INTERPRETATION OF FRACTURE PATTERNS IN THE PORPHYRITIC GRANITES OF TIRUMALAI HILL RANGE, A.P.

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The purpose of this paper is to focus attention on the differing fracture patterns that develop in rocks differing in texture, while essentially having the same mineral composition. The porphyritic granites of Tirumalai have joints oriented essentially in the north westerly direction, whereas in the coarse-grained granites they have diverse orientation. Dyke trends have similar divergences, those traversing the coarse-grained granites oriented E-W only, while those in the porphyritic granite have other trends also. Within the porphyritic granite, joint trend maxima coincide with the dyke trend minima. There has been some slipping along joint planes, as evidenced by mylonitisation and slickensiding and chloritisation of dolerite. It is concluded that porphyritic granite is a magmatic instrusive body in which fractures developed in response to E-W compressive stress and that the later epeirogenic earth movements that uprised the Cuddapah basin caused slips along the fracture planes to bring about dislocation metamorphism, slickensiding, and mylonitisation. Another significant point that emerges from this study is that granites with mesoscopic isotropic fabric are more prone to fracturing to form well-defined joints oriented in particular directions, whereas those vitiated by planar fabric and gneissic and xenolithic patches disfavour such well-defined and well-oriented pattern.

INTRODUCTION

SURYANARAYANA & ANJANAPPA (1975) have described the relationship and correlation between the 'joint patterns' and 'dyke trends' of Tirupati Area in Andhra Pradesh and the stress mechanism that caused their development. Fracture patterns in the coarse-grained granites have been described.

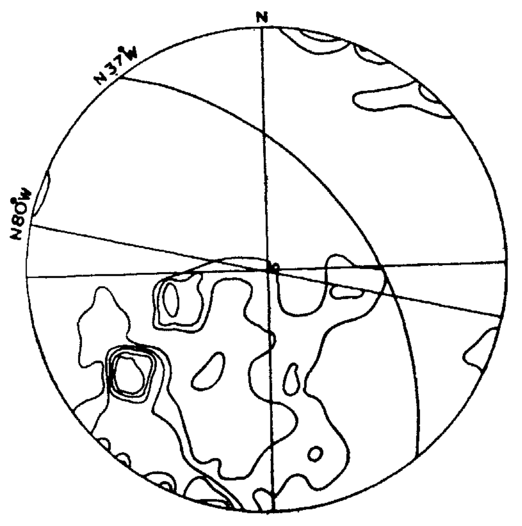
The survey of the granites underlying the Cuddapah quartzite and those exposed on the flanks of the Tirumalai Hill range north and northwest of Tirupati Township was undertaken for a similar study. Curiously enough these granites are of porphyritic type. The newly constructed second ghat road of Tirumalai rising westward from the foot Hills at Alipiri has exposed at various heights on the flanks of the hill the typical porphyritic granites. The porphyritic granite extends up to the top of the hill, as found at 16 km stone, and here the contact between porphyritic granite and dolerite on the one hand and the overlying quartzite on the other is clearly seen. The dolerite dykes that traverse these granites, the joint patterns developed in the granites, and zones of faulting indicated by brecciation, comminuted trap-shotten material, and slickensiding can be studied in all their details. Had it not been for this newly constructed second ghat road, much of the information that these rocks now reveal would have remained in obscurity, for the area is covered up by rock debris, soil, and vegetation to provide no scope for any investigation.

FRACTURE SYSTEMS

Notwithstanding the fact that the porphyritic granites have large phenocrysts of tabular feldspar and flaky mica, they exhibit no vectorial property. A mesoscopic isotropic fabric marked by the random orientation of feldspar and mica characterises the porphyritic granite. As contrasted with the absence of planar and linear fabric, joints are astoundingly well-developed in the porphyritic granites, as well as in the coarse grained granites of Tirupati area. The Chitaldrug granites of Karnataka which are porphyritic and which possess isotropic fabric are also well-jointed and compare well with the Tirupati-Tirumala granites. On the other hand, the Closepet granites and Chamundi granites of Karnataka, also porphyritic, exhibit planar structure characterised by the parallel orientation of their tabular minerals (Babu 1956; and Suryanarayana 1964) and have only longitudinal joints parallel to the planar structure. Others are exfoliation cracks of random development and of no tectonic significance.

Joints in the porphyritic granites are tightly closed, straight, highly planar, and often die out within short distances. Most joint surfaces are smooth and show slickensided surfaces. Generally, joints with east-west and north 70° west trends have slickensided surface. Often minor fracture cleavages spaced ½″ to 1″ apart branch off from east-west joints making an angle of 15° to 30° with the latter. Parallel to north 70° west joints occur a number of fracture cleavages. Crushing and mylonitisation are often seen along north 70° west joints. A black tachylitic material resembling a trap shotten has been produced by this mylonitisation. Fine crushed quartz and feldspar are found embedded in the tachylite.

Along the road cutting that meanders uphills, 700 joints were measured and their attitude is shown in Fig. 1, which is a joint diagram prepared by plotting the poles



CONTOURS 13·12·9·6·3·1% IN ONE PERCENT AREA

FIG. 1

TABLE I

Data on dykes along the new ghat road on Tirumalai Hills

Sl. No.	Distance from Alipiri (km)	Trend of the dyke	Thickness of the dyke (feet)	Effects of metamorphism
(1)	(2)	(3)	(4)	(5)
1.	1/6	N 60 W	5	Chloritised
2.	2/4–2/6	E—W	6	Chloritised
3.	2/6–2/8	N 70 E	4	Chloritised
4.	3/2–3/4	E—W	4	
5.	3/2–3/4	N 70 W	1½	
6.	3/2–3/4	N 75 W	20	
7.	3/2–3/4	N 60 W	2½	Chloritised
8.	3/2–3/4	N 45 W	6	
9.	3/4–3/6	N 50 W	300	Chloritised
10.	4/2	NW	1½	
11.	4/2–4/4	N 55 W	150	
12.	4/4–4/6	NS	10	Chloritised
13.	4/4–4/6	NS	2	
14.	4/4–4/6	N 30 W	200	Porphyritic
15.	4/8–5	N 65 E	20	Chloritised
16.	5/2–5/4	EW	15	
17.	5/2–5/4	NS	10	
18.	8–8/2	N 85 W	6	
19.	8/8–9	EW	8	
20.	8/8–8/9	EW	4	
21.	9	EW	½	
22.	9	N 50 W	40	
23.	9/2–9/2	EW	30	
24.	9/2–9/4	EW	30	
25.	9/8–10	N 40 E	30	
26.	9/8–10	N 83 W	80	
27.	10	N 85 E	2	
28.	10	N 68 W	15	Chloritised
29.	10	N 75 W	1½	
30.	10–10/2	N 70 W	80	
31.	10/2	EW	60	
32.	10/6–10/8	EW	5	
33.	11	EW	100	
34.	11/2	N 60 W	15	
35.	11/2–11/4	N 85 W	15	
36.	11/4	N 30 E	15	
37.	11/8	NS	100	
38.	11/8	NS	50	
39.	11/8	N 30 W	300	
40.	16	EW	100	

of joints on the lower hemisphere of the equal-area-net. Preferred orientation is the dominant note of the joints in the porphyritic granite. Majority of the joints have northwesterly trend with a dip towards northeast varying from 40° to 85°. The maximum in the diagram gives an average strike of N 37° W and a dip of 55° N E. There are a few low angle or flat-lying joints which fall into the category of sheet joints.

Joints in the coarse-grained granites of Tirupati have a diverse orientation and fall into several sets (Suryanarayana & Anjanappa 1975). Most of them have a steep dip. It is significant to note that the porphyritic granites, which the coarse-grained granites grade into, should have the only prominent set oriented N 37° W and that too with a lower angle of dip. Such marked divergences in the pattern of joint systems in a single geological rock unit is due to differences in lithology and texture.

The dolerite dykes that traverse the porphyritic granites show similar divergences in their trend from those that traverse the coarse grained granites. Table I shows the strike of every dyke exposed along the ghat road.

Joint and dyke trends are summarised in the rose diagram (Fig. 2). For the purpose of the diagram, the frequency of joints and dykes at 10° strike interval was used.

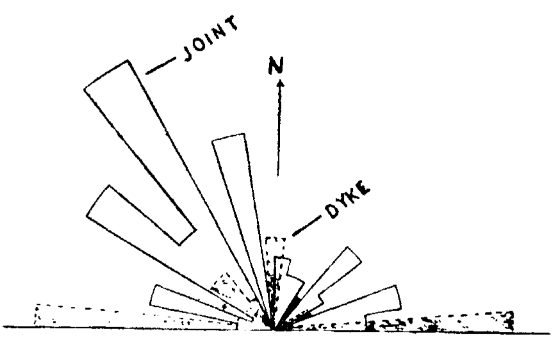


FIG. 2.

for joint, 1 cm = 2% joints

for dyke, 1 cm = 2 dykes

Joints show a well-defined maximum at N 30–40° W; but many trend N 10–20° W. The submaxima at N 45° E and N 75° E indicate the presence of north easterly joints of no little significance. In total, north westerly joints are the dominant ones.

The dykes have a prominent east-west trending maximum. There are also dykes with N–S and north westerly trend and a few north easterly too.

What is striking in the rose diagram is that there is no coincidence of joint and dyke trends; the maxima of one are the minima of the other, and, as such, one does not seem to exercise any control over the other.

INTERPRETATION OF DATA

It will be worthwhile to compare the joint and dyke trends in porphyritic granites of Tirumalai with those in the coarse-grained granites of Tirupati. All the dykes of Tirupati have an E–W trend. The rest are totally absent. This stands in contrast with the E–W, N W, N–S, and N E dyke trends in Tirumalai. Similarly, the dominantly northwest trending joints in the porphyritic granites of Tirumalai stand in contrast with joints of diverse orientations in the coarse-grained granites of Tirupati. These contra-indications i.e., the preferred orientation of joints and randomness of dykes of one area(Tirumalai) standing in contrast with the randomness of joints and preferred orientations of dykes in the other(Tirupati) are the conspicuous features of Tirumalai-Tirupati area. The fracture patterns of the two areas are thus entirely different.

Anderson (1951) draws the relationship between the joint and dyke pattern and the stress direction and states that the greatest stress, σ_1, is parallel to the tension fractures and that shear joints develop diagonal to σ_1. His inferences were applied in discussing the origin of fracture pattern in the Tirupati area, in accordance with which an E–W compressive stress was visualised based on E–W trending dykes which are nothing but tension fractures filled by dykes. Since the majority of dykes of Tirumalai area also have an E–W trend, a similar stress drection can be visualised. The northwesterly dykes of less frequency and the dominantly northwest trending joints have originated as a result of stress acting in the same E–W direction. They represent shear fractures that develop at more or less 45° to the direction of maximum compression (σ_1). There are joints with sub-maxima at N 45° E and N 75° E and dykes at N 35° E and N 65° E. This suggests that northeast trending fractures are not wanting, though less frequent. The northeast trending fractures similarly represent another set of shear fractures, that have developed diagonal to σ_1. The differing fracture pattern in the two areas is due to the difference in the lithology, texture, and structure of the rocks and as such, they differ in physical properties; and rocks of different physical properties have different susceptibilities to fracture (Chapman & Wingard 1958; De Sitter 1964; and Firman 1960). The coarse-grained granite of Tirupati with patches of gneisses has different susceptibilities from the porphyritic granite of Tirumalai. At the same time the boundary between the porphyritic granite and the coarse-grained granite marks a local irregularity which results in non-uniform stress being developed and in complex distribution of stress in space (Beloussov 1962). It may even become necessary to determine the position of the principal axes for each infinitesimal part of the rock individually, as one could postulate from the inequigranular texture of the porphyritic granite, and calculate the changes in the position of these axes during the course of deformation and also assess the additional stresses that arise in the rocks. All these postulates hold good in very many cases, and, truly as applied to Tirumalai-Tirupati area, the main E–W stress has not only generated a number of additional stress, but each stress appears to have acted in different directions. These diverse stress directions are apparent in Tirupati area, but as applied to porphyritic granites of Tirumalai the E–W compressive stress has generated shearing stresses oriented mainly northwesterly. Northeast shear fractures of less frequency have also developed. The northwesterly joints are of the nature of faults, because they are more planar with rock debris formed by crushing and mylonitisation smeared out into slickensides.

Another notable feature of these joints is that none of them has the nature of extension fractures. The surface of extension fractures (tension fractures) is usually broken by minute bumps and depressions. These features are conspicuous by their absence in any joint investigated in the area. The only tension fractures we can think of are the dyke filled ones having E–W and N–S trends formed respectively by E–W compressive stress and the elastic release of the compressive stress in the E–W direction. All the other joints, planar, more tightly closed and slickensided, are shear fractures or faults. The friction produced in the sliding creates several centres of strain and breaks the rock in a number of fractures. Such an effect is seen associated with shear joints in the area where, between two parallel joints of just a foot apart, closely spaced joints, less than ½" apart parallel the main joint to form fracture cleavages.

While the evidences in all cases favour the existence of shear fractures, only some of the dykes oriented N E and N W indicate the existence of tension joints parallel to the shear fractures. This suggests the possibility of some shear fractures having been opened up as tension joints by later earth-movements to be filled up by basic magma to form dykes. It then rises doubts as to whether a correct distinction can be made between extension and shear fractures. Experimental investigations made have impelled Brace (1964) to draw the conclusion that faulting and extension fracturing may not be two discrete types of fracturing in rocks, as is widely believed, but may be simply members of a continuous series. Muehlburger (1961), after analysing the diagonal fractures with small dihedral angles, concludes that there is a continuous spectrum between tensional and shear failures.

There are evidences in the area that the cracks have been repeatedly reopened as a result of several consecutive earth movements. Table I shows that some of the dykes have been metamorphosed to chlorite schist. Metamorphism has been effected by slip along dyke-granite contact and sometimes along the median line within the dyke. In either case, the product of this dislocation metamorphism is a chlorite schist, the schistose plane making an angle of 30° with the slip plane. Chloritisation of dolerite is also noticed in Tirupati area and a pointed reference to it is made by Suryanarayana and Anjanappa (1975).

Only a few dykes have been affected by this dislocation metamorphism. It does not follow from this that chloritised dolerites are older than the unmetamorphosed ones. Only those dolerites which are the loci of slippage under the impact of later stresses have been affected by dislocation metamorphism. The effect is not confined to dykes of any particular trend, for, as would be known from Table I, dykes of any trend have been metamorphosed. Another effect of this slippage has been the generation of closely-spaced fracture cleavages and the formation of slickensides which are again not confined to any particular joint trend.

Conclusions

It is reasonable to suppose from these observations that the porphyritic granite came up as a magmatic intrusive body in the last stages of igneous activity to form a non-migmatitic super-structure. Absence of any gneissic and basic xenolithic patches lends proof to this interpretation. It is difficult to know whether the joints were due to internal fracturing, a process depending solely on the property of the rock; but later regional stresses appear ot have played a dominant role in developing the fracture patterns as now seen in them. Regional east-west stress created fractures in them and the later epeirogenic earth movements responsible for the uprise of the Cuddapah basin must have generated additional strains that were relieved in the form of slips along the fracture planes of the porphyritic granite.

Another significant factor that emerges from this study is that granites with mesoscopic isotropic fabric are more prone to fracturing to form well-defined joints oriented in particular directions, whereas those vitiated by planar fabric and gneissic and xenolithic patches, as the Closepet and Chamundi granites, disfavour such well-defined and well-oriented pattern, for the stresses operating on them get complexly redistributed along local irregularities in different directions, each nullifying the effect of the other that in the end no fracture ever develops, except that the one parallel to the planar fabric gets emphasised to form more open longitudinal joints.

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