besides a few isolated inliers of Bagh Group are also exposed in the southeastern part. A narrow strip of Quaternary sediments occur along Narmada river course in the, southeastern part.

The geological sequence is given in (Table No. 1).

The Archaean Upper Proterozoic rocks are represented by pink granite gneiss and granites with xenoliths of hornblende/chlorite schists and dolomite Intruded by basic dykes and quartz veins.

The Bijawar Group includes metasedimentary rocks comprising phyllite, shale/slate and quartzite and unconformably overlies the Archaean rocks in southwestern parts exhibit close lithological similarities with Champaner Group of rocks exposed in adjacent area in 46J/15. These rocks are grouped together is treated as Champaner Group of rocks. the schistosity in the phyllite trends NW-SE with dips of  $60^{\circ}$  -  $70^{\circ}$  towards north-east; whereas the quartzite, shale and dolomite have gentler dips of  $15^{\circ}$  -  $50^{\circ}$  in northeast direction. These rocks have been transected by quartz veins.

The discontinuous units of the Bagh Group unconformably overlie the Archaean/Proterozoic and Bijawar rocks. This horizontally disposed sedimentary group comprises three formations which in order of in increasing antiquity are Nimar Sandstone, Nodular Limestone and Coralline Limestone. The thickness of these units varies from a few to 200 m. The nodular limestone and the Coralline Limestone are moderately fossiliferous.

The Larneta Group comprises a sequence of shales and reddish brown to green sandstones which at places are highly silicified, conformably overlying the Bag beds in the southwestern part.

The Deccan Traps of the area consists of a sequence of 46 basaltic flows with a cumulative thickness of 555 m exposed between altitudes 275 to 830 m above m.s.l. (Table No. 9). The flows represent a sequence of cyclic eruptions with fine to medium grained, aphyric to sparsely/moderately porphyritic flows with mega-porphyritic flows towards the top of each cycle. About two-thirds of the total thickness flows exhibit 'Aa' characters and rest are compound and simple pahoehoe type of flows. The thickness of 'Aa' flows in general varies from 14 to 18 m, while that of the pahoehoe units varies from 1 to 5m. The megacryst horizons contain feldspars varying in sizes from 1 to 6.5 cm and the average size is 2.25 cm. The levels of such horizons are identified at elevations of 275 m, 440 m, 520 m, 610 m, 690 m and 830 m. The pile of lava flow of the area has been classified into six formations; each characterized by distinct physical and petrological characters with mega-porphyritic flow marking the end phase of each cycle of eruptions. These formations have been named after the localities where their exposures are best seen, viz., Mandleshwar, Choral, Dhar, Indore, Bergonda and Singarchori and are correlatable with the Satwas, Kannod, Sonkach, Dewas and Remkot groups of flows respectively present in the QGM 46N/8 and with Mandleshwar, Kalisindh, Kankaria, Pirukheri, Indore Bargonda and Singarchori respectively in the QGM 46M and with Mahi, Nagda and Narwas formations respectively in the QGM 55B. The youngest formation of the area is named after the highest Singarchori peak. The thickness of lava pile of the individual formations varies from 78 m to 182 m. (Table No. 4 and 9)

### **Mandleshwar Formation**

This is the oldest formation with seven flows comprising 'Aa' type lava Identified between 142-275 m and covers a, wide area in the southern part. The flows are fine grained aphyric except the youngest flow which is highly porphyritic to megaporphyritic in texture. The megacryst unit contains plagioclase feldspar of about 2-4 cm size. The thickness of individual flows varies from 15 to 18 in. A total of four fossiliferous intertrappean beds with thickness varying from 50 cm to 3 m comprising limestone, chert and shale overlie flows F3, F4, F5 and F6. are delineated. The various fossils of gastropods, Bivalves and plant remains have been recorded from these intertrappeans beds. The flows of this formation show a westerly to southwesterly gradient.

### **Choral formation**

It is identified between elevations of 275-440 m consisting of eleven lava flows. These flows are generally fine grained aphyritic to sparsely porphyritic while the youngest flow is mega-porphyritic and amygdaloidal. The megacryst unit consists of plagioclase feldspars of 1-3 cm size. The thickness of individual flows varies from 15 to 16 m. In lava sequence three Intertrappean beds varying in thickness from 70 cm to 3 m are noticed mainly comprising argillaceous limestone have been reported from the upper flows of the Choral Formation. The fossils wood Gastropods and leaf impressions have been recorded from these beds occurring in southwestern part of the area.

### **Dhar Formation**

It is identified at an elevation between 440-520 m. This formation comprises five flows. These flows have a wide aerial extent in northern and western parts of the area forming moderately undulating topography. The flows are fine to medium grained, moderately to highly porphyritic with mega-porphyritic flow at the top containing megacrysts of feldspar 1-2 cm size. The flows show gradual change in their physical characters from compound pahoehoe on the west to 'Aa' types in the east.

### **Indore Formation**

It is identified between elevations of about 520-610 m. This formation comprises six flows which forms the central parts of Malwa plateau. The flows are generally fine grained; sparsely to moderately porphyritic showing lateral variation in physical characters from pahoehoe in the west to 'Aa' characters in the east. The average thickness of the flow is 14 to 15 m. The youngest flow of the Formation is mega-porphyritic having plagioclase—phenocrysts of more than 1 cm size.

### **Bargonda Formation**

The Bargonda formation is represented by eleven flows identified at elevations of about 610-790 m; this forms a small plateau around Bargonda in the southeastern part. The flows are generally fine grained, aphyritic to sparsely porphyritic, exhibiting 'Aa' characters. However, the youngest flow of the formation exhibits compound pahoehoe characters and mega-porphyritic texture consisting of megacryst of feldspars at the top containing phenocrysts ranging in size from 1 to 25 cm. The flows of the Bargonda formation form butte in the areas to the south of Indore and west of Mhow.

### **Singarchori Formation**

It is youngest formation named after Singarchori where it is best exposed in hill section and at few other places in its vicinity in the south-eastern part. It includes six lava flows identified between elevations of 790-830 m. These lava flows are fine to medium grained, sparse to moderately porphyritic in nature, it gradually become mega-porphyritic towards the top.

A large number of dykes and dyke swarms of basaltic and doleritic composition have been recorded in the Narmada plain in the southern part. The intensity of dyke occurrence is more in the oldest, Mandleshwar formation and gradually decreases in the younger formation and as such no dyke has been recorded from Bargonda and Singarchori Formation. The general trends of these dykes are ENE-WSW to E-W running parallel to the trend of Narmada lineament and a few are across to it having N-S to NNW-SSE and NE-SE trends. The length of dykes varies from 100 m to 20 km and width from 50 cm to 15 m. It has not been possible to discriminate post-trappean dykes from feeders on the basis of available data.

In all probability these dykes are actual feeders through which periodic eruptions of tholeiitic basalt took place resulting in formation of a 610 m thick pile. In this formation about forty six discrete flow events have been recognized. These have been grouped into six major episodes on the basis of flow characteristics and presence of marker horizons of megacryst plagioclase aphyritic mega-porphyritic basalts. As many as seven intertrappean fossiliferous sedimentary horizons have been delineated and identified recognized within the basal parts. It demonstrates episodic nature of volcanic activity, long periods of quiescence and resilience of both.

The Quaternary formation comprises a sequence of very coarse to fine sand, silt and clay with pebbles in the basal bed. It is exposed along the Narmada River in south-eastern parts of the area. Thick black cotton soil which is of transported nature is noticed in the Narmada plain as well as on the high plateau areas in northern parts. Khan et. al (1994-95) (Table No. 4 & 9)



### Correlation Of Deccan Basaltic Lava Flows

46I, 46J, 46M AND 46N

The Aravalli Group of rocks uncomfortably overlain by Cretaceous marine sedimentary deposits of Bagh Group. It includes Nimar sandstone nodular limestone and coralline limestone. These are almost horizontally disposed and their basal part is marked by conglomerate.

The Lameta Group consists of brown to yellowish brown, fine to medium grained cherty limestone. It is seen south-east of Bagh overlying the Nimar sandstone of Bagh Group.

The Deccan basaltic Lava flows have occupied a large area which consist 121 flows out of which a sequence of twenty one flows in 46I, thirty seven in 46J, seventeen in 46M and forty six in 46N with cumulative thickness of 555 m is exposed between the elevations of 275 m to 830 m. These flows represent a sequence of cyclic eruptions with fine to medium grained aphyric to sparse/moderately phyric and megaporphyritic towards top. About two third of the total flows exhibit 'Aa' characters and rest are compound and simple pahoehoe type of flows. The thickness of Aa; flows varies from 15 to 20 in in general while that of pahoehoe units varies from 2 to. 5 in. These flows consist of megacryst unit containing feldspar varies from 1 to 5 cm and average size is 2.5 cm. These megacryst horizons are identified in the area at different elevation in quadrangle 46I, 46J, 46M & 46N and on the basis of these horizons various flows have been grouped into six formations which has been given specific nomenclature and stratigraphic status. On regional basis as Mandleshwar formation, Kalisindh formation, Kankariya-Pirukheri formation, Indore formation, Bargonda disposition and equivalent are given in Table No. 10.

The Deccan Trap in the area occupied by quadrangle 46I (MP part) consist of 21 basaltic flows between elevation of 340 to 613 in above m.s.l. The exposed thickness of this lava flow is about 273 m.

These lava flows are both 'Aa' and compound pahoehoe type which contain megacryst unit of the top. The study of this pile of tholeiitic basalt (46I) reveal the presence of four megacryst horizons identified at an elevation of 340, 440, 500 and 613 m. These horizons predominantly consist of plagioclase feldspar ranging in size from 1 to 5 cm. with an average size 3.5 cm. These megacryst units are used in grouping the basaltic flows within the area occupied by quadrangle sheet 46I and correlation in the adjoining area in 46J in south, 46M in east and also assigning stratigraphic status and their specific nomenclature on regional basis. These groups in the area are designated as Mandleshwar, Kalisindh, and Kankariya-Pirukheri of Indore formations. These formations are correlated with the adjoining area of quadrangle of 46M and 46N on the basis of megacryst horizons

The Deccan Trap in the area occupied by quadrangle 46J comprised of a sequence of thirty seven basaltic flows of Deccan trap with cumulative thickness of 530 m between altitudes 220 in to 750 m. The flows represented a sequence of cyclic eruption with fine to medium grained. Sparsely to moderately porphyritic highly porphyritic, with Aa and compound pahoehoe flows having mega-porphyritic units at the top. The mega-porphyritic units consisting of mega-phenocrysts of feldspar ranging in size from 1 to 5 cm which are identified at an elevation of 220 m, 550 m, 610 m and 750 m above m.s.l. respectively. On the basis of occurrence of these megacryst units the pile of 37 flows of quadrangle 46J are divided into six groups designated as Mandleshwar Kalisindh, Kankariya-Pirukheri, Indore, Bargonda and Singarchori formations. These formations are correlated with the adjoining area of quadrangle 46I in the north and 46N in the east. On the basis of megacryst units and other diagnostic and salient elements and their equivalent formation in the area is shown in (Table No. 5)

The Deccan Trap in the area occupied by quadrangle 46M forms western part of the Malwa plateau with of Vindhyan in the north. These lava flows commonly termed as 'Malwa Traps' are correlated with the 'Middle Deccan Trap' group of Upper Cretaceous- Lower Eocene age. It consists of 17 lava flows between elevations of 440 m to 550 m above m.s.l. The exposed thickness of these lava sheets is about 110 m. The lava flows in the area are simple 'Aa' except middle sequence in the south—western part which shows pahoehoe characters. The lava sequence consisting of 17 flows has been divided into 3 groups on the basis of the megacryst horizons identified at 440 and 550 m above in m.s.l. These megacryst horizons comprised of phenocryst of feldspar ranging in size from 1 to 5 cm with an average size of about 3.5 in. These marker horizons in addition to the other salient and diagnostic elements are used in grouping the lava flows in various formations and correlating these formations with the lava sheets of adjoining area on similar characters in 46M in east and 46N in south and assigning specific stratigraphic

status and nomenclature to these formations on regional basis. These 17 lava flows are grouped into four formations which are correlated and designated as Kalisindh formation, Kankariya-Pirukheri formation, Indore Formation and Singranchori Formation while regional continuity and alike marker horizons and other diagnostic character of similar nature with adjoining formations (Table No. 10).

The area of quadrangle 46N is occupied by Deccan Trap basaltic flow which consists of a sequence of forty six basaltic flows with a cumulative thickness of 555 m is exposed in the area between altitude 275 m and 830 m above m.s.l. The flows represent a sequence of cyclic eruptions and consist of aphyric to phyrlic and to mega— porphyritic flows towards the top, among these lava flows about 60% of the total flows exhibit 'Aa' characters and rest are compound pahoehoe and simple type of flows. The thickness of 'Aa' flows varies from 14 m to 18 m. In general while that of the pahoehoe units varies from 2 to 5 m. These flows consist of five horizons of megacryst identified at an elevation of 275 m, 440, 520 m, 610 m, 690 m, and 830 m above m.s.l. This megacryst unit containing feldspar varies from 1 to 5 cm and average size is 2.25 cm. These levels are correlatable with mega horizons of 48M in north and 46J in the west and have significantly contributed in grouping forty six flows into six formations, each having distinct physical and petrological characters with mega-porphyritic flow which is comparatively more evolved and exposed marking the end phase of the cyclic eruptions. These formations have been named and designated as Mandleshwar. Choral. Dhar, Indore and Bargonda.

The study of various primary structure of basaltic lava flows such as inclination of pipe amygdule, primary flow gradient, and orientation of flow vesicles. change of flow character and thinning of lava sheets indicate the north—westerly gradient of lava flow in the area of 46I easterly and westerly gradient of older and younger flows in area of 46J; north-easterly and north—westerly gradient in the area of 46M and westerly and south—westerly gradient in the area occupied by 46N. It also reveals that source of cyclic eruption of lava flows of older formation lies somewhere in west—south—west in 46J whereas that of lava flows of younger formation in the east and south of Mhow in 46N.

In the area studied, a large number of dykes and dyke swarms of basaltic and doleritic composition have been recorded. The highest intensity of dykes is noticed in oldest. Mandleshwar formation. The intensity gradually decreases in number in increasing antiquity in the younger formation towards top and as such no dyke has been recorded from Bargonda and Singranchori formation. The general trends of these dykes are ENE—WSW to E—W parallel to the trend of Narmada lineament. This apparent parallelism may have some relation with the WNW-ENE lineament tectonics. Some dykes having trend in N—S to NNW— SSE and NE—SE direction exhibit discordant relation with Narmada lineament. The length of dykes varies from 100 m to 20 km and width from 50 cm to 15 cm. It has not been possible to discriminate post—trappean dykes from feeders on the basis of available data.

These are actually feeder dykes through which periodic eruptions of tholeiitic basalt took place resulting in 'formation of a 731 in thick pile of lava flows representing six discrete flow events in the area. These flows have been grouped into six major episodes on the basis of diagnostic flow characteristics and occurrence of marker horizons in the form of megacryst. As many as seven intertrappean fossiliferous sedimentary horizons have been recognized within the basal parts. These demonstrate episodic nature of volcanic activity, long periods of quiescence and resilience of both. Khan et. al (1994-95). Plate No.I (Table No.5)

### **Summary And Conclusions:-**

The geological studies of parts of Ratlam, Mandsuar, Jhabua, Dhar, Khargone, Indore, Ujjain and Shajapur districts of western parts of Madhya Pradesh occupied by quadrangle sheets 46I, 46J, 46M and 46N was carried out with special reference to Deccan trap basaltic lava flows, their megacryst horizons to build the lithostratigraphy on the basis of association of megacryst horizons for regional correlation with the assistance of available geological maps, and other literature supplemented by satellite imageries TM & MSS data.

The Deccan basaltic lava flows have occupied a large - area which consist of a sequence of twenty-one flows in geological quadrangle sheet 46I, thirty seven in 46J, seventeen in 46M and forty six in 46N with cumulative thickness of 73 m is exposed between the elevation of 142 in to 830 m. These-flows represent a sequence of cyclic eruptions with fine to medium grained, aphyric to sparsely/moderately phyrlic and mega- porphyritic towards top.

About two third of the total flows exhibit 'Aa' characters and rest are compound pahoehoe and simple pahoehoe type of flows. The thickness of 'Aa' flows varies from 15 to 20m in general while that of pahoehoe units varies from

2 to 5 m. These flows consist of megacryst unit 'containing feldspar and their size varies from 1 to 5 cm and average size is 1.25 cm. These megacryst horizons are identified in the area at different elevations in quadrangle 461, 46J, 46M and 46N and on the basis of these horizons various flows have been grouped into formation which has been given specific nomenclature and stratigraphic status.

#### **The Deccan Trap in the area occupied by quadrangle 46I (MP part)**

It consists of 21 basaltic flows between elevations of 340 to 613 m above, m.s.l. The exposed thickness of these lava flow is about 273m. These lava flows are both 'Aa' and compound pahoehoe type which contain megacryst unit at the top. The study of this pile of tholeiitic basalt (46I) reveal presence of four megacryst horizons identified at an elevation of 340, 440, 500 and 613 in. These horizons predominantly consist of plagioclase feldspar ranging in size from 1 to 5 cm with an average size of 3.5 cm. These megacryst units are used in grouping the basaltic flows within the area occupied by quadrangle sheet 46I and correlation in the adjoining area in 46J, 46M in east and also assigning stratigraphic status and their specific nomenclature on regional basis.

These groups in the area are designated as Mandleshwar, Kalisindh, Kankariya—Pirukheri and Indore formations. These formations are correlated with the adjoining area of quadrangle 46J, 46M and 46N on the basis of megacryst horizons (Table No. 5).

The Deccan Trap In the area occupied by quadrangle 46J comprised of a sequence of thirty seven basaltic flows of Deccan Trap with cumulative thickness of 530 m between altitudes 220 in to 750 m. The flows represent a sequence of cyclic 'eruption with fine to medium grained, sparse to moderately, highly porphyritic, with Aa and compound pahoehoe flows having mega-porphyritic units at the top. The mega-porphyritic units consisting of megaphenocrysts of feldspar ranging in size from 1 to 5 cm which are identified at an elevation of 220 m, 430 in, 550 in, 610 in and 750 in above m.s.l. respectively. On the basis of occurrence of these megacryst units the pile of 37 flows of quadrangle 46J are divided into six groups designated as Mandleshwar, Kalisindh, Kankariya-Pirukheri, Indore, Bargonda and Singarchori Formations. These formations are correlated with the adjoining area of quadrangle 46I in the north and 46N in the east, on the basis of megacryst units and other diagnostic and salient elements and their equivalent formation in the area is shown in Table No 4.

The Deccan Trap in the area occupied by quadrangle 46M forms western part of the Malwa plateau and Vindhyan in north, These lava flows commonly termed as 'Malwa Traps' are correlated with the 'Middle Deccan Trap' group of Upper Cretaceous – Lower Eocene age. It consists of 17 lava flows between elevations of 440 to 550 m above m.s.l. The exposed thickness of these lava sheets is about 110 m. The lava flows in the area are of simple 'Aa' type except middle sequence in the south-western part which shows a pahoehoe characters. The lava sequence consisting of 17 flows has been divided into 3 groups on the basis of the megacryst horizons identified at 440, 460 and 525 m above m.s.l. These megacryst horizons comprised of phenocryst of feldspar ranging in size from 1 - 5 cm with an average size of about 3.5m. These marker horizons in addition to the salient and diagnostic elements are used in grouping the lava flows in various formations and correlating these formations with the lava sheets of adjoining area on similar characters in 46I in east and 46N in south and assigning 'specific stratigraphic status and nomenclature' to these formations on regional basis. These 17 lava flows are grouped into three formations which are correlated and designated as Kalisindh Formation, Kankariya-Pirukheri Formation, Indore Formation and Singarchori Formation while regional continuity and alike marker - horizons 'and other diagnostic character', of similar nature with adjoining formations

The area of quadrangle 46N is occupied by Deccan Trap basaltic flow which consists of a sequence of forty six basaltic flows with a cumulative thickness of 555 in is - exposed in the area between altitude 275 in and 830 in above m.s.l. The flows represent a sequence of cyclic eruptions and consist of aphyric to phyrlic and mega-porphyritic flows towards the top. Among these lava flows 60% of the total flows exhibit 'Aa' characters and rest are compound and simple pahoehoe type of flows. The thickness of 'Aa' flows varies from 14 in to 18 in general while that of the pahoehoe units varies from 2 to 5 in. These flows consist of five horizons of megacryst identified at elevations of 275 in, 440 in, 520 in, 610 in, 690 m and 690 m above in m. s .l. These megacryst unit containing feldspar vary in size from - 1 to 5 cm and average size is 2.25 cm. These levels are correlatable with megacryst bearing horizons of 46M in north and 46J in the west and have significantly contributed in grouping forty six flows into six formations, each having distinct physical and petrological characters with mega-porphyritic flow horizons which is comparatively more evolved and exposed marking the end phase of the cyclic eruptions. These formations have-been- named and designated as Mandleshwar, Choral, Dhar, Indore and Bargonda are correlatable,

respectively. With the adjoining areas Sonkach, Oewas and Reinkot group of flows presented in Degree Sheet 55B, and Pirukheri, Indore and Singarchori in the west (46J) and Mahi, Nagda and Narwas formation in north (46M). The youngest flow formations of the area are named after the highest Singarchori peak.

The area studied embodies large number of dykes and dykes swarms of basaltic in and doleritic composition. The abundance of these dykes is recorded in oldest Mandleshwar formation exposed in Narmada valley. The intensity of these dykes gradually decreases in increasing antiquity in the younger formation towards top. The trend of these (tykes varies from ENE-WSW to E—W parallel to Narmada lineament. This apparent parallelism may have some relation with the Narmada lineament tectonics. Some of the dykes in the area have got N-S to NNW-SSE and NE-SW direction showing discordant relation with Narmada lineament. These are actually feeders dykes through which periodic eruptions of tholeiitic basalt took place resulting a thick pile of lava sheets representing six discrete flow events in the area on the basis of diagnostic association of marker horizon of megacryst. The pile of lava flows has been grouped in to six major episodes of volcanic activity which is represented by Mandleshwar formation, Kalisindh-Choral formation, Kankariya-Pirukheri Dhar formation, Indore formation, Bargonda formation and Singarchori formation.

The study of primary structures of basaltic lava flows such as orientation of flow vesicles, inclination of pipe amygdules, primary flow gradient, change of flow characters and thinning of lava sheets etc. of various formations in the area reveal the northwesterly gradient of lava flows in the area of Deccan basalt occupied by quadrangle 46I, easterly and westerly gradient of older and younger flows in the area occupied by quadrangle 46J; north-easterly and north—westerly gradient in the area occupied by 46M and westerly and southwesterly gradient in the area occupied by quadrangle 46N. It also suggests that source of cyclic eruption of lava flows of older formations lies somewhere in west-south-west in 46J whereas that of lava flows of younger formations in the east and south of MHOW in 46N. These sources fall in ENE-WSW to E-W trending lineament and there appears to be some relation with cyclic eruption of lava with Narmada lineament in the area.

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