CHAPTER I

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CHAPTER - I

INTRODUCTION

1. Introductory Statement

The geology of the rocks around Patharia hill is presented in this thesis. Patharia hill is the location point for the University campus of Sagar University. The rocks around Patharia are of much geological interest as the entire University campus comprising residential, office, hostel buildings are built on it. Patharia hill comprises the chief rock type namely basalt. Besides, basalt there are intertrappean, laterite and soil. The geomorphic and topographic features of this basalt present a spectacular scenery and evokes much geomorphic interest. In addition, the geohydrological study of these basalts presents a challenge particularly in regard to location of wells, quality of water and environmental hazards.

1.1 Presentation of the Problem

The chief rock type constituting the Patharia hill is basalt, which occurs as several lava flows, presenting a
variegated petrography. The geology of the rocks around Patheria was chosen as a topic of research for the following reasons:

(i) The area is small with good exposures having close proximity and easy accessibility.

(ii) The entire area is a virgin area with no detailed literature about its geology.

(iii) The area consists of contrasting lithologies of igneous (Deccan Trap) and sedimentary (Inter-trappean and laterite) which opens vistas for arduous, academic endeavour in the field of petrology.

(iv) Neither the traps of Patheria hill had been distinguished into various flows on the basis of field, petrographic and chemical characters, nor the mode of occurrence of individual flows and occurrence of the minerals in the flows studied.

(v) The petrology of the basalt presents many geomorphic features and related problems for study.

(vi) The Deccan Traps of Patheria hill constitute the eastern fringe of Deccan Trap area which are supposed to be the earliest traps. No detailed petrographic and petrochemical work has been done on these traps to substantiate whether they are differentiated or undifferentiated basalts.
(vii) No detailed sedimentary petrographic work exists on the intertrappeans of the area. Besides, no petro-mineralogical, chemical work involving modern techniques and petrological, mineralogical parameters has been done on this rock.

(viii) Deccan trap is the main source of water around Patharia hill, the geohydrological condition controlling the water level in the wells, present an intriguing problem.

(ix) In addition the engineering properties of the basalts which are used for road and building construction material has not been studied with regard to the petrology and physical property of the rocks.

(x) Laterites are found capping Deccan Trap. Occurrence of laterite over Deccan Trap and their origin presents a good problem for study.

The author is more interested in petrology and mineralogy (being a teacher of petrology) for which laboratory facilities are available in the Department of Applied Geology, University of Saugar and has tried to establish its relationship with time, geography and their control over the physical and engineering properties of the rocks as well as towards the geological aspects of the rock on which the University is situated.
1.2 Geography of the area

(A) Location

The area of study namely "Patharia Hill" on which the University campus is situated constitute the highest hill of Saugor tehsil. Saugor district is located between (Lat. : 23°05' and 24°25'; Long. : 78°10' and 79°15') and is 192 km. east of Bhopal (location map). It lies on Bina-Katni Rail route, 75 km. east of Bina Railway Junction. The area around Saugor comprises undulating topography formed by Deccan Trap hills (flat topped) and Vindhyan ridges. The area of study(Patharia hill, shown in location map) falls between (Lat. 23°49' and 23°50'; Long. 78°45'50" and 78°46'40") in Survey of India toposheet No.55 I/13. The elevation of Patharia hill varies from 530 m. to 610 m., and at three places (Boys Hostel, Girls Hostel and Water Works) it exceeds 610 m. The area of study encompasses 20 sq. km.

(B) Climate, Soil, Vegetation, Fauna

(a) Climate

The area falls under the tropical zone experiencing 'the monsoon' type of climate. The period of June to September is the rainy season with average rain fall of 100-150 cm. It is succeeded by winter commencing from
October to February and temperature goes down to $5^\circ$C. The months of March to mid-June constitute the summer and the mercury may shoot up as high as $45^\circ$C.

The contrasting climate has important bearing on the weathering of the rocks of the area. During the rainy season, the rivers and streams are flooded, which erode and transport the material at a tremendous rate thereby exposing fresh rock surfaces for erosion. During other seasons, gravity, wind, vegetation act as agents of decomposition and disintegration, but the rate of weathering is negligible in comparison to what it is during rainy season.

(b) **Soil**

The ultimate product of weathering is soil. The mechanically degraded products of the Deccan Trap are the typical "Black cotton soil" known as regur.

Black cotton soil is a fine-grained soil which swells enormously when soaked with water and becomes impervious. This property of the soil makes the surface water to flow as run off rather than trickle down. Only the joints in the basalt permit surface waters to be added to groundwater.

(c) **Vegetation**

The Deccan Trap soil is very fertile, it holds up water and hence support good luxuriant vegetation. Teak,
sal, eucalyptus trees with their abundant green-brown leaves forming a canopy 7 to 8 metres above the ground are characteristic of Deccan Trap terrain, resulting in thick growth of vegetation around Patharia hill.

(d) Fauna

The area is not of much interest with regard to wild life. The fauna comprises mostly of rabbits, jackals and occasional wolf.

1.3 Previous Literature

The literature pertaining to the geology of the Patharia hill is scanty. However, scanty literature concerning the regional geology around Saugor comprising basalts is:

(i) Everest (1831) studied the rocks on his way from Mirzapur to Saugor where reference has been made about basalts around Saugor.

(ii) A brief reference is found in the memoir of Geological Survey of India (1877) in the form of an allusion to the paper of Coulthard (1835).

(iii) Wilson (1868) while working around Saugor has mapped the rock formations around Saugor on a scale of 1" = 2 miles. However, his work and map was not published.
(iv) Spry (1833) has reported shells of "Physa princeps" from intertrappean limestone around Saugor. The few and scanty pieces of literature concerning the rocks of Patharia hill are:

(v) In the paper entitled "Geomorphology of the country around Saugor", West and Choubey (1964) have briefly dealt with geomorphology of the traps and Vindhys around Saugor.

(vi) A paper about the source of the insoluble residue of the intertrappean limestone associated with the Deccan Traps has been published by Babu (1970).

(vii) The geochemistry of core samples drilled by Geological Survey of India on Patharia hill has been described by Alexander (1977).

(viii) Geomorphology dealing with slope analysis of the Patharia hill has been described by Subramanyan (1976).

(ix) Jain (1985) in his unpublished thesis submitted for post-graduate diploma in environmental geology has described the environmental aspects of the Patharia hill.

1.4 Researches on Deccan Traps

(A) India

The Deccan Traps which constitute the well-defined flood or plateau basalts occupy a major part of peninsular India. A review of the researches on flood basalts, in India and outside India will not be out of context.
Deccan Trap, though occupies 5,000,000 sq. kms. of the sub-continent, paradoxically has not been much worked in comparison to its areal extent. Much of the work pertains to field characters and megascopic characters.

The first reported field description of the Deccan Trap is by Blandford (1869), while working on the traps and intertrappeans of Central and Western India. Fedden (1884) estimated the thickness of Deccan Trap in Girnar area to be about 1070 mts. Fermor (1916) has described pumice, pitchstone, rhyolite, felsite, quartz-andesite from Pavagadh hills, Gujarat. Washington (1922) has given an account of Deccan Trap and other plateau basalts. An excellent account of petrography of the lava flows encountered at Bhusawal in the borehole has been given by Fermor (1925). The rocks of Girnar and Osham hills of Junagarh comprising lamprophyre, limburgite, monchiqueite, olivine gabbro, nepheline syenite, granophyre besides basalts and dolerites have been described by Krishnan (1926). Mathur et al. (1926) have also worked on the differentiation of the rocks of Girnar hill. Mathur and Naidu (1932) have worked on the volcanic activity of coastal tracts of Bombay, Salsette and Bassein. The Deccan Traps of Linga area have been described by Fermor (1934). West (1958) has published the results of the petrographic examination of 48 flows from three bore-holes in Saurashtra. He recognised three types of basalts in them.
The petrology of the Pavagadh hill has been studied by Chatterjee (1961) who described mugearite, hawaiite, picrite and alkali olivine basalt. Sukheswala et al. (1964, 1969) described a variety of rock types from Deccan Traps of Baroda district, Gujarat. They comprise carbonatite, layered gabbro, anorthosite, granophyre and alkaline rocks. All these are regarded to have formed after the eruption of Deccan lavas. Shah and Babu (1973, 1976) described the detailed mineralogy and petrography of eight basalt flows around Rahetgarh. Deshmukh et al. (1977) gave details of the petrography of Mahabaleshwar and Amboli sections of lavas in Western Ghats.

The petrological characters of the Deccan Traps have not been covered fully, only some portions have been studied in detail, while in many parts, particularly the eastern traps, the petrology remains uncovered.

The petrochemical characters of Deccan Traps are given in Washington's analyses (1922). Fermor (1934) investigating the flows of Linga in Madhya Pradesh showed that the chemical composition of the different flows was extra-ordinarily similar. Vemban (1947) on the basis of petro-chemical studies concluded that the original magma was picritic in composition, and that both alkaline and calc-alkaline trends were present. Sukheswala and
Poldervaart (1958) have given an extensive account of the petrochemistry of the Deccan Traps of the Bombay area. Sukheswala and Sethna (1962) have also presented the chemistry of the Deccan Traps and associated rocks of Bassein area, near Bombay.

According to Saksena (1962), the value of differentiation index described by Thornton and Tuttle (1956) is around 29 for lower traps and 39 for upper traps. A statistical study of the Deccan Trap chemical analyses has been given by Muthuswami and Narsimharao (1962).

The geochemistry of the major and trace elements of the Deccan Trap has been investigated by Karkare (1965). Tiwari (1966) has studied the geochemistry of the Pavegarh Volcanic rocks and concluded that here, both tholeiitic and alkali olivine basalt trends of differentiation are present. Nockolds and Allen (1971) have determined trace elements in some Deccan Trap samples and concluded that the rocks belong to the typical iron rich tholeiite trend and the specimen with the highest Fe/Mg ratio is closely comparable to the trace element content of the quartz-dolerite belonging to the Scottish Tertiary tholeiitic trend. Shah and Babu (1975) have described the detailed major and trace element geochemistry of the eight flows around Rahatgarh. Alexander and Paul (1977) described the detailed geochemistry of ten
lava flows around Saugor. Krishnamurty and Cox (1977, 1980) studied petrologically and geochemically picrite basalts and related lavas of Western India and potash rich alkalic suite of Deccan Traps, Rajpipla and discussed their origin. The former suite is shown to be mildly alkaline and to have evolved from a picritic parental magma by high level fractionation of olivine and pyroxene. The latter is unique in Deccan Traps, being highly enriched in potash. Potash poor typical Deccan lavas and rhyolites are associated with it. Major elemental variation in alkalic suite is ascribed to crystal fractionation dominated by clinopyroxene. Regional geochemistry of Deccan lavas is considered by Krishnamurty and Udas (1980) and its genetic implication discussed.

Ghosh (1983) presented a review of the trace element studies on Deccan Basalts. Rare earth elements geochemistry has been dealt with by Alexander and Gibson (1977) and Alexander (1979).

Sr isotopic studies in different parts of Deccan basalt region are done by Faure and Hurley (1963), Murali (1974), Paul et al. (1977), Alexander and Paul (1977) and Alexander (1985).

$^{87}\text{Sr}/^{86}\text{Sr}$ ratio for Deccan basalts varies within wide limits. Lower values are similar to those of mid-Indian oceanic ridge basalts. Higher values are due to the likely
selective introduction of radiogenic strontium into the basaltic magma by wall rock reaction. Regional variations in the ratio are accounted for by the differences in Rb/Sr and $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of the source region of the magmas.

Of late, geochemical studies are related to tectonics of the Deccan Trap Volcanism. Chandrashekaram et al. (1976, 1978) and Chandrashekaram (1985) discussed this aspect of west coastal and inland Deccan lavas and proposed a model for evolution of Deccan volcanism. With available petrographic, geochemical and geophysical data pertaining to gravity, seismology and magnetic polarity, the Deccan Traps here are shown to be low and high potash tholeiites and olivine tholeiites. In chemistry they are similar to rift volcanics and show striking affinity towards oceanic ridge basalts. The main basaltic eruptive phase of the Deccan Traps accompanied the formation of rifts along the coast. Geochemical and geophysical data is suggestive of their derivation from a less depleted mantle source below a thin crust of 15 km. thickness. The thinning is attributed to northward drift of Indian sub-continent by anticlockwise rotation of the Indian plate.

Reviews on Deccan traps were presented by Bose (1972) and Ghosh (1976) and they discussed its origin.
A few symposia were held on Deccan basalts and similar flood eruptions of the world at Saugor (1969), Pune (1976) and Bombay (1979). Their proceedings give a good account of the study of various aspects of this volcanic formation. Geochronological studies on Deccan Traps were done by Rama (1964), Wellman and McElhinny (1970), Agrawal and Rama (1976) and Alexander (1981). Age proposed by them varies from 100 m.y. to 31 m.y.

Rao et al. (1985) showed that chemistry and palaeomagnetism together can be used to establish stratigraphy in Deccan basalts and on their basis correlation of the lava flows can be attempted.

(B) Outside India

Outside India similar continental flood basalts are known from Columbia-Snake river area, Western U.S.A., Karroo lavas from South Africa, Thulean province of north Atlantic, Paraná basalts of south Brazil and traps of Siberia U.S.S.R. and Western Australia. Geological work on a few of them is mentioned in the following:

Waters (1961) and Waters et al. (1981) demonstrated eruption of three distinct tholeiite lava series in Columbia-Snake river flood basalts. It is contended that each series originated from an independent tholeiite magma. Their classification into sequences of the flows is done on the basis of palaeomagnetism, geophysical logs and chemistry.
Swanson et al. (1981), established comprehensive stratigraphy of the flows here. Individual flows are linked to their feeder dykes on petrological, chemical, field and magnetic characters and shown to have flowed for distances over 300 kms. Rates of eruption of the lavas are calculated. The parental tholeiite magmas are shown to have originated in iron rich olivine poor clinopyroxenite mantle source which differed in composition in space and time.

Eleven chemical types of basalt flows are established in the stratigraphy of the Columbia river basalts by Wright et al. (1973) on the basis of variations in major elemental compositions.

Hooper (1981) recently used chemistry and magnetic polarity to work out stratigraphy, tectonic evolution and petrogenesis of Columbia river basalts. Chemical differences between individual flows of a group or the flows of different groups are attributed to differences in degrees of partial melting and crystal fractionation at depths of lower crust or upper mantle.

In Karroo basalts of south-east Africa Cox et al. (1965) and Cox (1972a and b) studied about 8000 mts. of picrite basalts, tholeiites and rhyolites and other rocks associated with a monoclinal structure. Rhyolites are shown
to be genetically not related to tholeiites. In structure and associated lava sequence this resembles Panwel flexure of the Deccan Traps. Across the Karroo basin the tholeiite magma consistently show low K, Ti, P, Ba, Sr and Zr. But tholeiites with high values of these constituents are also found here. This divergence from normal chemical composition is due the occurrence of different magma types, which reflect differences of composition in source rocks or in conditions of fusion or contamination by crustal rocks. Cox (1972b) proposed a model of comprehensive Karroo volcanic cycle of igneous activity related to the break up of Gondwana land in Mesozoic times.

Brito-Arctic province is a mixed tholeiite-alkali olivine basalt province. Much of it is foundered beneath the sea. Its remnant, the Hebridean coast of West Scotland has been a classic ground of igneous petrology (Turner et al. 1962). Large number of memoirs have been published on the igneous geology of various islands here. (Harker, 1904; Bailey et al., 1924; Richey & Thomas, 1930). It is here that the ideas about the existence of different primary basaltic magma types and their derivative magma series were conceived and proposed (Kennedy, 1933; Bowen, 1928). The present position regarding the magma type is that there is no direct relationship between them. From time to time different batches of basaltic magmas were produced locally.
Magmatic diversity is due to variations in source materials, degree and conditions of melting and later fractionation (Thompson et al. 1972). The basalts with associated dyke swarms at south-eastern coast of Greenland, the other end of this province have been studied by Brooks et al. (1982).

1.5 Methods of Study

A. Field Study

An area of 20 sq. kms. has been mapped on 12 cms. = 1 km. scale to bring out the geology of the rock formations for detailed study. Six sections have been carefully measured to estimate the thickness of the flows to determine the variation in the thickness of the individual flow and to compute the average thickness for each flow to demarcate the contacts between the flows on the map.

The thickness of the flows was computed using both Abney level method and the formula method (vertical thickness = slope distance x sine of slope angle). Various field criteria have been used to recognise flows. The vesicles, joints have been studied. The mode of occurrence of the minerals occurring in the various flows has been studied.

B. Geomorphology

The geomorphology of the area has been studied from the point of view of relief and topography, weathering,
drainage and erosional surfaces. Slope analysis and stability studies of the area have been carried out. The drainage texture of the area has been analysed and drainage density and drainage frequency maps have been prepared. Possible relations existing between relief, lithology and structure and their effect on the development of the drainage system has been discussed. The erosion surface encountered in the area has been determined from the superimposed profiles and the geological evidence.

C. Sedimentology

The intertrappean rocks have been studied from the point of view of the petrology and mineralogy. The rocks were disintegrated in 1 : 1 HCl and the insoluble residus obtained after digestion with the acid have been studied. The intertrappeans have been chemically analysed for major and minor elements. Various physical as well as engineering parameters have been determined for the intertrappean limestones to assess their industrial economic potential if any.

D. Petrography and Mineralogy

Fifty thin sections have been prepared from different flows to study the petrography and texture of basaltic rocks. Modal analysis of these thin sections has been carried out using point-counter. The ratios of groundmass and phenocrysts of felspars and pyroxene have been determined.
The anorthite percentage of the plagioclase felspar has been determined after the method of Reinhard (1931) as well as of Tatarsky (1958). The twin laws of the plagioclase have been determined after the method of Naidu (1959). Refractive indices of plagioclases as well as pyroxenes were determined by immersion method using sodium vapour lamp. For pyroxenes β value was determined by immersion method and Z, γ have been computed after the method of Hess (1949). Birefrangence has been determined by using Berek's compensator and extinction angle Z ∩ C was determined by using 4-axis universal stage.

E. Petrochemistry

The petrochemical analysis of the major elements has been carried out after the method of Groves (1937). The constituents TiO₂, MnO, P₂O₅ have been determined by using spectrophotometer. Some major and minor elements have been determined by using Atomic Absorption Spectrometer (Rb, CO, Cu, Ni, Mg, total Fe) and rare earth elements (Eu, La) by neutron activation. Other trace elements were determined by the use of mass spectrometer. In all 19 rocks have been analysed for major and 16 for trace elements.

Some of the zeolites present in the traps have been analysed for identification as well as for computation of 'd' spacing by X-ray diffractometer by using CuKα radiation.
The intertrappean clay has been determined by colouration method of Vikulova and Vedeneeva (1952).

F. **Groundwater and Engineering Studies**

The water levels of the wells around Patharia occurring in traps have been taken in summer and water surface map has been prepared. The physical properties such as porosity, sorption and specific gravity have been determined for the traps. The engineering property namely the compressive strength has been determined for all the flows after the method of Krynine and Judd (1957). The chemical quality of groundwater in the wells of Patharia has been determined.

An attempt has been made to bring out the relationship among the engineering, physical and the petro-mineralogical parameters.

An humble attempt has been made to study the basaltic glasses and to determine on them the primary and secondary velocities of elastic waves by sonic methods. The basalts were made into glass to remove the effect of composition of various minerals by fusing it in a silica crucible (without flux) in an induction furnace and after air quenching the glass was removed by breaking the silica crucible. From this glass, plates and cylinders were prepared to determine the P and S velocity by sonic method.