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Preliminary study on Tectonic strain pattern of Granites around Palayamkottai of Tirunelveli district, South India

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Abstract

Fry analysis is used to delineate the tectonic finite starin pattern recorded in the granites of Palayamkottai region of Tirunelveli district. From the oriented samples of 10 locations around Palayamkottai, a complex finite strain pattern of constriction-plane and flattening strains from the granites have been estimated. Subhorizontal and subvertical lineations are recorded from granite exposures in the field. The above features suggest that the granites were emplaced during a transpressive tectonic Achankovil shearing of Pan-African time.

Keywords: Granites, Fry method, Tectonic strain, South India, Achankovil shear zone.

Introduction

Strain is a change in the relative configuration of the particle in an element of body. Any quantitative strain analysis involves a well-define aim of the work that leads to the choice of techniques. Classical study of deformed ooids by Cloos[1] has demonstrated that strain variations are systematically related to the position of samples in large-scale folds of the Appalachian. He outlined many field and laboratory procedures for carrying out strain analysis. The first significant contributions to these problems were made by Ramsay[2] who devised graphical method (Rf/Φ) diagram) to determine the strain ellipse on a plane section from deformed, elliptical objects. He outlined more practical methods of strain analysis such as centre to centre method. Dunnet[3] refined Ramsay's Rf/Φ methods and produced curves for finding out the finite strain in many rocks with initial random fabric. Fry[4] refined center-to-center technique of Ramsay and offered a very practical and simple method for many types of analytical problems posed by the redistribution of objects and grains in rocks as a result of strain. In recent years, finite strain analysis has become an integral part of tectonic studies. The present study attempts to delineate the finite strain pattern of granites exposed around Palayamkottai and adjoinig Vallanadu area which falls across the Achankovil Shear Zone of South India (figure 1).

The geology of the area mainly comprises of khondalitic pelitic gneisses and charnockites of Amphibolite to granulite grade metamorphic terrain. Calc-silicate rocks, quartzites, cordierite gneisses intercalations are common in pelitic gneisses and charnockites. The youngest group of the area is represented by the grey granites and pink granites. The grey granite occurs as a band at North of Vallanadu and KTC Nagar of Palayamkottai. A pink granite band is also encountered at Meenachipatti. The veins and bands of granites are commonly intruded the pelitic gneisses and charnockites (figure 2).

Tectonic features: The major tectonic features include foliation, lineation joints, shear and folds. The general strike of foliation displayed by the rocks of the area is mostly from NW to SE and the amount of dip various from 25 to 80 towards southwest. At fold hinges the Khondalites show foliation striking either N-S with Easterly dip or E-W northerly dip. Usually the linear element is suggested by the orientation of minerals. In the earlier gneisses of study area, spangles of biotite and sillimanite needles display lineations. In charnockites, the lineation is developed due to the oriented laths of feldspar and hypersthene. The mineral lineation of subhorizontal plunging either NW or SE are common. At places horizontal lineation and subvertical are also observed in the field. The well-banded precursor gneissic banding of the area display minor folds and crenulations. Intra-folial isoclinal folds of gneissic banding are common, although their hinges do not define a simple systematic orientation and probably reflect near plastic deformation. Quartzite veins of the axial plane of the folds of tight and open types and the strike of the axial plane of the folds varies from N-S to SW-NE. The quartzite hillocks of Vallanadu show a moderately and northwesterly plunging overturned anticline, isoclinal fold.

The area is a part of Achankovil shear zone of sinistral nature. The later NW-SE sinistral Achankovil shears are found overprinted on the earlier shear system. The gneisses exhibits an earlier system of NW – SE dextral conjugating with NE-SW sinistral shears. At places, strike slip (1 cm to 200 cm) and oblique slips (1cm to 60 cm) are also observed along sinistral Achankovil shears (figure 4 and 5). The area is mainly traversed by strike joints running parallel to NW-SE and dipping steeply towards SW and is well developed in all rock units. Steep N-S joints dipping E and NE-SW joints dipping NW variably are the other master joints observed.

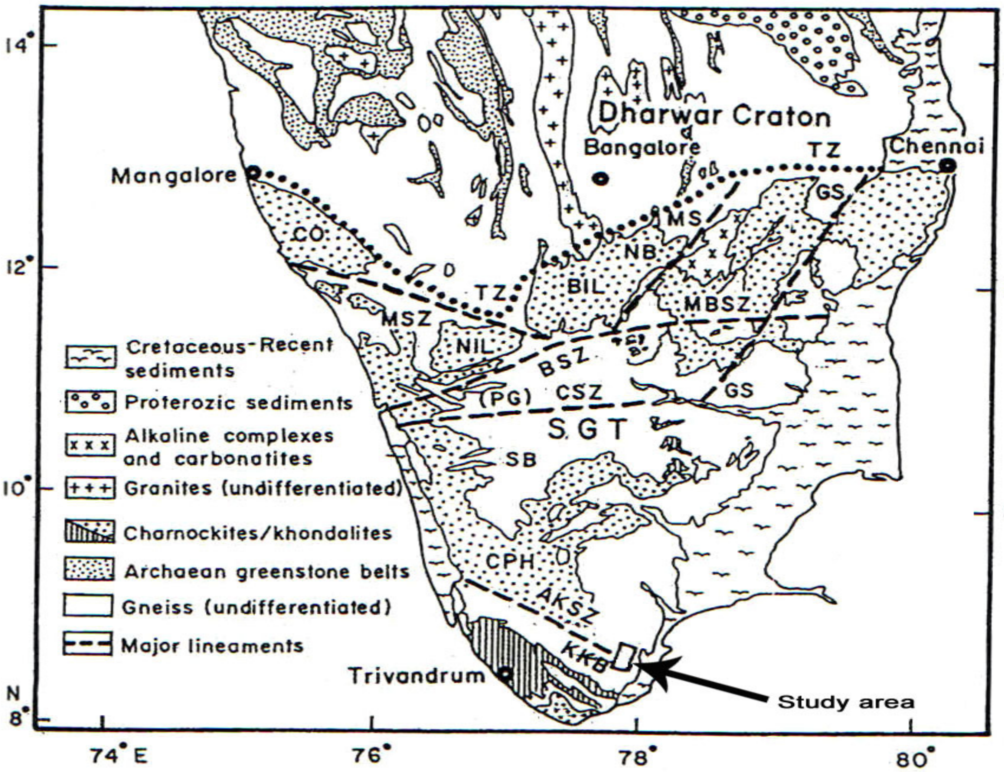

Figure-1
Generalised geological map of South India

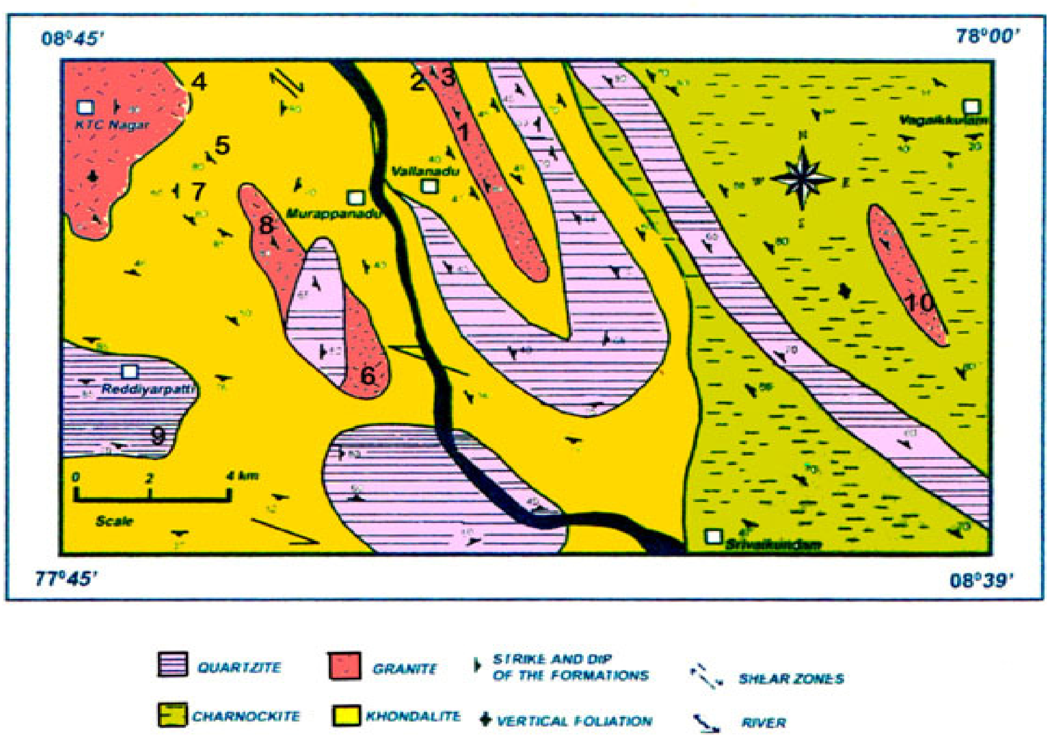

Figure-2
Geological map of palayamkottai area shows the locations for Fry analysis

Figure-3
Grey granite showing subvertical biotite lineation plunging 80° SE and subhorizontal biotite lineation plunging 20° NE. X pattern shear joints are seen, location – Vallanadu

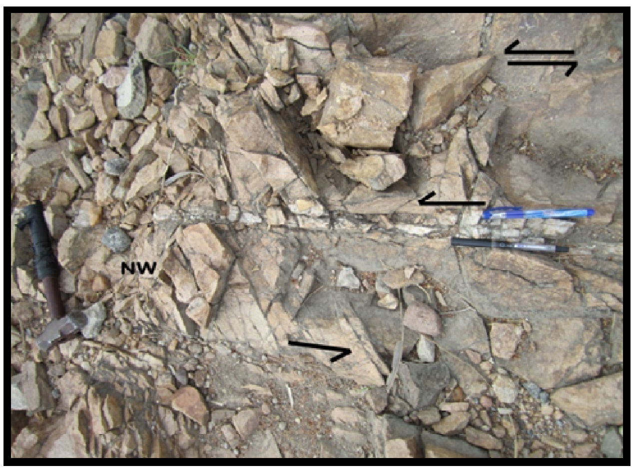

Figure-4
Highly sinistrally sheared pink granite along NW-SE direction showing boudinaged granite at Meenakshipatti near Vagaikulam

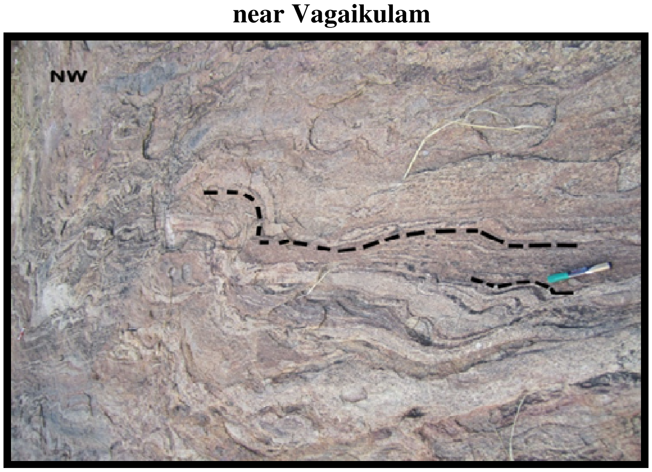

Figure-5
Cordierite gneiss at Paraikulam showing NW-SE sinistral and also NW-SE dextral shears

Fry method: This method is based upon the principle that the centers of the particles are mutually independent in the undeformed state and possess a non-poisson distribution. In such state there can be no possibility of strain measurement. Let us consider, in the undeformed state, a two dimensional sample having close packing of equal radius. The distance between neighbouring centers cannot get closer than twice the particle radius (2r). For each particle centers there will be six near neighbours at a distance 2r. The surrounding particles are situated at a distance of 2√3r, the pattern of neighbour continues with six centers situated at a distance of 4r from the first chosen (figures 6a and 6b). The type of packing, therefore, set up certain characteristic distance of the centers of neighbouring particles from any chosen particle. In the deformed state, the distance between particle centers are modified in the direction of clustering or anti clustering depending upon the value of longitudinal strains along that direction i.e., proportion to the diameter of strain ellipse. This strain geometry can be used to establish the shape and orientation of ellipse.

The rock strain must be homogeneous over a planar sample and big enough to contain large number of particles and of not high strain value. Fry[4] suggested manual plotting procedure for this method. On the tracing paper, centres of each object are located within a reference grid. On another transparent overlay, a centers reference point is plotted and placed over one of the centers of objects. The positions of all other center points are transferred on the overlay with the grid as the reference azimuth. This procedure is repeated for all the centers of objects till all points on the sheet have been used as centers on the second. The resulting plot on the second sheet has an ellipticity of the strain ratio and orientation as the strain ellipse around the center reference point.

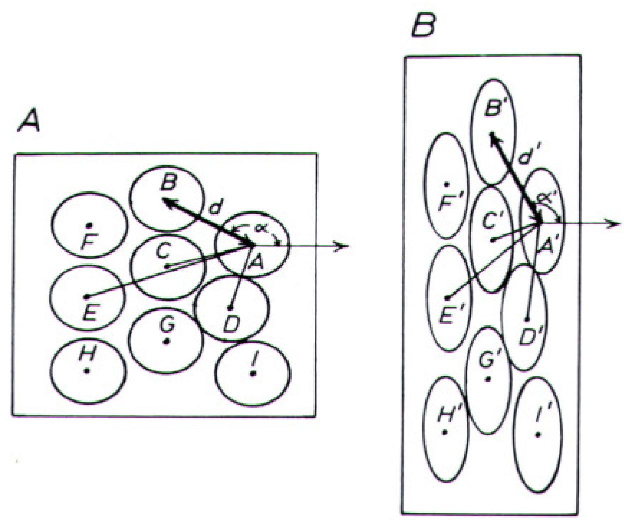

Figure-6 a
Diagram showing how the distance between grains centers change with direction when strain develops (A) Unstrained grains (B) Strained grains[5]

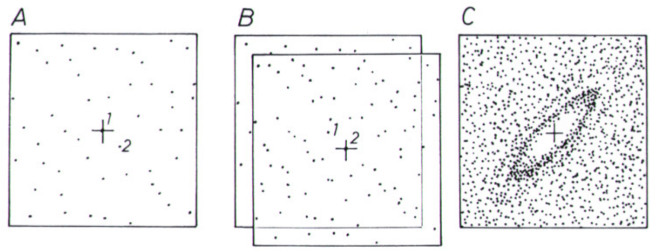

Figure-6 b
Construction of Fry plots (A) The position of an overlay centered on point 1 with all other points located relative to point 1 (B) The overlay centered over point 2 and all points located relative to point 2 (C) The final diagram once every point has been used as the center for the overlay. The central void defines the shape and orientation of the strain ellipse[5]

Methodology

The quartz grains of graintes are stretched out along the prominent stretching lineations as elongated lenses and ribbons in the exposures. Since the strongly linear the X direction of the strain ellipsoid[5], the X direction is taken as parallel to the stretching lineation(X>=Y>=Z). Strain data by Fry method on three mutually perpendicular principal planes are determined and the three dimensional principal strain'K' are calculated. The fry method are attempted on XY plane (A-section, granite rock surface parallel to X direction ie.streching lineation direction) YZ plane (B-Section, granite surface parallel to Z direction ie. right angle to the X and Z directions) and C section (XZ plane) perpendicular to X and Y directions.

Big oriented samples are collected from each location. North and stretching lineation directions [x-direction] are marked on the sample in the field. XY, YZ and XZ planes are marked with marker pen and from each plane quartz grains more than 75 grains associated with feldspars are chosen. For each grain the centre is marked at the junction of maximum long axis and maximum short axis at right angle to it. Along the Achankovil shear zone around Vallanadu area 10 locations are selected for Fry method of strain analysis (figure 2). XY, YZ and XZ planes are photographed from half feet vertical height uniformly.

The photographed each plane is developed to uniform size of 8cm x 6cm magnifications. Long axis, short axis (in mm) and angle orientation of long axis with reference to X- direction of stretching lineation / Y-direction are measured from the photographs. And centres are marked for each grain. And procedure for Fry method are followed and finally two dimensional, finite strain ratio are calculated from the strain ellipse derived from the centre ellipsoidal void space recorded from the each plot. The figure 7-a shows randomly picked quartz grains from YZ section from Vembadi SasthaKovil location. The figure 7-b shows long axis and short axis and centre of the grain, reference line and orientation of long axis (Y). The figures 7- c, d, e shows various steps of Fry method in finite strain estimation. Figures 8-a, b and c to 17.a, b and c show the estimated two dimensional finite strains for XY, YZ and XZ sections of each location from 1 to 10.

Figure-7 a
YZ principal plane of coarse grained granite, location - Vembadi Sasthakovil

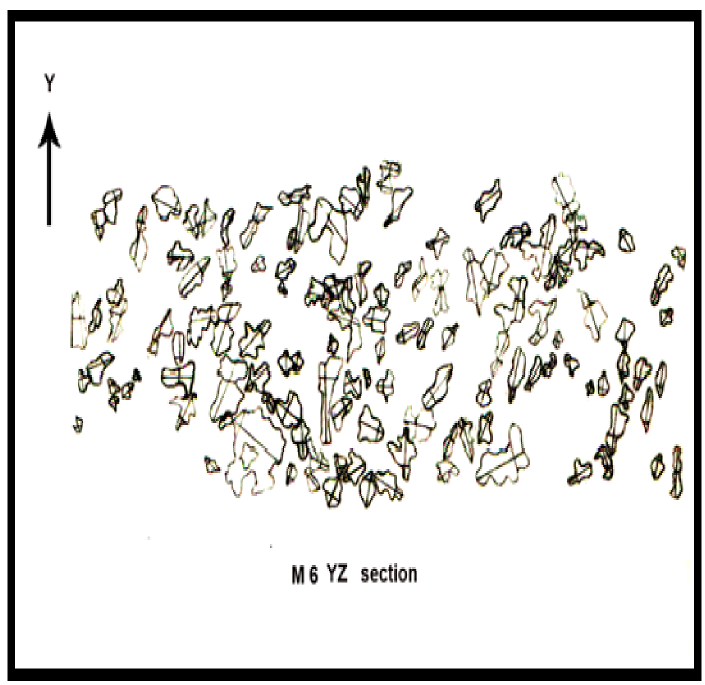

Figure-7b
Maximum long axis and maximum short axis of quartz grains from YZ section, location – Vembadi Sasthakovil

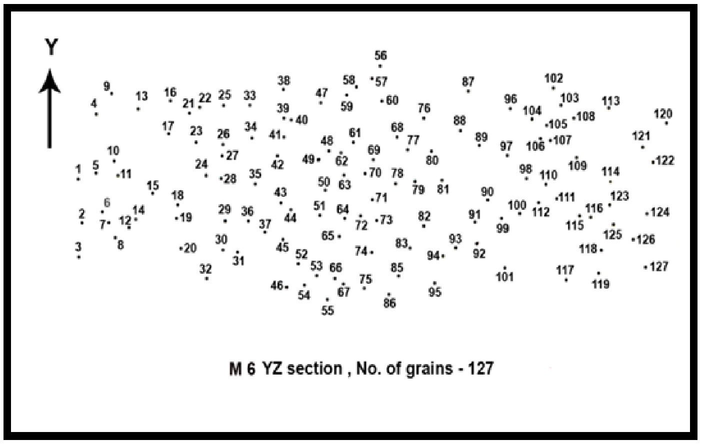

Figure-7c
M6 YZ section, No. of grains-127

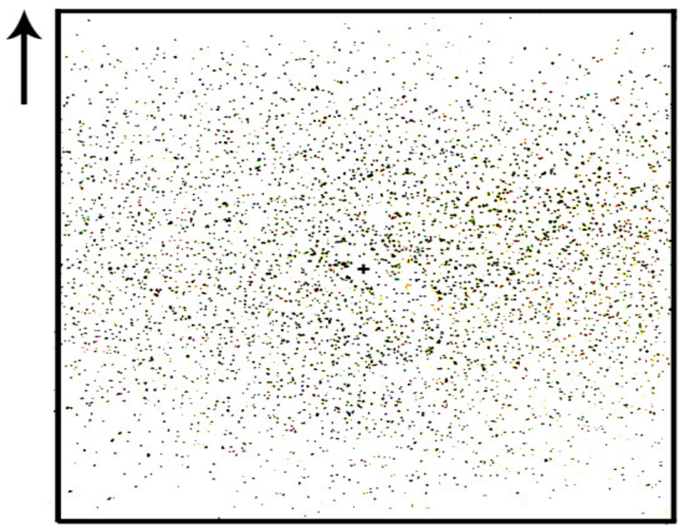

Figure-7d
M6 YZ section, No. of grains - 127

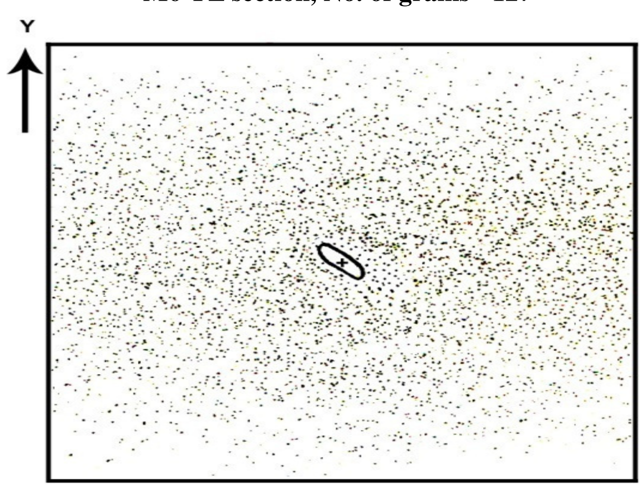

Figure-7e
M6 YZ section, No. of grains - 127

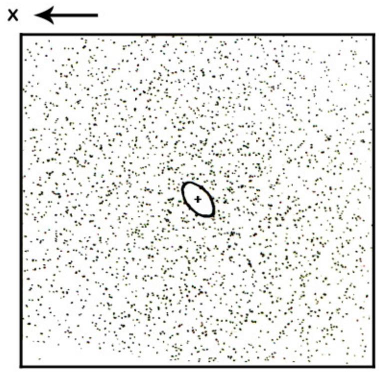

Figure 8 a
M 1 section, No. of grains -85 Location - VALLANADU

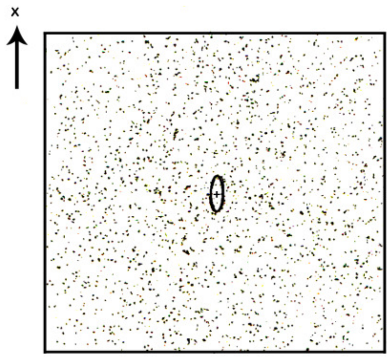

Figure 8 b
M 1 section, No. of grains -86 Location – VALLANADU

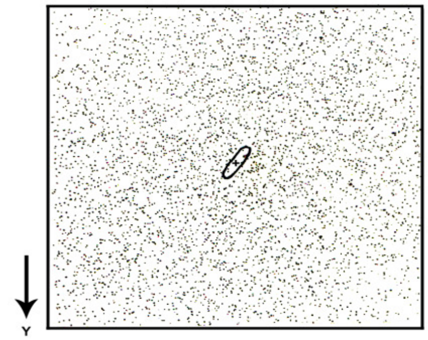

Figure 8 c
M 1 section, No. of grains -109 Location - VALLANADU

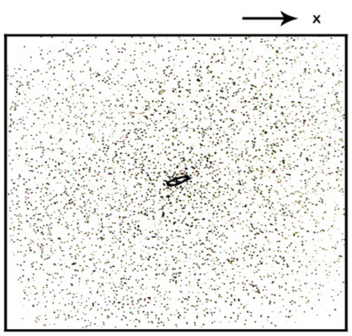

Figure 9 a
M 2 section, No. of grains -129
Location – North of Vallanadu

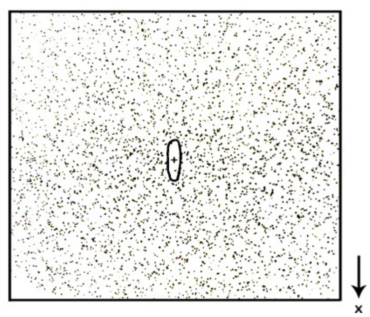

Figure 9 b
M 2 section, No. of grains -113
Location – North of Vallanadu

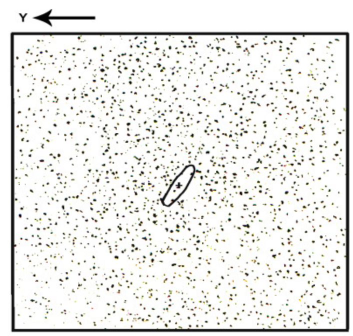

Figure 9 c
M 2 section, No. of grains -97
Location – North of Vallanadu

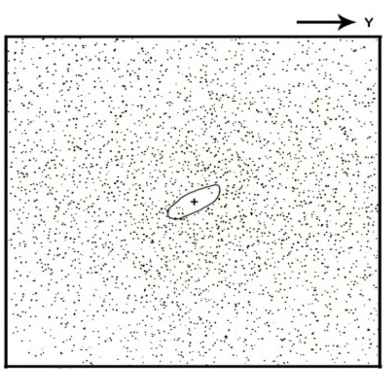

Figure 10 a
M 3 XY section, No. of grains -100
Location – 4 Km NNE of Vallanadu

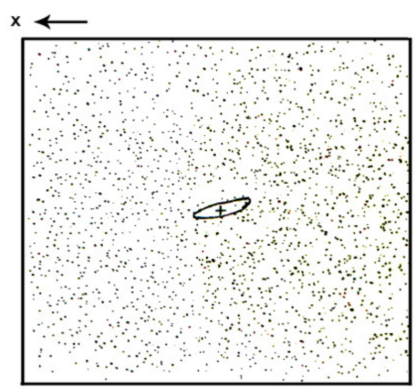

Figure 10 b
M 3 XZ section, No. of grains -82
Location – 4 Km NNE of Vallanadu

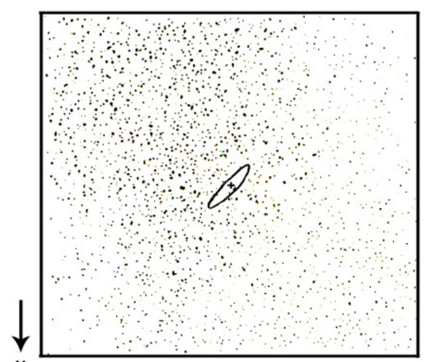

Figure 10 c
M 3 YZ section, No. of grains - 91
Location – 4 Km NNE of Vallanadu

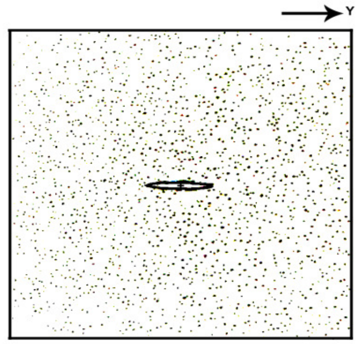

figure 11 a
M4 XY section, No. of grains – 86
Location – Parkitma Nagaram

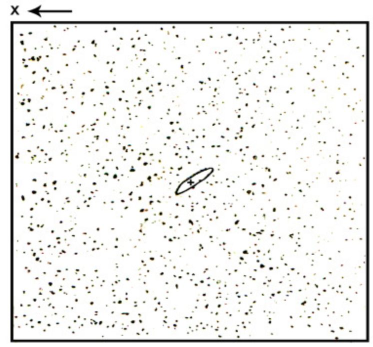

figure 11 b
M4 XZ section, No. of grains – 71
Location – Parkitma Nagaram

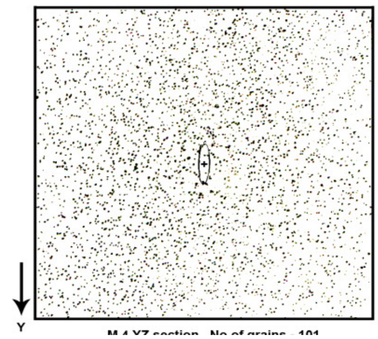

figure 11 c
M4 YZ section, No. of grains – 101
Location – Parkitma Nagaram

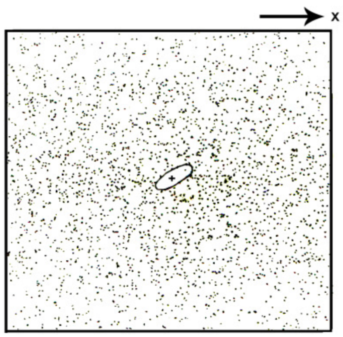

figure 12 a
M5 XY section, No. of grains – 70
Location – Ariyakulam

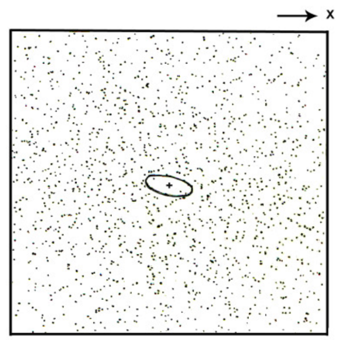

figure 12 b
M5 XZ section, No. of grains – 58
Location – Ariyakulam

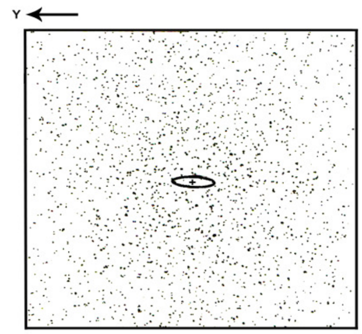

figure 12 c
M5 YZ section, No. of grains – 70
Location – Ariyakulam

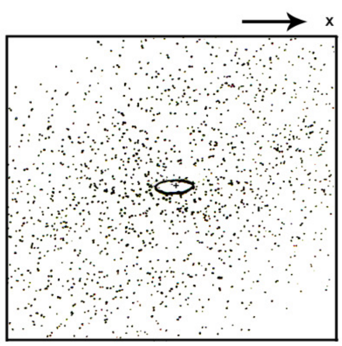

figure 13 a
M6 XY section, No. of grains – 56
Location – Vembadi Sasthakovil

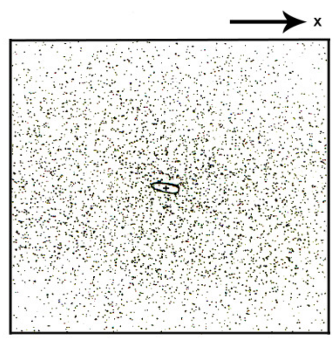

figure 13 b
M6 XZ section, No. of grains – 76
Location – Vembadi Sasthakovil

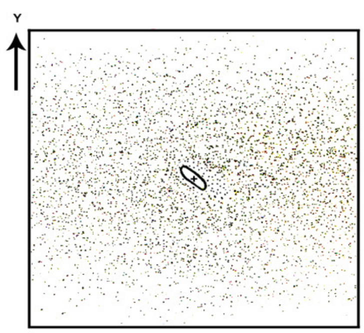

figure 13 c
M6 YZ section, No. of grains – 127
Location – Vembadi Sasthakovil

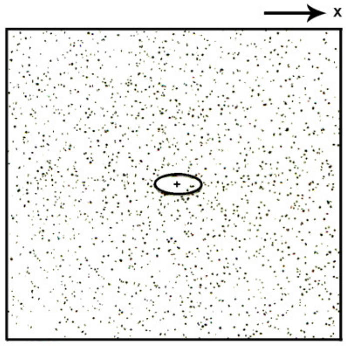

figure 14 a
M7 XY section, No. of grains – 71
Location – Paraikulam

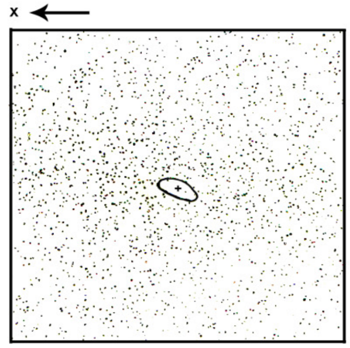

figure 14 b
M7 XZ section, No. of grains – 79
Location – Paraikulam

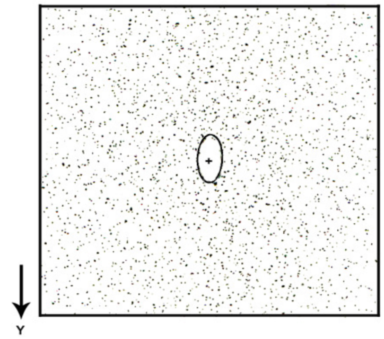

figure 14 c
M7 YZ section, No. of grains – 84
Location – Paraikulam

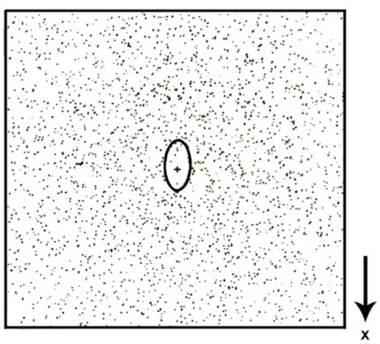

figure 15 a
M8 XY section, No. of grains – 75
Location – IIPE School near Paraikulam

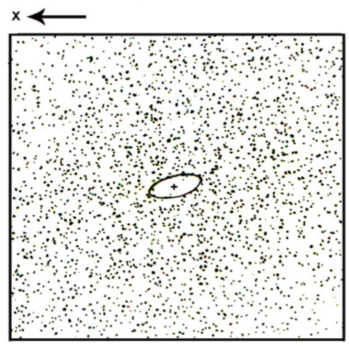

figure 15 b
M8 XZ section, No. of grains – 85
Location – IIPE School near Paraikulam

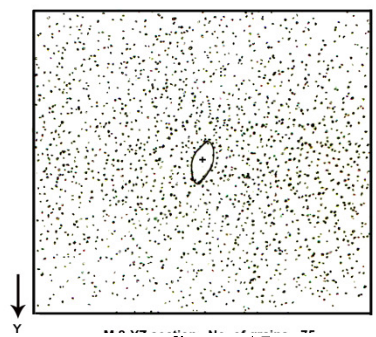

figure 15 c
M8 YZ section, No. of grains – 75
Location – IIPE School near Paraikulam

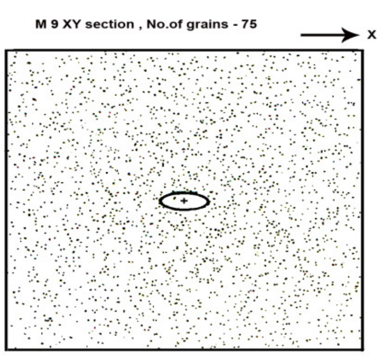

figure 16 a
Location - Rettiyarpatti

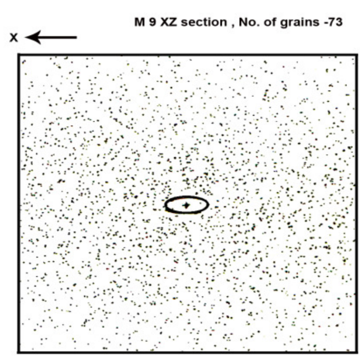

figure 16 b
Location - Rettiyarpatti

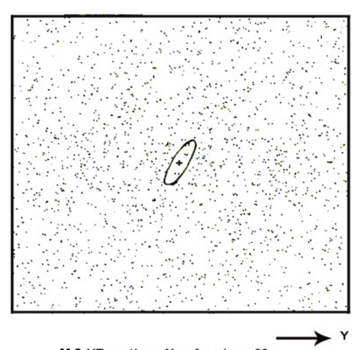

figure 16 c
Location - Rettiyarpatti

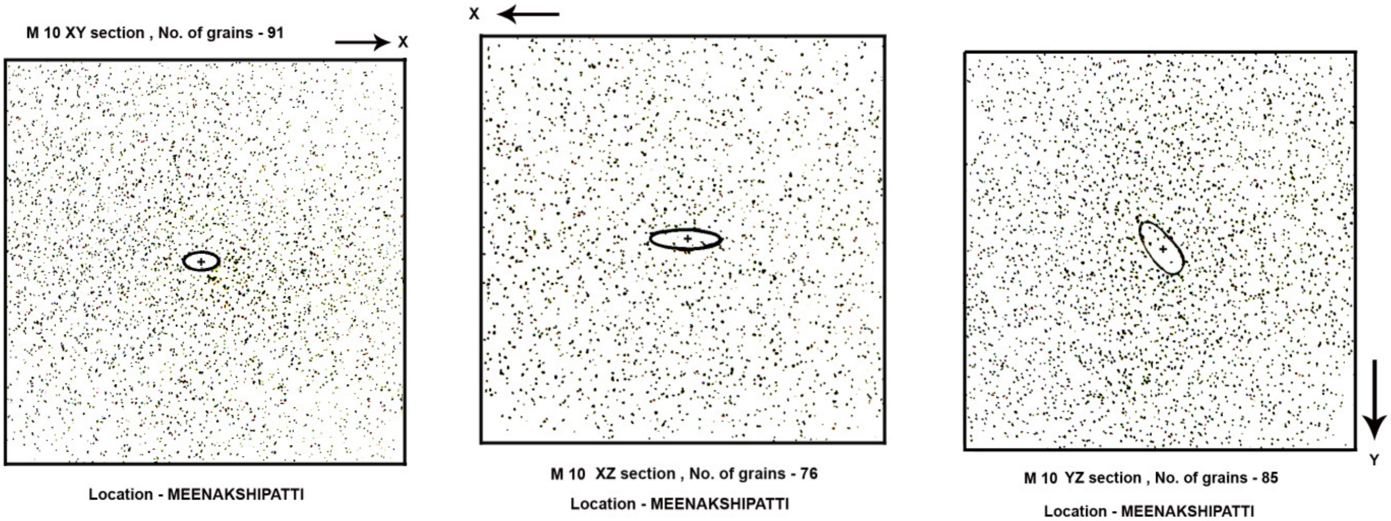

Figure-17abc

Three Dimensional Principal Strain: Two dimensional strain ratio data obtained through fry method of strain analysis from all the locations have been integrated by three dimensional strain analysis to determine the shape of strain ellipsoids 'k'(table 1).

Assuming that deformations do not change the volume, the three dimensional finite strain ellipsoids 'k' are computed using the following expression[2, 5].

$$k = R_{xy} - 1 / R_{yz} - 1$$

The ellipsoidal shape 'k' value is a parameter which expresses the degree of oblateness or prolateness of the ellipsoid plotted in Flinn graph.

Table-1

Sample No.	Location	k value
1	Vallanadu	0.297
2	2 km N of Vallanadu	1.042
3	2.5 km NNE of Vallanadu	0.713
4	Parkitamanagaram	2.154
5	Aryakulam	0.83
6	Vembadi ShasthaKovil	1.25
7	Paraikulam	1.00
8	IIPE school, Paraikulam	0.096
9	Rettiyarpatti	0.472
10	Meenakshipatti	1.037

Results and Discussion

Achankovil shear zone is sinistral sense dominant NW-SE striking shear zone [6, 7, 8]. The Palayamkottai area forms a part of Achankovil shear zone and NW-SE dextral and NW-SE sinistral shears are commonly observed in the area. The NW-SE sinistral shear zones are predominant in the outcrop scale (10m to 100m). Since the sampled granites are within the shear zones, all of them are invariably sinistrally sheared.

The calculated k values are plotted at their respective locations of Achankovil shear zone of Palayamkottai area (figure 18). On the Flinn graph (figure 19) for Rxy and Ryz the plotted points lie on the constriction, plane and flattening strain fields.

The granite intruded the core of the Vallanadu isoclinal quartzite fold has recorded flattening strains at 1 and 3 locations and constrictional strain at location 2. The granites in the host of charnockite are recorded constrictional strains. The granite locations present in the country of pelitic gneiss have recorded flattening strain at locations 5 and 8 constrictional strain 1.25 at location 6 and plane strain at location 7. The above locations are aligned along NW-SE striking Achankovil shear zone. The upright fold of the Rettiyarpatti location 9 quartzite hillocks has recorded the flattening strain. The granites of Achankovil shear zone have recorded complex finite strain pattern of plane, constriction and flattening strains.

Vertical stretching lineations along subvertical shear zone perpendicular to the direction of tectonic transport were first interpreted to be the result of transpression deformation[9]. Right over-stepping lineaments, sinistral shear bands suggest sinistral transpressive deformation of Achankovil shear zone[10]. Braun[11] assigned 550 Ma Pan-African age for granites of Achankovil shear zone from EPMA monazite dating. Transpression, a combination of simple shearing and an orthogonal pure shearing result in a distinctly non-plane flattening deformation[12]. Both shallow and steep stretching lineations are seen in same ductile shear zone of transpressive tectonic regime[13,14].

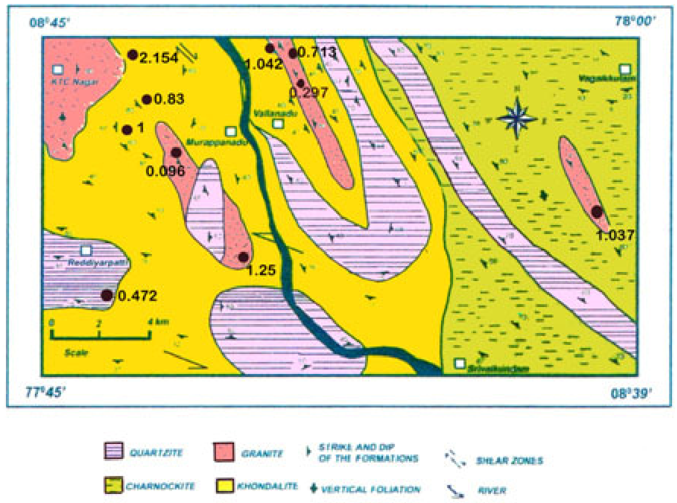

Figure 18
Spatial variation in three dimensional elipsoidal strain-estimated K values for Palayamkottai area

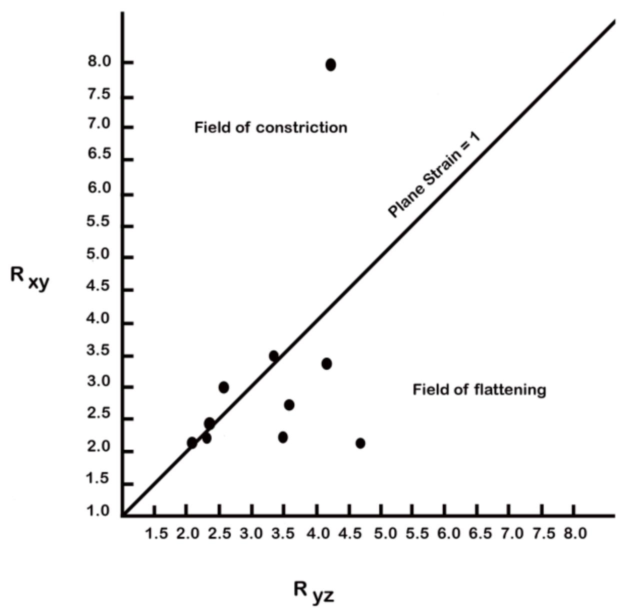

Figure 19
Plotted Flinn Graph for R_{XY} / R_{YZ} Finite Strain two dimensional values estimated from Fry plots for each selected location from Palayamkottai area

The identified sub horizontal to steep or vertical stretching lineation and the estimated complex three dimensional finite strain pattern of plane to constriction and plane to flattening for the Achankovil shear zone from Palayamkottai area strongly suggest a transpressive tectonic regime.

Conclusion

The identified sub horizontal stretching lineations of granites are also showing steeply plunging stretching lineations at Vallanadu, Paraikulam areas of Achankovil shear zone and estimated complex finite strains from fry method of strain analysis yielded plane – constriction – flattening strain suggest a transpressive tectonic regime of Achankovil shear zone and NW - SE sinistral Achankovil shearing and granite formation are as syntectonic event of Pan-African time.

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