CHAPTER XVI
PLUTONIC - VOLCANIC HISTORY OF THE ACID IGNEOUS COMPLEX OF BARDA HILLS

The igneous activity in the Barda hills area comprises both the volcanic and subvolcanic phases. The major volcanic phase in Kathiawar is represented by the eruption of the Deccan Trap flows and they may be ascribed to the fissure eruption type of volcanism. The eruption of the Deccan Trap basaltic flows was followed by the emplacement of the subvolcanic phase of acid magma which formed the granophyres and felsites, as near surface intrusions and rhyolite as the extrusive phase. The different varieties of granophyres and felsites appear to belong to a series of overlapping or successive intrusions, on the bases of their field relationship and petrography. The emplacement of coarse granophyre was followed by the intrusions of fine granophyre and felsites, in the forms of simple and composite plugs. The uniformity in the trends of joint patterns (as referred to in the Chapter VII) developed in the different varieties of acidic rocks indicates that their emplacements took place in a short span of time. The minor occurrences of granodioritic rocks form a number of plug-like or dyke-like bodies in the granophyre and may represent a differentiated fraction of the acid magma. The minor intrusions of acidic (namely, microgranite, porphyritic felsite, pitchstone or rhyolite) and later basic (dolerite) rocks in the form of dykes, are related to the major acid intrusive phase and the latest basic intrusive phase respectively. The presence of dolerite and finer grained basaltic dykes within the acidic rocks indicate that the basaltic magmatism was still active after the extrusion and cooling of acidic magma.

The rocks comprising the acid igneous complex of Barda hills were emplaced towards the close of the Deccan Trap period and may be considered as a central focus of eruption within the Deccan Trap basaltic flows (Fedden, 1884).
Adye (1919) stated that the eruption of Deccan Trap basaltic flows was practically closed towards the dawn of Eocene epoch, and the outbursts of acidic rocks became centralised at a few centres e.g., Barda, Alech and Girnar hills in Western Saurashtra. Subba Rao (1972) suggested that the tectonic weakness in the crust, e.g., the Narmada rift zone seemed to have extended originally into Kathiawar peninsula connecting some of the eruptive centres of acid rocks in the western Saurashtra. Earlier Auden (1949) also referred to the dyke patterns in Saurashtra and indicated that tectonic deformation of crust may have controlled the dyke patterns. Auden also referred to a radial disposition of dykes in the area around Girnar Hills.

It has been referred to earlier (Chapter XV) that the combined mechanism of fractional crystallization differentiation of Deccan Trap tholeitic basalt and melting of the lower crust by the heat of ascending basaltic magma (as postulated by Sukheswala and Poldervaart, 1958) is responsible for the origin of acid magma in the present centre of eruption.

The whole igneous activity (including both the basic and acid igneous phases) in the present area, was probably spread over in time. The eruption phase of Deccan basalts may be followed by a brief period of quiescence, during which the acid magma in the underlying magma chamber in the lower crust has accumulated and may have undergone some differentiation. Subsequently, the acid magma forced its way up to give rise to the subvolcanic and volcanic activity, due to later development of enough pressures in these centres of tectonic weakness. The late basaltic magmatism forming dolerite and a later phase finer grained basaltic dykes indicate of magma generation in the upper mantle forming basaltic melts.
EPIZONAL EMPLACEMENT OF ACIDIC ROCKS

The Tertiary acid igneous complex of Barda hills, appears to have been emplaced within epizone of Buddington (1959) as also mentioned by De and Bhattacharyya (1971) and the subsequent time after the emplacement was probably too short for deep erosion. The stock-like masses are wholly discordant with the subhorizontal Tertiary lavas of Deccan basalts. The geological map (Plate I) shows that the acid complex is composite in character, caused by a successive series of magma emplacements forming different varieties of granophyre, felsite and granodiorite. The diversity in the subvolcanic rocks is further enhanced by the different varieties of pyroxene, from augite at the early stage through ferrosalite, ferro-augite and hedenbergite at the intermediate stage to alkalic pyroxene at the late stage. The acid subvolcanic mass is homophanous in character without any foliation and lineation. Rhyolitic rocks are associated in close genetical relationship with the hypabyssal or plutonic rocks, which are shallow intrusions in the epizone. The presence of miarolitic cavities in the granophyres, is a remarkable feature of epizonal acid rocks. The Deccan Trap basaltic rocks, outside the contact metamorphic zone are relatively unmetamorphosed, whereas the basaltic rocks at the contact zones show effect of thermal metamorphism.

MECHANISM OF EMPLACEMENT OF ACID ROCKS

Acid rocks in the present area occur as a stock-line bodies in different forms. The overall form is circular in plan and has a maximum diameter of around 18 km considering the entire Barda Hills of which the present area forms the eastern half. Some of the smaller stocks are irregular and elongated and have a scalloped border, apparently due to coalescence of several stocks. The contact of the Barda complex against the basaltic country
appears to be vertical in the Ghumli-Khambiyara Nes area. Two basaltic stoped blocks of dimensions about 3 sq. miles (7.7 sq. km) and 1 square mile (2.6 sq. km) respectively, are located within the acid stocks. Minor thin dykes of acid and basic rocks have also been observed in the present area and two of them (Katkola and Verad areas) appear to be part of cone sheets, which have arcuate plan and flowlines converging downwards.

The emplacement of the stock-like bodies can be explained by the mechanism of piecemeal stoping (Daly, 1933). But in the present case, the piecemeal stoping mechanism does not appear to have played a major role, in which case the small caught up patches of basalts would be found more frequently. The underground cauldron subsidence phenomenon appears to be more suitable for the present situation and this mechanism is illustrated in the figure 68. In the simplest form (Clough, Maufe and Bailey, 1909), it involves the sinking of a cylindrical block bounded by vertical fractured sides and cut off at the top by a horizontal fracture. The cylindrical block gradually subsides and the magma rising upward through the vertical fractures fills the cavity between the subsiding block and the overlying roof and ultimately a disc-like or cylindrical intrusive body forms. Erosion subsequently exposes the body, which would have a more or less circular form in plan and have vertical contacts. But according to Anderson's hypothesis on cauldron subsidence (Anderson, 1942), the walls of the subsiding block and consequently the contacts of the resulting intrusion may dip steeply outward. In another mechanism (Billings, 1945) for cauldron subsidence tension fractures in the roof would form parallel to the upper contacts of the reservoir as a result of release of pressure in the magma reservoir. The magma would then rise and fill the potential cavity left by the subsiding block bounded by them and by other minor fractures.

Comparable examples of similarly emplaced acid volcanic-subvolcanic complexes occur in Northern Nigeria (Jacobson et al., 1958), New Hampshire (Billings, 1945) and the Tertiary volcanic districts of Scotland (Clough et al., 1909).
BLOCK DIAGRAMS REPRESENTING THE ORIGIN OF STOCKS

(DIAGRAMS FOLLOWING BILLINGS, M.P. 1945)

A. PIECEMEAL STOPING MECHANISM
   (DALY, 1934)

B. CAULDRON SUBSIDENCE MECHANISM
   (CLOUGH, ET AL. 1909)

C. CAULDRON SUBSIDENCE MECHANISM
   (ANDERSON)

D. CAULDRON SUBSIDENCE MECHANISM, BY
   TENSION FRACTURES IN THE ROOF

---

PRESENT LEVEL OF EROSION.

BASALTIC COUNTRY ROCKS.

ACID MAGMA INTRUSIONS.
In the present area, the presence of large basaltic stoped block, sharp and straight contact of acidic rocks against the basalt observed at Ghumli-Khambiyara Nes area, presence of small xenoliths of basalts and minor arcuate dykes, favour the idea that the large blocks have subsided. It is however clear that the stocks of Barda acid igneous complex have been emplaced by some stoping mechanism, which has been accomplished chiefly by the sinking of large blocks approximately having the total size equal to that of the present stock.