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VOLCANISM, TECTOGENESIS AND SEISMICITY OF DECCAN TRAPS

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Abstract

Deccan trap volcanism is regarded as a result of eruption through fissures. These fissures are considered to be represented by dykes. Three main regions showing concentration of such dykes are noted around Narbada trough, North Konkan and Kathiawar. The dykes show an alignment parallel and sub-parallel to the fractures in these regions. Both the fractures and the dykes in the Narbada trough are in general aligned in E-W direction, where as in the North Konkan they are in N-S direction. The two regions also show presence of eruptive centres and the associated acidic and alkaline rocks. Narbada trough and North Konkan region are geotectonically akin to one another and are probably an outcome of linear crustal uplifts in the E-W and N-S directions respectively. In Kathiawar, where similar central type of volcanism is also noted, the dykes and the fractures show a radial pattern. This suggests a domal uplifting of the region.

The three above noted areas represent separate units in the Deccan traps—the Narbada trough forming a part of the Satpura rift, North Konkan area lying within rift zone along the West Coast and Kathiawar situated at their intersection. The structure and volcanism of these three regions indicate that they are independent geotectonic provinces, which were responsible for the evolution of Deccan traps. It is therefore imperative that attempts to establish the volcanism and tectogenesis of the trappean province must take into consideration the presence of dykes, fractures and eruptive centres and their genetical inter-relationships.

Plotting the epicentres of past earthkuakes over Deccan traps show two areas where they are linearly distributed, one trending nearly N-S, parallel to the west coast of Maharashtra and the other extending from the mouth of Narbada river and stretching across Central India, spread over the ancient Satpura strike upto Rajmahal hills, and from the mouth of Ganges delta to Sylhet in Shillong Plateau. These epicentral zones bear a striking correspondence to the areas which have uudergone crustal upwarping. Further they also correspond to the delineated gravity anamolies along the regions.

This paper deals with the mechanics, evolution and emplacement of Deccan traps and attempts to examine the available evidence to see if any genetic or tectonic relation can be established between the rift phenomena and the epicentres of earthquakes in the area.

Introduction

The historical and scientific data collected after the December 11, 1967 Koyna Earthquake has revealed that Western Coast of India, particularly the portion occupied by Deccan traps, has shown seismicity in the past. Such a seismicity is noted to be episodic and of short durations, and followed by long period of quiescence. It has also been noted that probably the entire coast line extending from Daman in the North to Ratnagiri in South is seismogenic, that is liable to being visited by earthquakes. In can not be a mere coincidence that this seismogenic belt lies within the trappean province. Obviously there should exist a relationship between the two.

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Deccan trap activity of India ranges in age from Upper most Cretaceous to Oligocene, probable extending into Miocene or even Pleistocene. Very few contributions to the problem of the erruption of Deccan lavas extist in scientific literature. Views of Glennie first propounded in 1932 and improved upon by Auden (1949) do not differ considerably from those of West who is 1959 summed up the present status regarding the source for these erruptive rocks. Glennie on the basis of geophysical studies, postulated an upwarping of the crust along the West Coast of India. A similar upwarp, though on a much smaller scale extending from mouth of Narbada and Tapti into the Satpura belt was suggested by Auden. Auden further stated that "these two zones of upwarp may have been the main foci of extrusion". Such a view is quite probable although West considers the areas of swarms of dykes within the Trappean province to be the real source. Apparently there exists a general correspondence between the concentration of dykes and the areas of upwarp, the two having a possible genetical relationship.

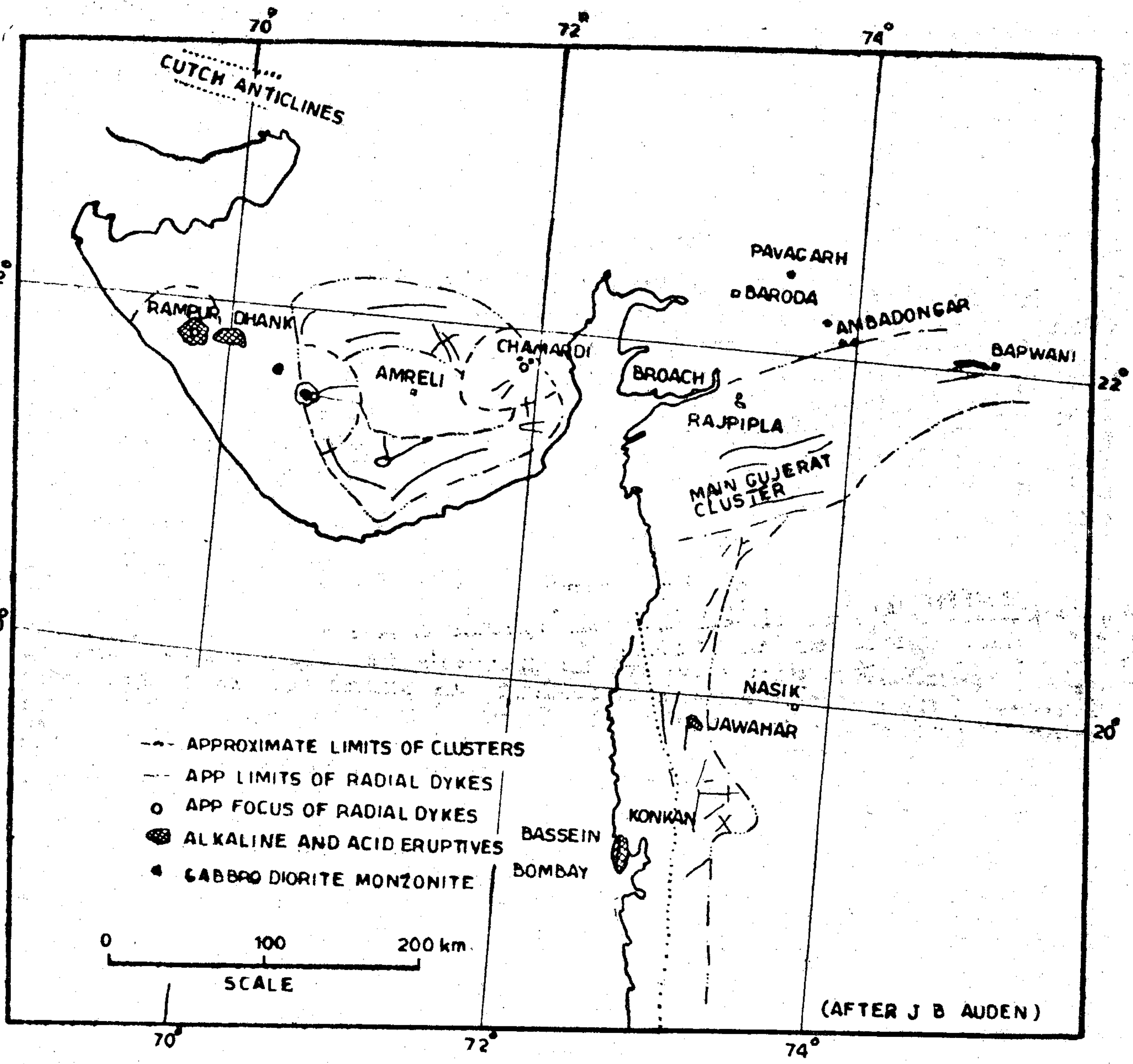
Based on geological studies over similar volcanic provinces in other countries attempts have been made to correlate Deccan volcanism with suboceanic eruptions similar to those associated with mid-oceanic rift valleys (Menard 1965, Francis and Shor 1966). It would not be out of place to mention here that Deccan Traps in their lithology and structure resemble the Scottish Hebrides (West 1958) and East Greenland Volcanics (Auden, op. cit.). Both these areas form a part of the Brito-Arctic province related to the Mid-Atlantic rift system (Menard 1965). Tomkeieff (1964) has in fact taken the help of hypothetical rifts to explain the association of plateau basalts with plutonic complexes and dyke swarms as seen in parts of Brito-Arctic province. Considering that no major lithological and structural difference exist between continental and oceanic rifts (Tipnis and Srivastava, 1968) and that volcanism in either case in attributed to the existence of deep fractures extending upto the 'wave—guide' of the tectonosphere serving as channels for upward movement of molten material (Beloussov 1968), Tomkeieffs speculations regarding the presence of hypothetical rifts deserves attention.

Detailed studies carried out by Auden (1949) has indicated three areas—Kathiawar region, Narbada Trough and North Konkan (North-east of Bombay), which show prominent net work of dykes occurring radially or in swarms (Fig. 1). The distribution of dykes in these areas show different patterns. They are arranged radially to the plutonic centres in Kathiawar hereby indicative of domal uplift, are aligned E—W parallelling the Narbada trough, and N-S in Konka region suggestive of linear upwarps parallel to these trends. These areas also possess certain common characteristic geological features such as distribution and pattern of fractures, presence of acid and basic volcanic eruptive centres and zone of mixed volcanism.

An attempt is made in this paper to utilise the presence of these geological features to build up a tectonic environment which can explain to satisfaction the volcanism of Deccan trap as well as some of its elusive aspects such as distribution of lava flows, presence of eruptive centres, the relationship between dykes and fractures and the seismicity.

Fractures

Fractures and fissures are supposed to represent the inherent lines of weakness in the Pre-Trappean basement. Their orientation therefore gains significance. It is seen that disposition of the fractures in the three regions is in general parallel to the trend of dykes. Such a close relationship between the two may imply that the phenomenon of dykes and fractures is contemporaneous, the dykes reperesenting the infilled fissures and fractures. The fractures and dykes pattern in Narbada trough is E-W while in Konkan it is N-S. These two trends imply deep seated tectonic control. At many places fractures and shear zones



MAP SHOWING DOMINANT TRENDS OF DYKE CLUSTERS AND NETWORKS AND LOCATIONS OF ERUPTIVE CENTRES

Fig. 1

have displaced the dykes indicating post-volcanic faulting of trappean rocks. Such displacements may be along transverse or oblique lineaments. These are of shallow depth and younger age.

Sengupta (1967) commenting on the structure of Gulf of Cambay states that the general N-S trend of the basin is disturbed by two major uplifts one of them being a subsurface extension of Kathiawar peninsula. This appears to continue eastwards between the Narbada and Tapti trough and is named as 'Satpura uplift' having an E-W to

ENE–WSW trend. As regards the Cambay basin, Sengupta further indicated that within the basin near its axial part there exists a system of median fractures along which subsidence has taken place. The eastern margin of basin coincides with the Western Coast of India and appears to be faulted. From this Sengupta has conculded that deep fractures exist within the traps which may be continuous upto Lacadiv Minicoy group of islands, their orientation being N–S. This fracture pattern follows the trend of the two orogenic belts namely Satpura and Dharwars which probably have served as the structural grains.

Volcanic Lineament

Presence of ancient volcanics linearly arranged implies to an eruption through volcanic cones as against the more common volcanism of Deccan traps through fissures. Along the West Coast these are noted at St. Mary's Island about 300 miles south of Bombay, along Western Ghats of Maharashtra (Agashe and Gupte 1966), the island of Bombay, Malad and nothwards. Another volcanic lineament showing an E–W arrangement was pointed out by Crookshank (in Auden 1949) along the Narbada trough and Satpura region, west of Barwani state. Sukheswala and Udas (1964) suggested the possibility of all such erruptive centres along Narbada trough as being of alkaline type and related to the extrusion of carbonatitic magma. In the absence of the detailed study of all these centres it is difficult to make any definite concluions regarding their alkaline or acidic affinities.

Eruptive centres similar to the two areas along Narbada trough and North Konkan, are also found in Girnar and Osham. Detailed study of Girnar area (Subba Rao, 1964) shows cone type activity in addition to fissure type (common in Deccan traps) in the region. Resemblance is evident between the main episodes of igneous activity between Girnar and Tertiary igneous complex of Scotland. As pointed out earlier, the igneous activity of Scotland has been corelated by Tomkeieff to rifts within the vicinity. This appears to bear conformity with the views expressed by Baily (1964) and Sveshnikova (1967), both of whom support the presence of alkaline magmatism of the central type to a special environment namely that of rift structure. Bailey is more convinced that uplifting of the continental crust is intimately related to the formation of rifts and the associated alkaline volcanism, where as Sveshnikova prefers to have a more difinite type of crust (either platform or stable block) dissected by deep fractures as the basic requirement for such igneous complexes (includin ring and cone intrusions), which may form independent provinces along the rift system. Since all these eruptive centres are confined to the western portion of Deccan traps, the region is indicative of a different tectonic enviornment as compared to the rest of the trappean province.

Mixed Province

Hybrid aspect of volanism confined to the western traps has led to the speculation that the area probably constitutes a mixed province (Bose, 1967). On the basis of rocks belonging to alkaline affinities Chatterjee (1964) considered this region to be an alkaline olivine basalt sub-province.

Presence of alkaline rocks in Konkan, Narbada trough and Kathiawar regions, which show the association of dykes, fractures, fissures and ancient volcanics, is considered significant and suggests a genetic inter-relationship. Occurrence of alkaline rocks in Deccan traps are reported from various places. Nepheline syenites are found to occur at Jawahar about 90 miles north-east of Bombay. Rocks of alkaline affinites are found to occur in the islands of Salsette and Trombay. The presence of carbonatite, and alkaline syenite has been noted at Amba Dongar, and Pheniamata in the Narbada trough. Pavagarh and Girnar in Kathiawar also show rocks of alkaline affinities.

Sukheswala has pointed out the possible tectonic implication of the presence of alkaline rocks of Narbada trough as belonging to similar environment as the alkaline rocks of East African Rift Valley, thereby implying that Narbada trough is a rift. A possible rift was also suggeted by him near and parallel to the Western Coast on the basis of occurrence of alkaline rocks. The seismicity of the region also supports such a postulation (Srivastava and Tipnis 1968).

Tectogenesis

The above mentioned petrological and tectonic observations as applied to the traps of the Deccan volcanics shows that the north Konkan, the Narbada trough and the Kathiawar regions have the following features in common.

1. Linear crustal uplifts in case of North Konkan and Narbada trough while domal uplifts in Kathiawar.
2. Fractures, generally conforming to the pattern of dykes, thereby, possibly representing initial tension cracks during the arching of crust.
3. Dyke swarms, which are parallel to the linearly oriented uplifts and radial in case of the uplift.
4. Subsidence along the axial fractures in the case of two linear uplift and into caldera in case of the domal one.
5. Linear disposition of ancient volcanic cones indicative of central type of eruption along with the normal fissure-types.
6. Presence of acidic and alkaline differentiates of volcanic rocks in the vicinity of these eruptive centres.

Working on Sveshnikova's hypothesis that tectonic magmatic complexes often form independent provinces along major rift zones it is suggested that Narbada trough and North Konkan are in fact independent complexes belonging to two major rift systems, the Satpura rift and West Coast rift. The Kathiawar igneous complex with its various plutonic centres of eruption is explained as resulting from intersection of rift systems by working upon Bailey's hypothesis that concentration of eruptive centres takes place at junctions of rift intersections or of a rift with fault. Such an intersection could be due to—(1) the westward extension of Satpura rift as suggested by Auden (1949) and confirmed by Sengupta (1967) ; (2) the northerly continuation of West Coast rift whose bend of strike to northwest would reflect its tendency to trend parallel to the Carlsberg ridge of the North-West Indian Ocean—a feature commonly observed in the case of marginal igneous activities (Menard 1964) ; and (3) the westward splaying of western strike of the ancient orogenic belt of Aravallis.

The suggestion of the possible presence of two intersecting systems of the rifts in Kathiawar complex has a precedence by the example of similar orthogonal set up of East African and Red Sea rifts. These also show definite intersection but do not bypass one another.

Mechanism and Significance of the Hypothesis

The mechanism which can explain the association of various geotectonic features as seen within the trappean province appears to result from upwarping of the crust as suggested by Bailey. Such a phenomenon is manifested in : (i) crustal uplifts situated above orogenic belts, (ii) rift or fractures occupying the crestal position of these uplifts, (iii) erruptive and intrusive centres of igneous activity confined within or outside the rifted zone and (iv) basaltic lava flows occupying the inside and outside spread of these rifts.

It is well known that orogenic belts are zones of isostatic imbalance and that crustal upwarps in pre-Cambrian shield in general develop along them due to uplifting of their roots.

Upwarping of the competent crust causes streching at the surface and relief of pressure in the underlying region of the tectonosphere. This is responsible for the formation of deep fractures and fissures at the crests which extend from the interior upto the surface of the uplifted crust as also in the melting of rocks at its base. The molten material move upwards through these associated fractures and fissures, whose disposition may be meridional at the crest or parallel to en echelon on the limbs of the upwarps extending on either side. It is important to note that main rift is due to lagging behind of the central block during general uplift of the area and that along other fractures accompanying the limbs subsidiary rifts and horsts get developed as a result of a series of overlapping step faults. All these fractures would show an orientation parallel to the uplift. Subsequent fractures. unrelated to the initial upwarp may result from subsurface and surface adjustments due to sliding and movement of magma. These trend parallal transverse or oblique to the tension cracks. Isostatic adjustment of the subsided crustal block is liable to give rise to further set of fractures and faults.

An outcome of the relief of pressure would also be in the partial melting of the rocks at depths. Such a melting would induce the flow of volaties and magma to areas of low pressures in the subcrust or at the surface, therefore, giving rise to intrusive and extrusive types of volcanism. The type of magma generated would be governed by the thermodynamic conditions, and inside the magma chamber which contain the molten upper mantle material there will be a tendency to adapt itself compositionally under the existing condition. Field evidences indicate that the magma thus generated is either tholeiitic or alakaline olivine types. The same area, therefore, can witness either or mixed type of volcanism.

From the position of the upwarp it is clear that the initial fractures and fissures which extend from the tectonosphere to the surface of the upwarp provide an easier channel for the transfer of material when they are *inclined* rather than *vertical*. In the latter case they would be met with greater resistance to upward movement. This view upholds Florensov's suggestion that bounding rift faults do not form the main conduites for lava flows and that fissures in the basement rocks are the major channels for the same. This also explains the field association of the intrusive comagmatic phases as dykes within or in the vicinity of the uplift areas and the general absence of extrusives in some of the rifted structures. The extrusion of magas more often through fractures and fissures accompanying the arched limbs cause large scale spreading of volcanics on the surface. Repeated extrusion in the different stages of crustal warping or episodic revival of activity produce huge sequences of lava flows thereby burrying the surface evidences of the presence of rifts and other fractures.

Erruptive centres are often seen confined to just within the rift zone or are met with at some distance away from it. Their genetical relationship to the rift however is irrefutable. They are younger to the main event of trappean volcanism. The concentration of erruptive centres especially, of the alkaline type appear to be related to either the junction of two rifts, or to a rift with a fault which would facilitate easier movements for magma from depths. Such areas are often represented by domed up volcanic cones signifying forceful injection.

The sequence of events for the development of eruptive centres seems to be : (i) initial upwarping of the crust and the extrusion of plateau basalts through fissures and fractures, (ii) formation of rift structures above the crest of the uplift, (iii) development of later fractures either parallel, oblique or transverse to the median rift, and (iv) coming into existence of intersecting fracture zones thereby facilitating upward migration of magma along them.

The eruptive centre developed by the mechanism stated above would be regions of volcanism where the generated magma would produce various differentiates and derivatives. The tholeiitic magma gives rise to acid differentiates while alkaline olivine magma forms the basic differentiates such as nepheline syenites, oceanites, and ankaramites. This also explains the appearance of andesitic or trachytic types during the later stages of basaltic volcanism in rift zones as pointed out by Florensov et al (1968).

Alkaline Eruptive Centres

Within the trappean province the presence of Alkaline eruptive centres show a concentration mainly along latitude 20°N between longitude 74° to 75°E. This needs explaination. It is envisaged that the Eastern Aravallis take a bend towards south in the vicinity of Panchmahals (Krishnan 1966) and then further join the E-W Satpura trend. The trend of eruptive centres is close to this postulated bend to the Aravalli strike. Movements involving frequent uplift have affected this region as is evident from the exposed cores of carbonatites. There is every possibility therefore, that the eruptive centres occur at the junction of Satpura rift being intersecied by Aravalli orogenic belt.

Working on the principle that alkaline eruptive centres are often concentrated at junction of two rift zones it is suggested that discovery of similar centres of eruptive rocks is not unlikely towards the western extremity of Satpura rift, especially in the vicinity of of Daman, Surat and parts of Baroda district.

To explain the alkaline eruptive centres of Kathiawar, it is felt that the possible deep seated intersecting system of fractures due to the Satpura and the West Coast rift as well as the presence of splayed Aravallis helped in easier movement of magma, the accompanying vertical uplift and doming achiveing a significant magnitude.

Satpura Rift

Sengupta (1967) suggested that the area between the Narmada and Tapti be mentioned as "Satpura Uplift" in view of the structural control exerted by the Satpura orogenic trend, upwarping of which has perhaps led to rift-formations. Satpura trend is seen to have E–W to nearly ENE–WSW direction. Between Narmada and Tapti it is made up of Deccan traps. The trend coutinues through Mahadeva Hills, Maikal range, Manipal hill and north of Chota Nagpur to Rajmahal hills which also occupy elevated regions. Further east the trend merges into the Garo hills in western Shillong plateau.

The Satpura rift, with the Narbada trough at its western end and Rajmahal and Sylhet at its eastern extremity is characterised by continued presence of extrusive igneous rocks all along its trend. Pre-Cambrians exposed within this belt strike parallel to Satpura orogenic trend and although several orogenic cycles are considered to be involved, granite-gneisses, ultra basic rocks, granophyres and soda granites also trend the same.

Towards west the Deccan traps are confined to a belt 70 kms wide and 700 kms long. Its external boundaries are occupied by the Narbada and Tapti troughs. The trough continues eastwards as Son-trough having nearly ENE–WSW trend. In this zone intrusives belong to Deccan trap age. Further east along the Damodar trough the Gondwanas have been intruded by igneous rocks of either Rajmahal or Deccan Trap age. These intrusive occurring as dykes or sills generally follow straight corurses and are controlled by fractures in the basement rock (Krishnan 1952).

There are certain evidences of laterites which suggest a much wider distribution for Deccan traps. Lateritic and bauxitic cappings of Lohardaga, Ranchi district, may mark the former extension of Deccan traps (Krishnan 1960). Ahmed (1962) has mentioned laterite cappings to the east of Shahabad. These are believed to be altered traps, thereby confirming their extension along the Son trough.

The above indicates that the Satpura rift seems to have witnessed activity not only confined within the Narbada–Son troughs as observed, but with extensions in adjacent areas and comagmatic intrusions upto Rajmahal and Sylhet region.

West Cost Rift

The Deccan trap activity covering major portions of Maharashtra is considered to be associated with the West Coast rift extending from Cambay to Ratnagiri. As stated earlier this zone is characterised by volcanic lineaments and fractures trending N–S. Hot springs also follows this alignment. Volcanic rocks of Deccan trap type are also exposed at St. Mary's island and Laccadiv group of islands off the coast of Mysore. This suggests a possible extension of rift further south of Ratnagiri extending upto Laccadiv islands.

The ancient land mass of Peninsula extended upto Laccadives, and strikes of Kerala and Laccadive rocks are similar, the crust between the Laccadives and India being mainly continental in character. The intervening area which is supposed to have existed as a Dharwarian ridge suffered intensive subsidence along meridional fractures during Paleogene and Neogene times thus giving to it the present appearance of an intra-crationic graben shaped northernly plunging basin (Eremanko 1967). It is suggested that this subsidence may have been associated with crustal unwarping, followed by wide spread volcanism similar to that of other rifts. Elevation of Western Ghats and Mysore plateau could be the aftermath of such a subsidence. This also conforms with Sengupta's suggestion of a "basinal depression and the presence of an uplift near the axial part" in the Cambay associated with horsts in the trap and the system of fractures within the trap which probably extends upto Laccadive Minocoy islands, the zone of positive gravity anamoly also showing a significant correspondence to this.

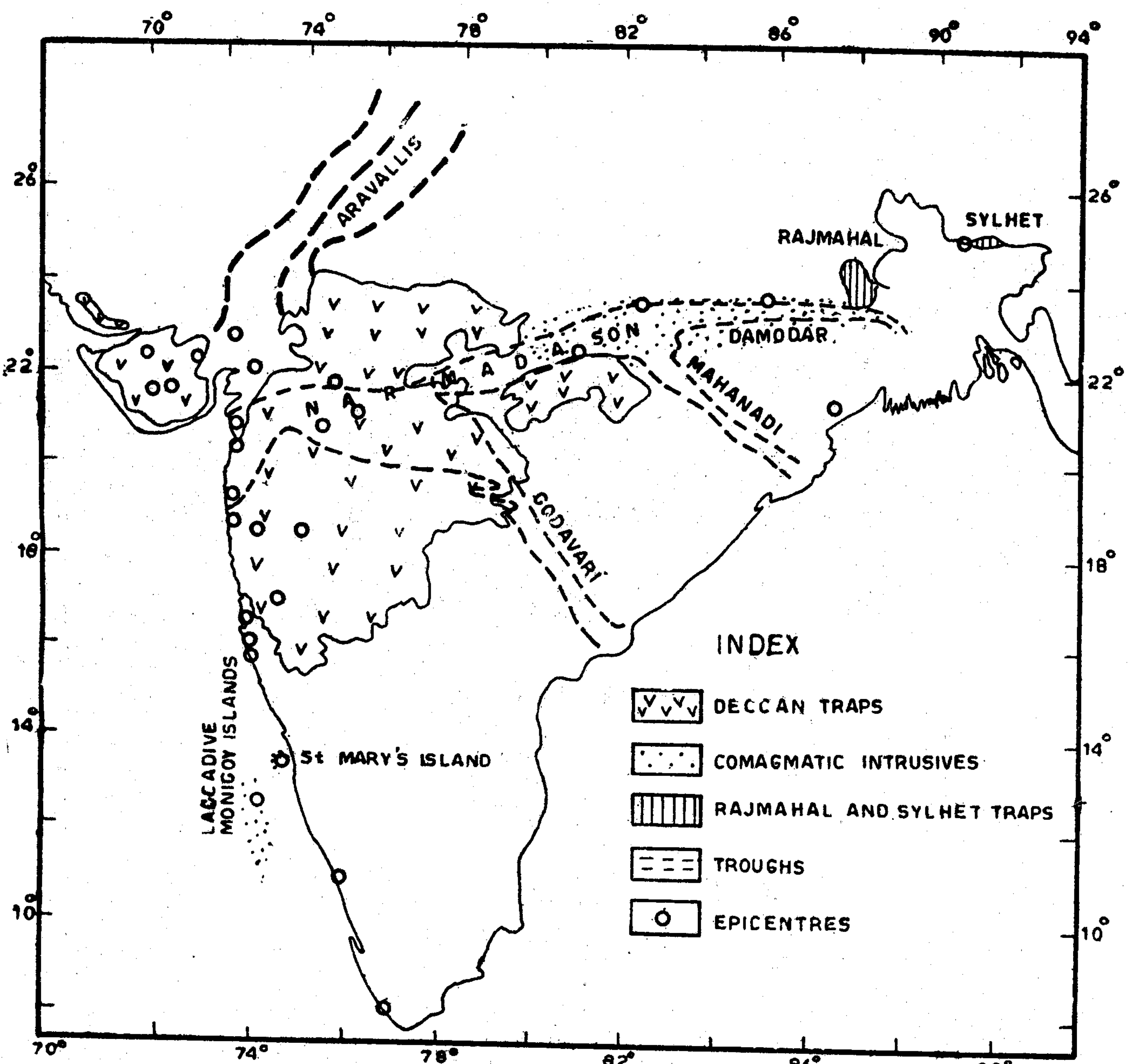
Seismicity of Rift Systems

The rift structure as mentioned above is closely connected with the Upper Mantle, its axis representing a deep lineament. The various orogenic, tectonic and thermodynamic processes acting at depth along such lineaments build up strain energy, release of which is responsible for the seismic activity observed along them (Beloussov 1968). It is now believed that the entire rift zone is not seismically active and that concentration of earthquake activity occurs either along bounding rift faults or wherever a rift intsects another rift, fault or other tectonic or volcanic lineament (Sutton in Tipnis and Srivastava 1968). In the latter case a marked increase in seismicity is noticed and absence of transverse lineament is attributed as the main cause for lesser seismic activity.

It is seen that along the main rift there is generally a tendency for dip slip movements for adjustment of stresses while transverse fracture zones show a predominence of strike slip movement. The earthquakes resulting from latter possess higher magnitudes. This may be due to the fact that dip slip movement under go relaxations due to isostatic adjustment prohibiting the accumulation of strain energy, while strike slip movements are indicative of lateral displacements involving considerable strain build up.

A plot of epicentres (Fig. 2) in the Peninsular shield reveals very clearly that the three areas showing occassional seismicity, namely West Coast Rift of Maharashtra the east-west trending Satpura Rift and Kathiawar region fall in the zones of crustal weakness.

Eruptive Centres and Seismicity :—It has been suggested earlier that presence of eruptive centre are indicative of a rift environment related also to probable zones of crustal



MAP SHOWING DECCAN TRAPS AND RELATED SEISMO-TECTONIC FEATURES

Fig. 2

weakness. Since the seismicity of a rift also obviates from movements along fractures at depths, a reasonable correlation ought to exist between epicentres and areas of central type of volcanic activity. Areas showing central type of volcanic activity are delineated and it is ascertained as to whether they have shown any seismic activity in the past. While doing so, however, a major handicap crops up namely in the lack of intimate knowledge about the Trappean province. Yet, on the basis of recent work (Sukheswala et al 1966, Agashe and Gupte 1966) along Narmada trough and western coast it would not be wrong to assume that cone type activity has a much wider distribution than what was once suspected for Kathiawar alone. The Kathiawar region is included in the seismic zone because of its nearness to the highly seismic belt of Kutch. It is felt, howerer, that even on the basis of geological evidence Kathiawar demands inclusion as an independent seismic belts. The past earthquake activity at Amreli, Paliyad and the very recent activity near Dhoraji and Jetpur can safely be correlated to this.

Epicentres along Satpura Rift : Satpura rift is made up of three troughs Narbada, Son and Damodar. The distribution of epicentres are such that the Narbada and Damodar troughs show greater seismccity as compared to the Son trough. The precise location of these epicentres can also be correlated to transverse or oblique lineaments intersecting E–W to ENE–WSW trending Satpura rift. This may possibly be the reason for increased seismicity noted at such junctions. The presence of earthquakes in Nimar province (22° N : 75° E) namely at Barwani, Satpura, Dhulia, Khandesh show a very significant correspondence with the eruptive centres possibly related to transverse Aravallis intersecting the Satpura rift. The earth tremors around lat. 24°N and long. 82°E can be related to the transverse Mahandi rift—with its northern extension cutting the northern bounding fault of Satpura rift. Satpura trend is regarded as a continuous belt extending upto Rajmhal hills. The presences of earthquakes around Hazaribagh, Manbhum and Damuda correspond to a possible bifuration of Damuda trough towards Rajmahal hills. This belt continues further into S W Shillong plateau which is the displaced part of the Rajmahal Plateau along the Dauki Tear fault. The Sylhet traps of Shillong plateau represent the displaced portion of Rajmahal traps. The active and youthful behaviour of this fault is evidenced in the high seismicity of the region around Sylhet.

Epicenters Along West Coast Rift : Many earthquakes of significant intensity have occured in this region, their epicentres generally aligned N–S, along a zone of crustal weakness which may be the bounding fault of the North–South oriented West Coast rift. A volcanic lineament trending N–S is seen paralleling it. The focal mechanism as revealed by detailed seismological study of the December 11, 1967, Koyna Eartquake shows that strike slip movement along a fault plane striking N 26°E and dipping at an angle of 66° towards north-west (Tandon and Chaudhary 1968) was probably responsible for this shock. If so, this could represent a fault oblique to the main rift along which higher seismicity is observed. The other epicentres in the region off-set from the general North–South alignment could also be lying along or at the intersection of other faults. Seismic activity at the junction of Narbada rift with postulated West Coast rift zone is another evidence of seismicity along transverse junction. This would incorporate the epicentres of Daman and Surat in south and Ahmedabad and Baroda in north. The presence of trans-current fractures similar to those observed at other places have not been reported from Western Ghats. However, a distinct off setting of the Ghat ridges is apparent over its entire length as seen even from topographical map of the area. It is possible that this displacement has resulted from transverse shear zones and could be the reason for concent-ration of most of the epicentres as well as eruptive centres along or on either side of the continental divide of Western Ghats. Fractures transverse to West Coast rift south of Ratnagiri are also likely to occur following the Burrard's hidden trough (Krishnan 1953) extending from Belgaum to Nellore through Bellary which also shows seismicity. Under these circumstances the coast between Vengurla and Devgarh is likely to be dissected by fractures, paralleling the hidden trough and lying transverse to the coast of that region. It it no wonder therefore, that the coastal region shows seismicity.

Conclusion

The geological observations on the rift systems situated over the continental crust having volcanism show the presence of lineaments of eruptive centres either parrallel or transverse to the main rift and vast lava flows erupted through fissures, fractures and volcanic cones. The volcanism is associated with dyke swarms, fractures and flexures having similar dispositions. Areal extent of such rifts overly areas which have undergone considerable crustal uplift whih subsidence along the crestal portions. These subsided blocks often show mild seimicity. Fortunately, Deccan traps of India show all these features. A rift environment for the volcanism of Deccan traps would explain the association of features such as volcanic vents and fissures, presence of tholeiitic and alkaline olivine magma types, their many derivative, and the parallelism between dykes, fractures and fissures. It would also explain the spread of volcanics to great areal extent on either side of the main soure of eruption by considering the extrusion through fractures and fissures which are connected to the magma chamber at great depths. These fractures and fissures may occur along the limbs of the upwarped crust and hence the lavas appear to have travelled large distances from the source. Any lack of evidence pointing to the presence of these fissures in such areas is probably due to younger lava flows burrying the features.

The seismicity of Deccan traps is very intimately related to their problem of tecto-genesis. Distribution of various epicentre in relation to the main rifts, indicates that movements along the junction of transverse or oblique lineaments and the bounding faults are probably the main cause for the marked seismicity. Such areas of crustal weakness are also expressed by the presence of eruptive centres. To test the validity of this it would be desirable to establish the existence of eruptive centres, median, transverse or oblique fracture zones, zones of subsidence and crustal upwarps in the seismically active parts of the Deccan trap regions.

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