(i) Location and communication:

The area between Chalisgaon and Igatpuri lies in the west-central and western part of the Deccan Trap formation in the Chalisgaon and Nasik districts of Maharashtra State. The two towns, Chalisgaon and Igatpuri, fall on the main railway line between Nashik and Bombay.

The area under investigation is covered partly by the toposheets of Survey of India, 46 F/3; 46 L/3, 4, 8, 11, 15; 46 H/15, 16; 47 E/9, 10 and 13. The hills and ridges which comprise the area occur in between East longitude 73°30' and 75°2'; and North latitudes 19°34' and 20°20'. In between this Chalisgaon and Igatpuri area, very high mountains like Kalsubai △ 5400', Trimbak △ 4210', Chandvad △ 3932', Ankai △ 3152', etc; long narrow ridges with many vertical scarps like Tringalvadi △ 3238', Mordan △ 3490', Ajanta Range △ 2878'; extensive plains with different erosion surfaces, 2700', 1900', 1500' and 1100' and deep valleys and gorges of less than 1000' altitude are present covering an area of
about 4,000 square kilometres, some 200 kilometres in length from east to west by 20 kilometres in width all along the railway track.

The accessibility of the region is fairly good. All the places can be approached from the railway stations by the buses and even by bycycles upto the foot of the mountains or ridges. The top of several mountains like Trimbak, Kalsubai, Ankai, Chandvad, Pandulema, etc. can be ascended along a climb of about 1000 stony steps which are constructed for the pilgrims to go to the temples at the top. However, many high hills and ridges with steep scarps are inaccessible. For instance, the top of Tringalvadi ridge and Mordan (Igatpuri), Chandvad (Manmad) etc. are very difficult to ascend. Some of the deep valleys and gorges of Kasara Ghat (Igatpuri) are approachable only through the spurs of the ridges which make gentle slopes.

(i1) Geomorphology:

Physiographically the region can be described as extremely hilly, forming high hills and deep valleys of the north Konkan and West Khandesh. The area is composed of thick and wide-spread lava flows of variable characters. The geomorphic features so produced display a variety of land forms, which are the results of the action of denuding agents. The most striking feature which it presents in the districts (area) is the great regularity of the
terraces formed by its layers. These terraced arrangements are known as a peculiarity of these rocks everywhere. Medlicott (1860, p. 218) states that, "the ground rises from the lowest levels in terraces which correspond in height on the different hills, themselves all flat-topped save only the highest, when frequently a little boss of the last trap flow has been left by the denuding agents. Long irregular ridges with many minor eminences, and branching spurs form a very striking land scape, in every portion of which the terraced out line of the trap rock is distinctly marked".

On a wide scale the land features of the area under study may be broadly divided into the following three groups, so that their characteristic features can be described without taking into consideration the individual land forms.

(i) Low-lying plains,
(ii) Scattered group of hills, and
(iii) Highly dissected uplands.

The low-lying plains extend in between Chalisgaon and Nasik (Plate No. 1). As a whole the plains are gently sloping towards the east. The average height around Nasik is 605 metres, while that around Chalisgaon is reduced to 315 metres. Thus the average slope comes to .85 metre per kilometre.
BLOCK D GEOMORPHIC FEATURES IN AON AND IGATPURI TE

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PLATE 1.
These plains have produced undulating topography, which is used for cultivation purposes. Separated by sufficient distances there are a number of small conical or rounded hills produced as an end-product of erosion.

The scattered groups of hills, sometimes with long narrow ridges of which the maximum concentration is to the north and south of Manmad and Nasik towns, are composed of a number of lava flows. The hills of smaller magnitude are usually conical, while the larger ones have stepped like slopes in all directions. However, the remnants of the later flows on the top of the larger hills maintain a perfect cone shape (Plate No. 2, Fig. 1 and 2). These scattered hills at so many places show the continuity of lava flows proving their occurrences over a wide area. On the slopes of this group of hills grows thick vegetation in the form of herbs, shrubs and trees as compared to the low plains and uplands.

The western portion of the area is characterised by highly dissected uplands, deep valleys and long narrow ridges, continuous or locally dissected, with spurs protruding from the main hills. The elevation of hill peaks approaches even upto 1650 metres while the elevation of ground level is nearly 650 metres. The elongated upland is aligned roughly in the north-south direction and also acts as a major water divide between the
Fig. 1 & 2: Conical hills around Igatpuri and Nasik.
easternly and westwardly flowing streams. A similar topographic expression is present to the south of Chalisgaon in the form of long continuous ridge parallel to the railway line. This ridge also forms a major water divide for the northerly flowing streams (tributaries of river Tapti) and south-easterly flowing streams (tributaries of river Godavari).

The physiography around Igatpuri is characterised by steep sided hills in the form of vertical cliffs, separated at certain intervals by step-like platforms. The top is often represented by a small boss or a prominent conical erosion remnant. Col. Sykes (1833, p. 92) describes the Deccan Traps of Khandesh and he mentions, "the pseudo-bedded character as very prominently marked by terraces on all the hills save where the many strata instead of being arranged in steps form a continuous wall or gigantic scarp of sometimes more than 1500 feet height. On the other hand the steps are sometimes effaced, and a hill has rapid slope. This originates in a succession of beds of the softer amygdaloids without any basaltic interstratification; their superior angles disintegrate and a slope results. But most usually three or four beds of amygdaloid are found between two strata of compact basalt. The former disintegrate leaving a slope, which is not unfrequently covered with forest trees forming a picturesque belt. The basaltic scarp remains entire, or
it may be partially buried by the debris from the amygdaloids above, but its great thickness usually preserves it from obliteration, and it rises from the wood below with majestic effect; its black front being finely contrasted with the rich and lively green of its Sylvan associates.

Spurs of different lengths extend from the main range, leaving many narrow tortuous valleys between them, some of which have the character of gigantic cracks or fissures cut by numerous narrow and deep ravines. Stupendous scarps, fearful chasms, numerous water falls, dense forests and perennial verdure complete the majesty and romantic interest of the vicinity of the Ghats”.

The drainage of this part is in its initial stage of development and at many places the streams give rise to steep sided deep valleys and gorges. For instance, the rivers Vaitarna and Ethima, which flow towards the west, have cut their courses through deep valleys and form gorges. The eastward flowing river Godavari and westward flowing river Vaitama originate from Trimbak mountains located about 35 kilometres north of Igatpuri.

**Drainage:**

The whole of the drainage is of consequent type as they have developed initially on the sloping surface of the
lava flows. Almost all the streams have a typical dendritic pattern (Plate No. 1). In the Nasik and Igatpuri area streams flowing in the direction of east or southeast join the river Godavari and in the Manmad and Chalisgaon area streams flowing in the direction of north or northeast constitute a part of the river Tapti.

In the Igatpuri area some of the streams and rivers have given rise to or culminated into shallow lakes of fairly large size. Out of these, one is lake Beale, which is 15 kilometres east of Igatpuri and the other one is lake Arthur (not shown in the block diagram, Plate No. 1), which is in the south of Kalsubai mountain. Although at the moment there is no clear field evidence to explain the origin of these lakes, but most probably the lakes in such a situation can be formed by the following causes:

(a) Blocking of the course of a river by the sediments deposited by the tributaries,

(b) Due to an underground collapse or compaction of underlying strata producing a shallow basin, and

(c) Quite possibly the meandering of the streams may be one of the causes (but more often it is an effect rather than the cause).
Development of landforms:

The characteristic feature of the Deccan Trap topography in this area is its terraced nature, vertical cliffs of varying heights, horizontal platforms (representing the junction of flows, terminating in scarp slopes which make an angle of about $25^\circ$ to $30^\circ$ with the horizontal). The development of this type of topography seems to have been controlled more by the principles of 'Scarp retreat' or 'pediplanation' as proposed by King (1953) rather than the principles of Davis (1922).

The topography owes its origin to the fact that many of the flows have an upper vesicular layer, or an upper weathered surface, which is softer than the other portion of the flow, providing a plane that is easily eroded. Applying the principles of 'scarp retreat' to explain the physiography of this area, it has been noticed that horizontal platforms are denuded mainly on their sloping sides without any erosion on the top. As a result scarp slopes with concave pediments appear on the sides of horizontal platforms. This leads to the formation of a conical hill when the scarp slopes meet one another. A similar explanation has been offered by West and Choubey (1964) to explain the formation of conical hills in the trappean country around Sagar, Central India.
Spines:

In the present area, in addition to the conical hills, vertical pillar-like masses are also present (Plate No. 3, Fig. 1 and 2). They have been termed 'spines'. In certain places like Summit Railway Station (lat. 20° 13' and long. 74° 24' 30''), near Manmai and Kalvan (lat. 20° 24' and long. 74° 9' 30''), 15 kilometres northwest of Chandore, vertical pillar-like masses, more than 15 metres high, stand boldly on the top of the basalt plateau. The diameters of these masses are more than 12 metres at the base and gradually taper upward. Though they may be easily mistaken for a volcanic neck (plug) from a distance, close examination reveals that they may be actually conical hills now turned into pillar-like masses. In calling them 'spines' the author follows Lacroix (1903, quoted from Billings, p. 274) who cited the classic example of a large spine, Mount Pelee, West Indies, which is a volcanic neck and in appearance resembles very much the Deccan pillar-like masses.

The final stage of the conical hill may be a spine. The flows which have produced spines of the above mentioned places have two distinct sets of joints, vertical more prominent and horizontal less conspicuous. Such joint patterns are responsible for the formation of blocks, which are wornout and easily removed and the final feature
Fig. 1: Closed up view of a spine, Ramgungi, near Manmad.

Fig. 2: Distant view of the same spine.
FIELD PHOTOGRAPHS

Fig. 1.

Fig. 2.
may be a beautifully carved spine. The process has been illustrated in Figures A, B and C (Plate No.4). However, this is only a possibility and in the formation of such features other factors like the nature of igneous activity and the type of lava poured out, physiographic and climatic conditions of the area and the rate of velocity of wind might also be responsible for carving out such features, which need further and detailed investigation. It is interesting to note that such features are localized only in certain parts of the Deccan Trap formation in contrast to the conical hills, which are characteristically present in almost all the areas.

(iii) Climate, soils and vegetation:

The climate over the area is dry and healthy during the major part of the year. The winter season extends from the month of November to the end of February, which is the best season for field work. The temperature varies considerably throughout the year from a maximum of about 105°F in the month of May to a minimum of about 50°F in the month of January. Monsoon is very heavy in the western part in the Ghat area and is irregular in the eastern part, breaking in the month of July and extending till the end of September. The average rainfall varies from 45" at Chalisgaon town to 60"-75" at Igatpuri and Kasara Ghat.
Diagram illustrating the process of block formation.
All the slopes of highly elevated regions and vertical scarps of different ridges are free from soil and as such provide good exposures of bare rocks. On the slopes of the smaller hills only soil of shallow depth is found. In the plains, valleys and gullies, the soil is of considerable depth. Amongst the soils black cotton soil or 'Regur' is the predominant type, which makes the land very fertile for the cultivation of sugar cane, cotton, jawar and wheat. On the terraces of different flows in the higher elevations red lateritic soil and in the gullies and river banks clayey and sandy loam are also found. The soil erosion is very severe in the western part of the area due to heavy and sudden showers and is less frequent in the eastern part.

The common forests and reserved forests in this area constitute a very wild romantic hilly tract and are full of trees chiefly of the Bamboo (Bambusa arundinacea and Bambusa stricta), Teak (Tectona grandis), Bayr (Zizyphus jujuba), Aul (Morinda citrifolia) and Butea frondosa. Small valleys and sloping sides of the low-lying hills are covered for the most part with stunted vegetation.

(iv) Archaeology:

Trimbak and Nasik are famous throughout India as centres of pilgrimage, drawing thousands of people from
all over the country. According to Hindu mythological records, Nasik is the place from where Goddess Sita was forcibly taken away by Ravana, the King of Lanka. From then onwards considerable importance attaches to these places from religious and archaeological point of view and a number of Hindu temples were constructed in ancient times. Godavari, a river considered holy by Hindus, originates from Trimbak, flows in the east direction upto Nasik, turns southeast flowing in the Maharashtra and Andhra Pradesh States and finally meets the Bay of Bengal having many tributaries. In Trimbak mountain a number of temples are present at different heights and on its summit stands the main temple of Lord Shiva and the ascent to the top is by a flight of stone steps. Other temples on the tops of different mountains like Kalsubai (south of Igatpuri), Chandore (north of Manmad), Gorakh Nath and Kapil Nath (west of Chalisgaon in Ajanta Range) are of local importance only, where a festival mela takes place once in every year.

Some of the small fort or fortress constructed during the reign of Shivaji Maharaj are present in this area, for instance, Ankai Tankai near Manmad. This fort was later possessed by Tipu Sultan, but now it has been completely destroyed. A few ancient caves at Ankai and Pandu Lena (5 kilometres west of Nasik) and Bhandardara Hill Station (30 kilometres south of Igatpuri) constitute common picnic resorts for the visitors.
(v) **Previous work:**

The area between Chalisgaon and Igatpuri has never been investigated previously to any extent assuming it to be a monotonous sequence of interstratified and huge pile of basaltic lava flows. The only short petrographic description and chemical analysis is given by Washington (1922) of one specimen from Igatpuri, which was sent to him by the Geological Survey of India and in which he noticed olivine crystals in "well formed phenocrystic individuals".

Agashe and Gupte (1968) studied some flows of the Nasik district when they were investigating eight districts of Maharashtra for proposed Engineering Project Sites. Their work was mainly confined to the project areas and the area under study by the writer has not been investigated.

(vi) **Scope of the work and technique employed:**

The existing literature directly concerned with the area is so meagre that considerable work remain to be done in order to find out the structural features, petrology, mineralogy, petrochemistry of the flows and their correlation with one another. In the present investigation of the area, mapping of three compound flows of variable thicknesses was carried out near Igatpuri in the Tringalvadi ridge on a map of scale 1"= 1 mile published by the Survey of India. The non-availability of large
scale maps has made it difficult to represent all the flow-units of a compound flow separately. The field studies required a period of about ten months spread over three years. The field work included the demarkation of the boundaries of the main rock types and a critical study of their interrelationship and their variation in the field. In the course of work an exhaustive collection of about 500 specimens was made. Rock specimens were collected from different flows or major flow-units of a compound flow and also from the different parts of the same flow to study the lateral and vertical variations within a single flow.

From the above rock collection about 400 microsections were petrographically studied in detail. The microscopic study included micrometric analyses of rocks, determination of optic axial angles of the minerals olivine and pyroxene and anorthite content and twin laws of plagioclase feldspar on 'Four-Axis Universal Stage', and refractive indices by the immersion method.

Twenty representative rocks were chemically analysed and the significance of the analyses has been discussed. Out of these, five rocks were spectrographically analysed to study the trace elements variation in them.

An attempt has been made to find out the nature of igneous activity and the parent magma of the region from
the petrographic data and chemical analyses of the rocks. Finally, the genesis of the main rock types has been discussed from the above observations and from the comparative study of the problems with other similar areas, especially the Hawaiian Islands and Iceland.