GEOLOGY OF THE PAVAGAD HILL

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PAVAGAD HILL is an outlier of the Deccan Traps situated about 25 miles north-east of Baroda. Blanford[1] examined this hill in 1869 and noted that it was capped by a 'peculiar light purple argillaceous rock' which was later identified by Fermor[2] as rhyolite. Fermor[2] collected specimens of basalt, rhyolite, rhyolite-breccia, and pitchstone from the hill during a one-day visit and his descriptions are even now the only published detailed account of these rocks. Subsequently, a controversy started about the relationship of these rocks which has not yet been resolved.

Fermor found large boulders of rhyolite at different levels along the path leading to the top alternating with basalts, and came to the conclusion that the basalt and the rhyolite were interbedded. Beer[3] later gave a description of an ascending section of the hill in which he recorded the different levels where the different types of basalt and rhyolite were found.

Mathur and Dubey[4] later worked in this area, and concluded that the basalt and rhyolite lavas were not interbedded. They further recorded the occurrence of ultrabasic lavas which they considered intrusive into the basalt. In a separate communication Dubey[5] stated that the rhyolite and the basalt were not interbedded. According to him, while the ultrabasic magma followed the basic throwing out much basic tuff, the flows of rhyolite occurs on the surface at all levels which showed that they formed the last phase of igneous activity much later than the Deccan Trap. He proposed a Miocene age for the rhyolite from the determination of radioactivity and helium ratio. The rhyolite flows were further considered to have been erupted from vents and the topmost flow was regarded as an intrusive plug, surrounded as it is by thick deposits of agglomerates and ash.

The same views were reiterated by Mathur[6] in his Presidential Address to the Geology Section of the Indian Science Congress, 1934. Mathur also noted the occurrence of ultrabasic rocks closely associated with the ashes and tuffs and older than the rhyolite flows (p. 335). Fermor[7] got the view about the eruption of rhyolite from vents of Central type examined by Heron who reported that the top rhyolite represented a single horizontal flow.

The author of this note had an opportunity of examining the Pavagad area about a year back with a party of his senior students. In course of the survey of the main hill along the pilgrim route and a part of the base, and the adjoining smaller hills, definite evidence of interbedding, both horizontal and vertical, of two different types of lava was found. One of the lavas is basalt, but the other lava is purple-coloured, resembling a rhyolite, and produces purple and reddish soils. The colour of the lava varies from purple to reddish in more weathered outcrops and to a dark chocolate in many fresh outcrops. Along the path leading to the top from the Baroda-Shivrajpur Road, huge blocks of this lava are seen. There are also boulders of rhyolite. While many of them seem to have rolled down from higher levels, there are other exposures of rhyolite which appear to be *in situ*, judging by the parallelism of their joint planes and flow direction, six furlongs from the base. The latter is seen by the side of the first tank on the hill and in the two smaller hillocks to the south-east. In the smaller hill to the north of the road, this purple lava overlies bedded flows of anakaramite and is, in turn, overlain by basalt. Agglomerates in which fragments of basalt, sometimes olivine-bearing, are enclosed in the purple lava are common in different parts of the hill. The purple lava has many small included dark patches of tuff of the same composition, which are sometimes more vitreous than the main rock. It was evidently erupted with some explosive violence. There are dykes of an oceanite type of rock with many phenocrysts of olivine, and a few of pyroxene in a ground mass consisting of many grains of olivine, microlites of feldspars and some glass with iron ores, in the purple lava south of the road and another dyke of olivine basalt was noted in the smaller northern hill. From the broader relations of the two lavas—one basaltic and the other the purple-coloured one—the dykes seem to be of the type of composite dykes. The purple lava has a platy structure in some outcrops.

In its microscopic characters the purple rock has many similarities with *mugearites* which are associated with olivine basalt as composite lava flows in the Scottish Carboniferous province and as composite sills in Skye and Renfrewshire.[8] In fact, the mugearite lavas are interbedded with the olivine basalt lavas in several areas in Northern Ayrshire.[9] Mugearite has not so far been recorded from

India. The purple rocks show under the microscope a well-developed trachytic texture with small grains of pyroxene in between the microliths, and a few micro-phenocrysts of feldspars, often altered, pyroxene and olivine. There is plenty of magnetite granules and orange-coloured chlorophæite, besides secondary biotite round magnetite and zeolites. Fig. 1 shows an olivine micro-phenocryst on the right and an oligoclase lath on the left. There are many variations from these general characters. The feldspars are generally oligoclase as has been determined both from extinction angle and optic axial angle. In addition, the presence of orthoclase as individuals and as a mantle round the plagioclase, which is an important characteristic of mugearites, has been confirmed by staining with sodium cobaltinitrite and by the optic axial angles of micro-phenocrysts showing only Carlsbad twinning. The pyroxene micro-phenocrysts have a $2V$ varying from 55° to 57° indicating a diopsidic augite which is to be expected in alkaline basic rocks.

FIG. 1

In the main Pavagad Hill, west of Budhyia Gate, about 1,100 ft. above the sea-level, below the rampart, is a section showing a series of purple-coloured lavas gently dipping to the north-west followed upwards by bedded basalt with well-marked columnar jointing. It was found that the lower flows consist of a trachyte with micro-phenocrysts of feldspars both sanidine and oligoclase, and granules of pyroxene with plenty of opaque reddish iron oxide and glass as shown in the second microphotograph while the basaltic rock is a porphyritic one with phenocrysts of bytownite in a ground mass with intersertal texture. The pyroxene of the basalt is almost identical with that of the trachyte and has a $2V$ of 55° to 57°. Fermor had noted the similarities between the pyroxene of the basalt and that of the rhyolite and the dacitic affinities of some of the rhyolites. Trachyte had not been recorded previously, but most of the flows of the lower slopes of the hill are of a trachytic (when olivine-free) or mugearitic (with olivine) type, the former with well-developed pyroxene crystals (Fig. 2). Dubey and Bajpai[10] in a paper on the radioactivity of the Deccan Traps described two porphyritic basalts, one containing phenocrysts of andesine and the other of oligoclase, the former at an altitude of 1,400 ft. and the latter at 1,600 ft., but in hand specimens they were indistinguishable from typical plateau basalts and so the oligoclase-bearing basalt was considered to be a more alkaline variety approaching andesite. It does not seem therefore, that it was of the mugearite type found by this author although the possibility is there.

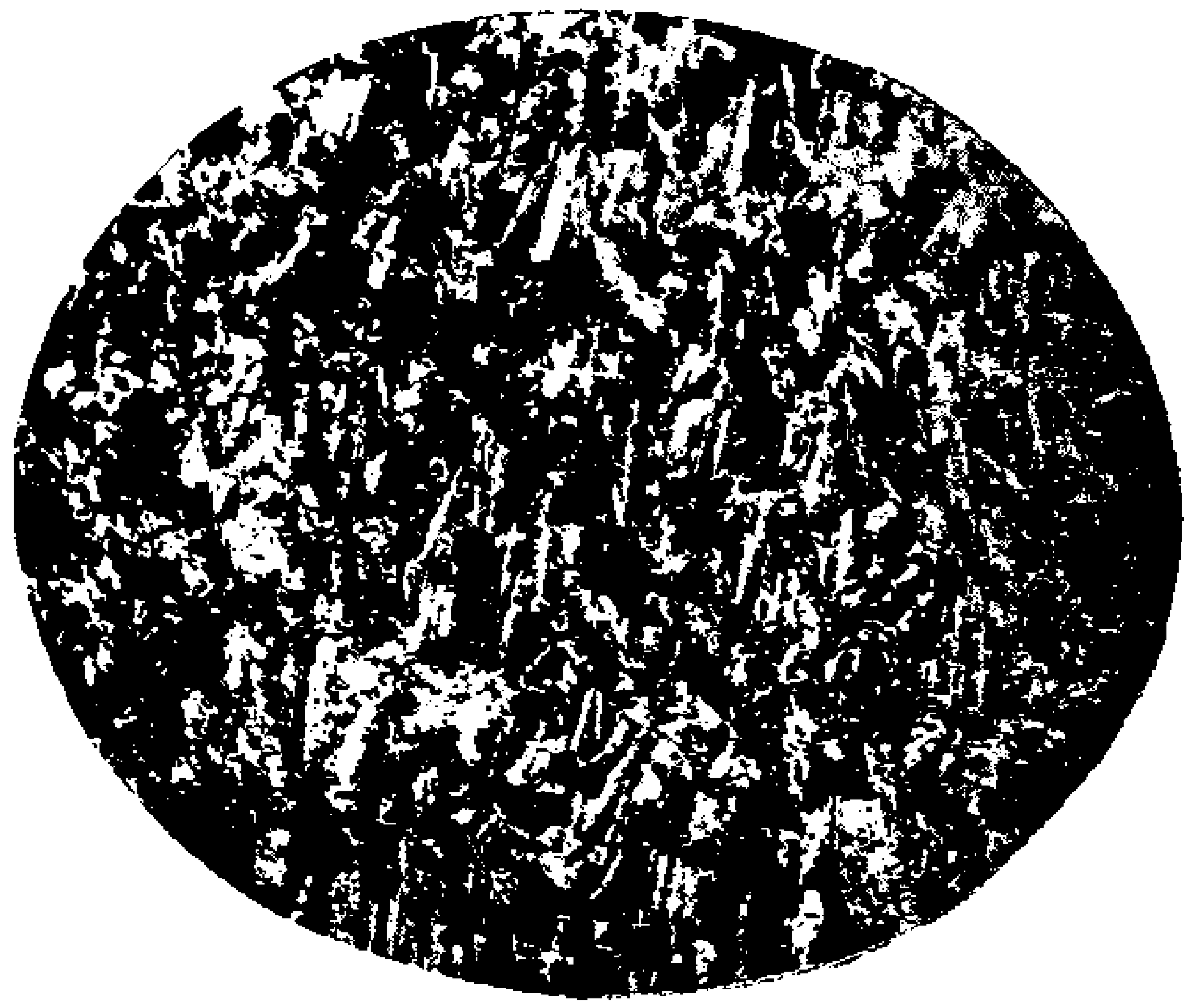

FIG 2

In the main hill, the first outcrop of normal basalt *in situ* was found about 1,000 ft. above the ground-level. Farther up is the interbedding of trachyte and basalt noted previously. Farther up is an extensive flow of porphyritic olivine basalt without feldspar phenocrysts and with pink iddingsite pseudomorphs after olivine, which extends along the eastern spur of the Pavagad Hill at the end of which stands the Bhadrakali Temple But the temple itself stands on a flow of mugearite which is highly vesicular at this place The mugearite forms a ridge. Besides, vertical impersistent sinuous bands of mugearite were also found in the basalt. Towards the main hill in the north-west, the next higher flow is of normal basalt (olivine-free and with feldspar phenocrysts). The temple is at a height of 1,734 ft. above sea-level while the normal basalt occurs about

2,000 ft. This is again followed by massive bedded flows of coarse-grained feldspar-phyric olivine basalt just below the wooden bridge above the trench which cuts off the main hill top. The feldspars show beautiful cruciform twinning. The olivine phenocrysts in all these flows have almost the same $2V$ (88° to 90°) indicating a high MgO content. There is no marked difference in the composition of the olivine and the pyroxene of the olivine-rich basalts of different levels. In the mugearites the olivine appears to be less magnesian. In both, the olivines are often zoned, particularly in the olivine-rich portions, and the pyroxenes are also zoned in some rocks.

On the last level of the Pavagad Hill, surrounding the turret of the top, are thick deposits of green ash beds containing phenocrysts of sanidine and albite, south-south-east of the temple at the top, and pink, brownish, whitish and variegated ash beds to the west and the north. The ash beds are followed by an extensive mass of rhyolite which forms the top. The flows show a slight basining near the top and the stratified ash beds form vertical bands. The rhyolite has very prominent vertical jointing which naturally suggested the idea of a plug to Dubey, surrounded as it is by ash beds, tuffs, agglomerates, and rhyolite-breccia, besides pitchstone and obsidian. The pitchstone forms a flow on the way to the ash beds and shows phenocrysts of albite, pyroxene and fayalite. There seems to be little doubt that the end of the magmatic period was marked by explosive type of eruption through localised vents and fissures in both the main Pavagad Hill and the south-eastern outlying hills.

In the smaller hill to the north of the road, a thick flow of basalt was found overlying the trachytic type of rock along the northern scarp on the face of a waterfall and a quarry.

The object of this note is to record the findings of certain new facts in their bare outline pending the working out of the mass of materials. In the Pavagad Hill are not only basalts and rhyolites, but also ankaramites, olivine-basalts, mugearites and trachytes. The olivine-basalt-mugearite-trachyte form a series in which there has been interbedding of flows of different kinds. The rhyolite seems to be younger as has been determined by Dubey from radioactivity, and overlies the former series. The relation of the rhyolite to the alkaline series still awaits investigation but Holmes' suggestion[11] about the association of basic and acid lavas in Central Complexes seems to be the probable explanation.

The above facts point to the existence of lavas of different composition, with more or less intratelluric crystallization, for eruption almost simultaneously or alternately as was supposed by Fermor, both for the Pavagad lavas and the Bushawal lavas. Geological literature provides well-known instances of similar association such as the lavas of the Scottish Carboniferous province, the islands of north-west Scotland, and the Hawaiian lavas described by MacDonald. MacDonald[12] has suggested a mechanism of such alternate eruptions from a common magmatic wedge in which some gravitative arrangement might have occurred with fractional differentiation, and fissures tapping different levels would bring to the surface lavas of different composition. West[13] found in Western Kathiawar an alternation between normal porphyritic basalt, porphyritic olivine-basalt, and oceanites and anakaramites in the lavas penetrated by deep boring.

A detailed study of the minerals of the different flows together with their composition in relation to the lavas and further field study are in progress, and the results will be published elsewhere in due course.

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