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Mega Sheath Fold of the Mahadevi Hills, Cauvery Suture Zone, Southern India: Implication for Accretionary Tectonics

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Abstract: The Mahadevi hills, located in the axial zone of Cauvery Suture Zone, comprise a sequence of granulite facies rocks represented by garnet-bearing pyroxene granulites and quartzo-feldspathic gneisess interfolded with banded iron formations. Structural mapping with hand held GPS reveals that the Mahadevi hills constitute a mega sheath fold structure exposing well developed easterly plunging extension lineations. Depressional and culmination surfaces are well demarcated in association with elliptical map patterns. The development of the mega sheath fold structure is genetically related to the regional thrust-nappe tectonics, supporting the model of subduction-accretion-collisional history for the evolution of the Cauvery Suture Zone.

Keywords: Mega Sheath fold, Cauvery Suture Zone, Mahadevi, Subduction, Accretion, Granulites, Tamil Nadu.

INTRODUCTION

Sheath folds are defined as non-cylindrical folds with more than 90% hinge line curvature and are generated in a wide variety of tectonic settings involving non-coaxial deformation dominated by simple shear (e.g. Aslop and Holdsworth, 2006, Marques et al. 2008). The existence of large-scale sheath folds have been recognized in the internal domains of major orogenic belts (Goscombe, 1991; Shackleton, 1993). Sheath folds have also been described from exhumed high pressure granulite facies rocks in subduction settings (e.g., Quinquis et al. 1978). Sheath folds are also reported to develop in several deformational regimes like pure shear, either plane strain or constrictional (Borradaile, 1972), diapirism or three dimensional differential (i.e. non-planar) flow. However, recent models are mostly related to deformational regimes with a dominant component of sub-horizontal simple shear as found in some nappe complexes (Skjernaa, 1989). Mega sheath fold structures are rarely preserved in a deeply eroded Precambrian suture/shear zones.

Here, we document a well exposed and highly deformed sheath fold structure that is well preserved in the south central part of the Cauvery Suture Zone in southern India (CSZ, Fig. 1) from the Mahadevi hills (2x3km) (Fig. 2). The Mahadevi sheath fold (MSF) provides an excellent example for mappable kilometer-scale sheath folds as rarely described from other parts of the globe (e.g., Goscombe, 1991).

The MSF structure occurs along the axial zone of the CSZ, that separates the late Archean Dharwar craton to the north and the Proterozoic granulites of Southern Granulite Terrain to the south (Chetty et al. 2006) (Fig. 1). The Mahadevi hills are located about 45km east of Namakkal town on the road between Namakkal and Tatayyangaripet in Tamil Nadu state (E.long.78° 24'37.65"and N. lat.11° 09' 42.66"). The CSZ extends in an east-west direction for a strike length of about 400 km with a width of ~70 km. The recent geological and geophysical studies have established that the CSZ is a Precambrian suture zone forming part of a major continental collisional suture developed through southward subduction (Chetty et al. 2006; Santosh et al. 2009; Naganjaneyulu and Santosh, 2010, 2011; Santosh and Kusky, 2010). The CSZ has also been demonstrated as a crustal-scale ‘flower structure’ that formed as a result of Neoproterozoic dextral transpression resulting from oblique collisional processes (Chetty et al. 2003; Chetty and Bhaskar Rao, 2006), similar to the structures described from other major collisional belts (e.g., Abd El-Wahed and Kamh, 2010; Li et al. 2010). The CSZ extends into the Betsimisaraka suture zone in Madagascar in defining the site of Mozambique ocean closure (Collins et al. 2007; Santosh et al. 2009). Several recent studies have documented the presence of high

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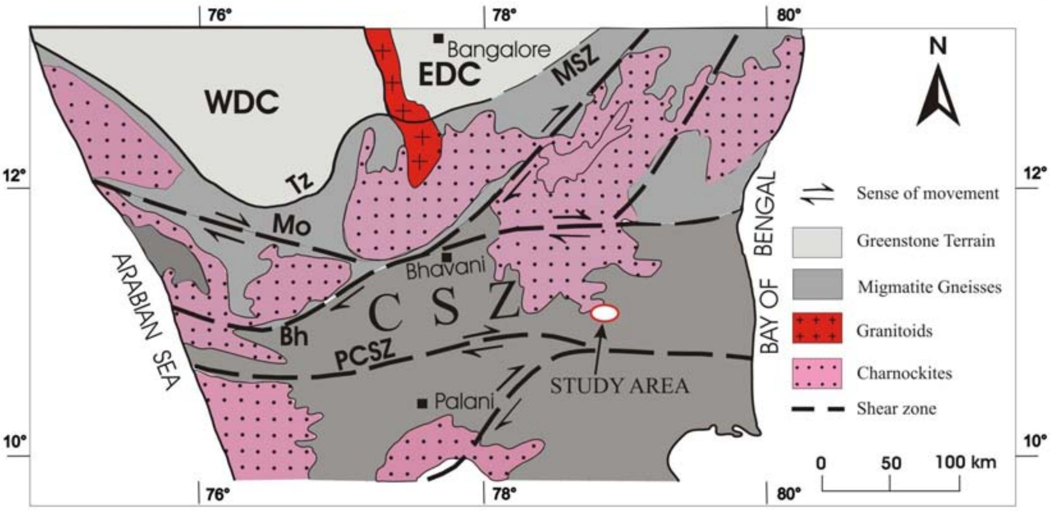

Fig.1. Geological sketch map of the Cauvery Suture Zone showing broad lithologies , major shear zones and the location of the study area (*after* Chetty and Bhaskar Rao, 2006).

pressure granulites within the CSZ, with pressures in the range of 12-20 kbar (Shimpo et al. 2006; Collins et al. 2010; Sajeev et al. 2009; Santosh et al. 2010) as well as ultrahigh temperature mineral assemblages (Tsunogae and Santosh, 2004, 2007; Tsunogae et al. 2008; Santosh and Kusky, 2010; Shimizu et al. 2010). The presence of ophiolites in CSZ has been recently established based on field, petrological and geochemical characteristics, developed within a supra-subduction zone tectonic setting (Yellappa et al. 2010). U-Pb zircon geochronology has correlated the ophiolite formation to Neoproterozoic subduction tectonics with final collisional metamorphism during Cambrian (Sato et al. 2011). A recent plate tectonic model identified Pacific-type orogeny culminating in Himalayan-style collision along this zone, associated with the final closure of the Mozambique Ocean and the birth of the Gondwana supercontinent (Santosh et al. 2009). We present here the first detailed structural analysis of this important mega sheath fold structure and correlate this with regional thrust-nappe tectonics in the region. Our study has important implications in understanding the tectonics associated with the subduction-accretion-collision processes proposed for this region.

REGIONAL GEOLOGIC FRAMEWORK

The eastern part of CSZ constitutes an anastomosing network of shear belts, an east-west tectonic zone, a less deformed fold dominated domain and zones of high strain fabrics (Chetty and Bhaskar Rao, 2006a). Discrete high strain zones include east-west striking Salem-Attur Shear Zone (SASZ) and Cauvery-Tiruchirapalle Shear Zone (CTSZ). The former represents the northern boundary, while the latter marks the southern boundary of the CSZ. Wickham et al. (1994) described the effects of retrogression (400 Ma) and copious influx of mantle derived CO_2 fluids along the SASZ. The SASZ and CTSZ are connected by a set of sigmoidal and narrow linear ~1 km wide shear belts. These belts separate the domains of low strain and high strain. While the low strain zones preserve well defined folds displaying the multiple events of folding events, the high strain zone is characterized by mylonites, phyllonites, augen gneisses and highly asymmetrical fold structures after erasing and modifying the pre-existing structures. Interestingly, the MSF occurs distinctly as elongated and elevated ridges (Fig. 2) at the northern margin of the CTSZ. The deformational history of the eastern part of the CSZ has been described in detail by Chetty and Bhaskar Rao (2006a). The main characteristic features of the study area include (i) presence of dominantly east-west trending shear zones at the margins viz, SASZ and CTSZ, (ii) predominance of south verging

Fig.2. Well exposed mega sheath fold of Mahadevi hills as seen in Google image.

back thrusts coinciding with the CTSZ, (iii) dominant presence of early formed major and mesoscopic scale antiforms and a few synforms with east-west fold axes, (iv) occurrence of mylonites with well developed extension lineations plunging east and southeast. These back thrusts constitute a part of southern part of the well described crustal-scale flower structure related to Neoproterozoic dextral transpressional tectonic regime (Chetty and Bhaskar Rao, 2006a). Further, a series of dome and basin structures surrounding the Perundurai gneissic dome, suggesting constrictive type of deformation within a broader transpressional characteristics, have been described from the western part of the CSZ, which suggest the exhumation of lower crustal rocks (Chetty and Bhaskar Rao, 2006b). The MSF of Mahadevi hills is located in the south-central region of the eastern part of the CSZ.

MAHADEVI SHEATH FOLD

A hand-held Global Positioning System (GPS) (Garmin Etrex Vista) was employed to record accurate location of several geological and structural measurements. The geological observation includes lithological composition, extent, the structural measurement including the geometry of the rock type, internal structure, lithological boundaries etc. The real time locations prepared from the GPS software have been conveniently used for plotting the structural data and the nature of the lithologies and their boundaries and the locations were chosen carefully to bring out the geometry of fold structure.

Location of these points was stored as waypoints in GPS and the other geological and structural information was recorded in the field note book. The orientation of extension lineations and a few well exposed axes of minor folds could be measured and recorded. These waypoints facilitated the accurate plotting of lithological and structural measurements manually in finalizing thematic maps with accurate locations. The waypoints stored in map source in vector form has been imported into Arc GIS Version # 9.

GEOLOGICAL SET UP

The Mahadevi hills comprise a sequence of granulite facies rocks dominated by pyroxene granulites and garnet-orthopyroxene-biotite bearing quartzo-feldspathic gneisses interlayered and interfoded together with meta-supracrustals particularly magnetite-chert bands (Banded Iron Formations) (Fig. 3). Hornblende gneisses are also observed as isolated patches at a few places. These are tectonically interleaved in close association with 2.5 Ga charnockitic rocks, which have been co-folded together, and may possibly represent the basement to the Neoproterozoic ophiolitic rocks in the area (Chetty et al. 2011). The band width of BIF ranges from 10-20 meters and represent marker horizons. They are highly strained and well exposed at several sectors of MSF. A well defined mega fold hinge is exposed in the central part of the MSF (Fig. 4a). The earliest recognizable structure in these rocks is metamorphic gneissosity (S1), which is developed during D1 deformation. F1 isoclinal folds with east-west trends along with possible gently dipping axial planes are presumably developed during D1. These F1 folds were refolded on an east-west axis giving rise to F2 folds with broadly similar orientations during D2 non coaxial deformation. At places, the intensity of deformation varies

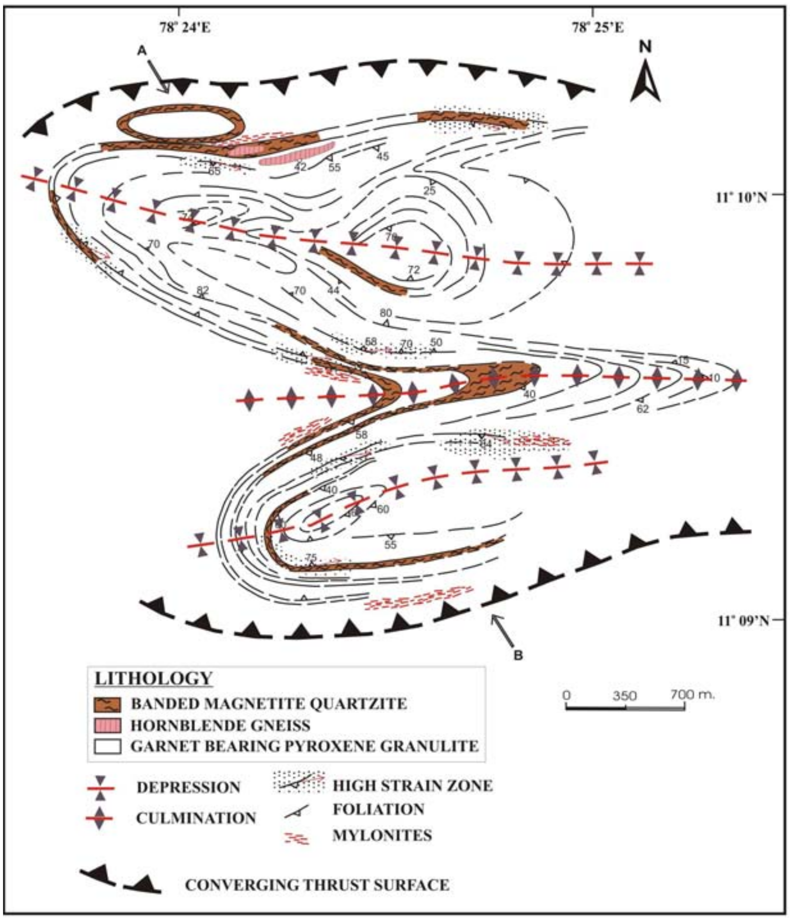

Fig.3. Geological and structural map of Mahadevi hills displaying major lithologies, elliptical shaped structures and the geometry of foliation trajectories.

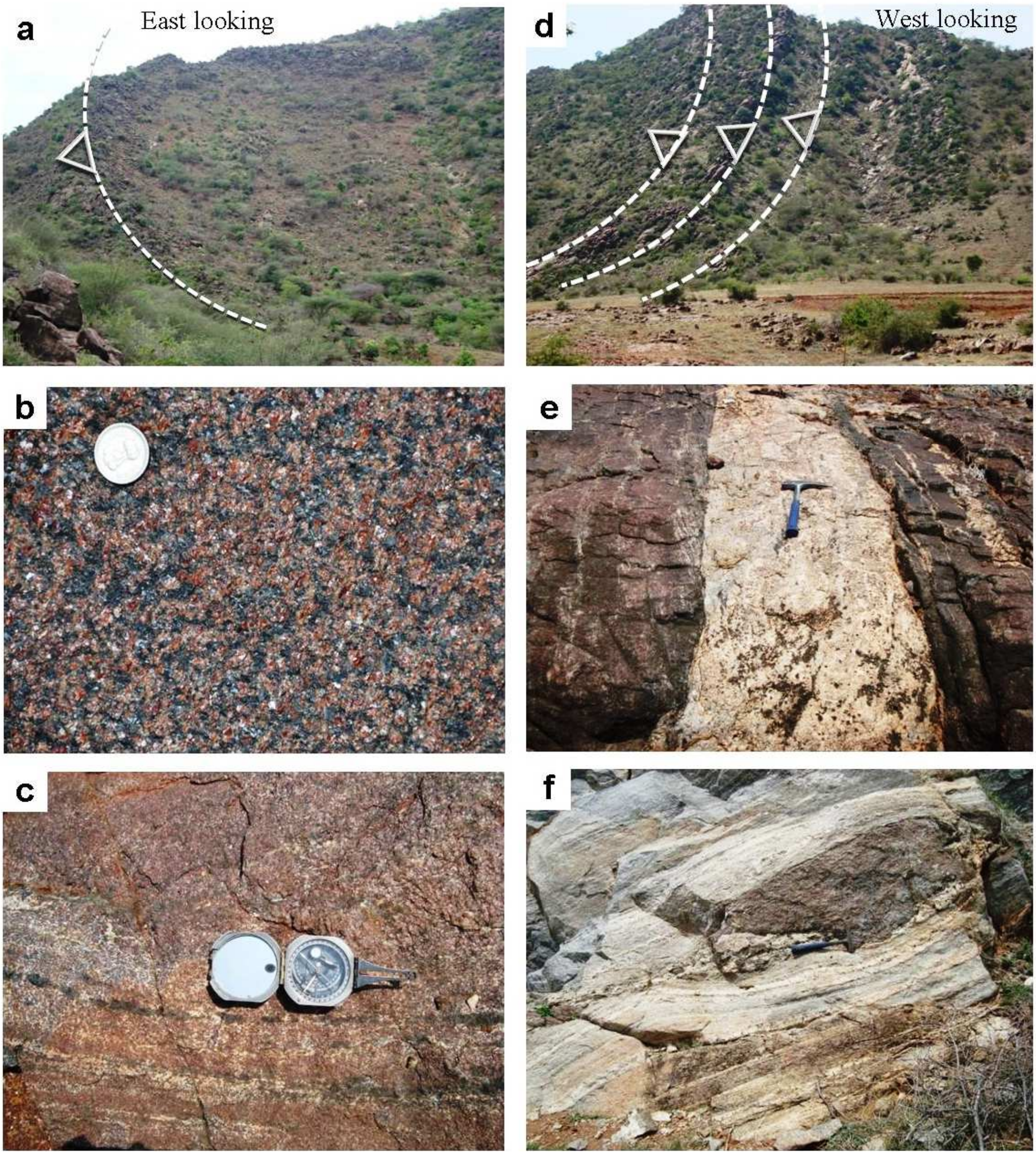

Fig.4. Field photographs showing **(a)** Folded sequence of BIFs and other granulites exposing the inclined YZ-section of the MSF; **(b)** Close up view of ganet rich concentrates in some pockets; **(c)** Gneissic foliation, transforming into mylonitic foliation, melt segregation along the foliations; **(d)** Moderately southward dipping layered sequence of granulite facies rocks; **(e)** A quartzo-feldspathic band intruding the host rock, cutting across the gneissosity; **(f)** Intense mylonitic fabric in a tonalite intrusive in the NE-corner of the MSF with well developed extension lineation.

gradually during D2 deformation with the development of mylonitic foliations (S2) (Fig. 4c). The S1-fabrics dip gently towards north as well as south and often intensifies into mylonitic zones in the proximity of D2 shear zones. Gneissic banding (S1), and mylonitic foliation (S2), in general, lie sub parallel to each other and the southerly dipping fabrics are well exposed in the southern part of the MSF (Fig. 4d). The zones of S2 are mostly concentrated along the limb regions. The region to the south is dominated by D2 structures. D2-ductile thrust is consistent with the thrusts forming during continued shearing within an evolving progressive deformation framework. Quartzo-feldspathic (tonalitic) rocks occur in the form of masses and bands of varying thickness along the presumed shear zones. They are found to be

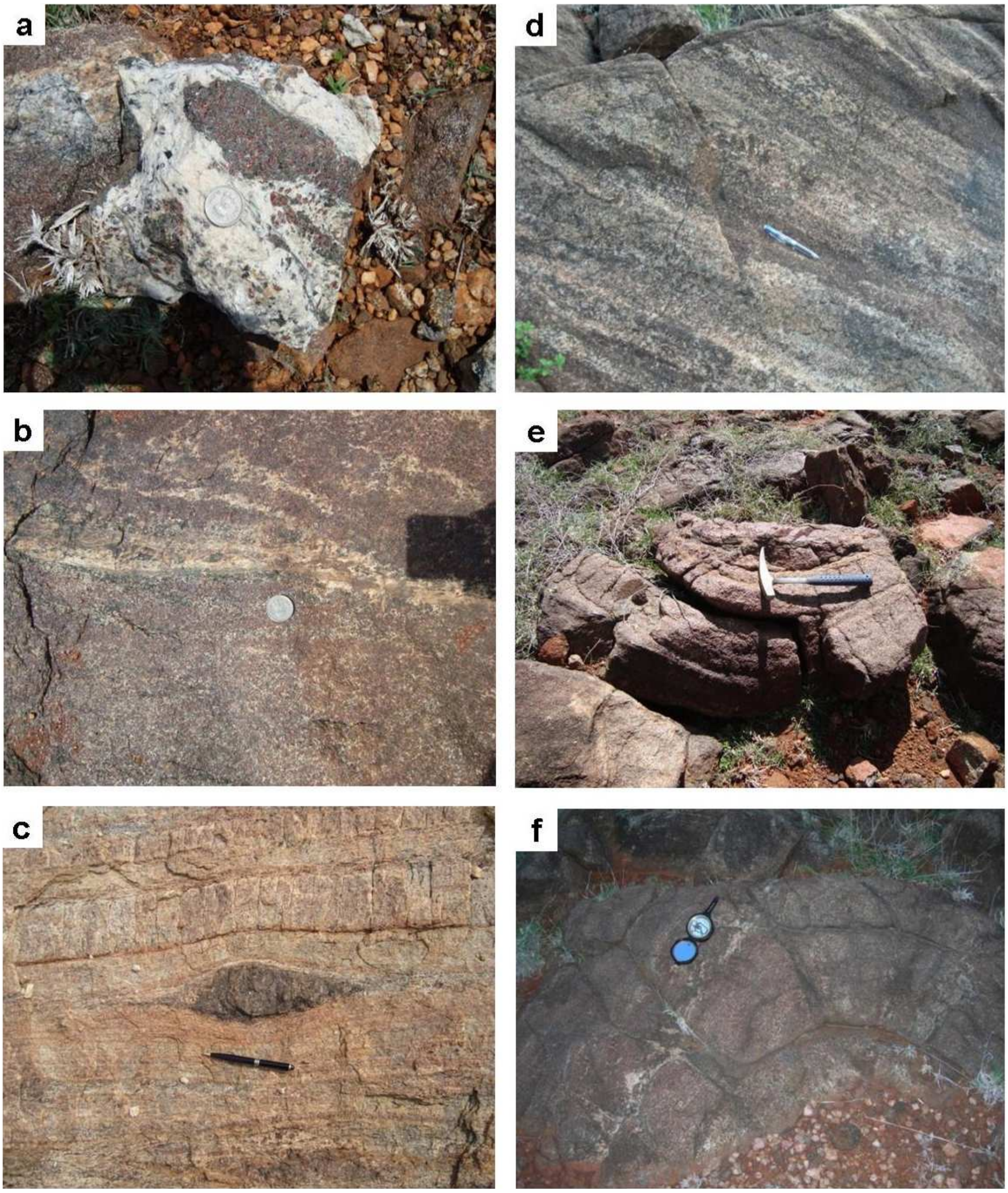

Fig.5. Field photographs showing **(a)** Recrystallized quartz-feldspar matrix with enclaves of intense aggregates of garnets; **(b)** Mesoscopic shear zone associated with melting and high strain fabrics; **(c)** Mafic enclave in the form of a boudin surrounded by intense mylonitic fabrics; **(d)** Well developed extension lineations developed along the gneissic foliation; **(e)** Mesoscopic sheath fold developed at the western margin with in the MSF; **(f)** Partly exposed and well developed mesoscopic eye shaped elliptical structure.

intrusive and occur at an angle to gneissic banding (Fig. 4e). A large wide band of tonalitic composition occurs in the NE- corner of the MSF, which has undergone intense deformation (Fig. 4f). These gneisses show a range of fabrics from strong to weak gneissosity. Often, they show relicts of host rocks that are distinct and fresh with rich concentrations of mafic minerals and garnets (Fig. 5a).

Several tight to isoclinal folds within these gneissic rocks are well preserved and their axial planes lie sub parallel to the plane of gneissic foliation (S1). These fold hinges lie at a small angle to the local extension lineation. These folds are mostly preserved in felsic bands and folded mafic bands and are now observed in the form of highly strained enclaves. Boudins as well as pinch and swell structures occur on all scales in these rocks. These boudins are widely separated, indicating layer-parallel shearing. Mesoscopic shear zones are also common in two pyroxene granulites displaying excellent deflection of foliation trajectories along the shear zone walls (Fig. 5b). Some of the shear zones developed parallel to the gneissic foliation supports the inference of layer parallel shearing. These zones are invaded by quartz-feldspar fluids suggesting minor anhydrous melting during D2 deformational event with well developed S2-L2 fabrics and melt segregations (Fig. 5c).

The mafic granulites/gneisses are moderate to very coarse grained (garnet and pyroxene grains up to 1cm grain size) brownish rocks (Fig. 4b) consisting dominantly of garnet, clinopyroxene, orthopyroxene and hornblende. Pyroxene-bearing mafic granulite, the major lithology affected by the Mahadevi Sheath Fold, comprises of coarse-grained (up to 1.5 cm) garnet (Alm_{31-53} Pyr_{31-44} Sps_{0-1} Grs_{14-23}) and clinopyroxene ($X_{Mg} = 0.71$-0.86) with minor pargasite, plagioclase (An_{35-41}), orthopyroxene and rutile (Fig. 6a and 6b). Garnet and clinopyroxene are both subidioblastic and contain few inclusions of clinopyroxene (in garnet) and plagioclase (Shimizu et al., 2010). Orthopyroxene occurs only as orthopyroxene + plagioclase symplectite between garnet and clinopyroxene (Fig. 6b). The metamorphic temperature and pressure computed for plagioclase-rich sample using garnet-clinopyroxene-plagioclase-quartz geothermo-barometers (Shimizu et al. 2010), yield 890-900°C and 13.8-14.2 kbar. The *P-T* condition is consistent with the stability of garnet + clinopyroxene + quartz assemblage ($P > 14$ kbar at 900°C; Green and Ringwood, 1967).

Planar Fabrics

The earliest recognizable prominent planar structure in the granulite facies rocks of Mahadevi hills is the metamorphic gneissic foliation (S1) formed during D1, which is defined by mm-cm spaced parallel layering of mafic and felsic minerals. At several places this has been overprinted by tectonic foliation, characterized by intense grain size reduction of pre-existing textures and marked by mm-scale foliation fabrics, which can be termed mylonitic foliation (S2). S2 typically parallels the gneissic and lithological layering (S0-S1) and S2 is considered to be coeval with F2 folding because of its axial planar development. S2 is defined by the preferred orientation of biotite, elongated minerals in pressure shadows and ribbons of fine grained aggregates of quartz, feldspar, garnet and pyroxene. The aggregate ribbons are formed by recrystallization at grain boundaries.

Figure 7 shows the plot of foliations (S1/S2) from the MSF. The foliations show a prominent E-W strike direction with dips (40°-60°) on either side with two other important strike directions: NE-SW and NW-SE with dips varying from 20° to 60°. While, the former (NE-SW foliations) dip mostly southeasterly, the later (NW-SE foliations) dip northeasterly with the same dip angle. There are also zones of E-W trending foliations in the central part and southern, as well as, northern boundaries of the MSF with dips invariably exceeding 60°. N-S trending foliations with gentle to moderate dip amounts are also common at the hinge zones of the fold. Such variations in foliation trends/orientations has been interpreted as due to an antiformal sheath fold subsequently modified by folding and flattening. The gneissosity also traces out kilometer scale elliptical structural domes and basins with moderate dipping limbs and a curved enveloping surface presented by the XY-section of the MSF. The gneissic foliations, when plotted in a stereo diagram (Fig. 7) show the spread in the entire western sector, but the maxima can be seen in the SW and NNW quadrants defining a great circle on the stereogram. This suggests that geometry of

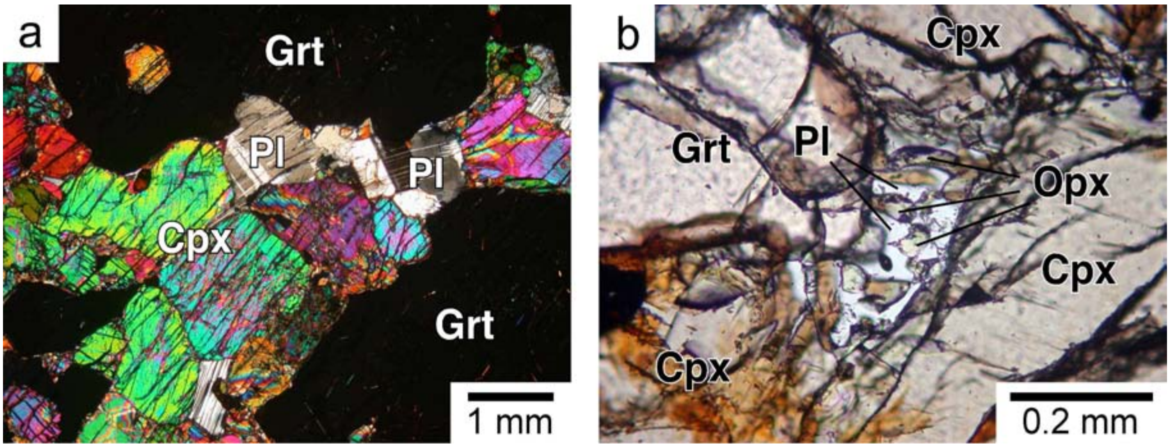

Fig.6. Photomicrographs showing representative textures of garnet bearing mafic granulite; **(a)** Granoblastic texture of mafic granulite (garnet + clinopyroxene + plagioclase); **(b)** Orthopyroxene + plagioclase symplectite between garnet and clinopyroxene.

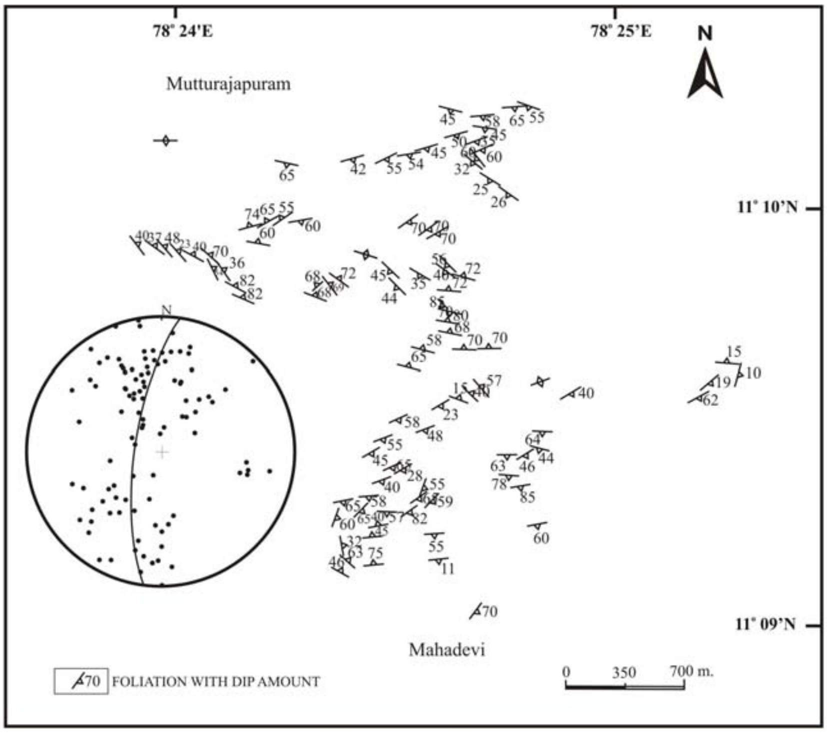

Fig.7. Map of the exposed MSF showing the plot of strike and dip of foliations with Stereodiagram showing the plot of poles to foliations in the form of a great circle.

the fold structure is a fold with conical geometry with low to moderate plunges. This diagram also depicts non-cylindrical geometry with gentle to moderate easterly plunging fold axis.

Linear Fabrics

Moderate to strongly developed mineral lineations on the gneissic and/or mylonitic foliation planes are well defined by linear arrangement of minerals (Fig. 5d) and their aggregates with a well defined preferred orientation (Fig. 8). These are considered as extension lineations (L2) defined by elongated quartz and feldspar aggregates consistently plunging eastwards with gentle to moderate values and considered to lie parallel to X– direction of the strain ellipsoid. The trends of L2 and associated foliations remain unaffected by a lineation defined by parallel open folds that plunge gently to east. No change in the orientation of lineation has been observed from zones of gneissic fabric to zones of mylonitic fabrics.

The stereoplot of extension lineations (L2) from the MSF (Fig. 8) exhibit dominant eastward plunge with a subsidiary maximum to the west along with moderate variations on either side of the E-W axis. Although, the plunge values show a large variation between 10^{o}-70^{o}, the dense cluster lies between 20^{o}-40^{o}. This kind of plunge variations which are tightly spread around a steep E-W plane are common in more elliptical cross sections and that plunge variations might have resulted from progressive modifications of the sheath fold geometry. Lineations in XZ plane will not rotate out of the plane and the result is the development of curved lineations on the sheath fold limbs. According to Fowler and El Kalioubi (2002), the extension lineations are expected to fade towards the tip of the fold. However, in the present study, the development of extension lineations is common because the extension is not equal in all directions.

The occurrence of both east plunging and southwesterly plunging L2-extension lineations are mostly restricted to the zones of elliptical shaped structural forms that were mapped in the study area. Several variable trends of extension lineations were reported by Greiling et al. (1988), which are sometimes interpreted as two different tectonic transport directions. However, the present study considers that these trend variations are all of a continuum, defining curvilinear trajectories and the variations are mostly restricted to elliptical structures that are mapped from the MSF.

ELLIPTICAL MAP PATTERNS

Sheath folds are traditionally depicted as displaying symmetrical geometries (Fig. 9) about two orthogonal mirror planes, the (X-Y) axial surface and the (X-Z) medial (culmination/depression) surface, which bisects the parabolic fold nose (e.g. Alsop, 1994). Accordingly, curvilinear folds which are convex up when viewed in the inclined (X-Y) axial surface and closing in the direction of thrust transport are termed culminations, whilst, those, which are convex down and open in the direction of thrust transport are named depressions (Aslop and Holdsworth, 1999). Assuming that the MSF is exposed in X-Y plane and exhibit well developed medial surfaces of culminations and a depression (Fig. 3) with the central E-W axis of the MSF representing the X-axis. The elliptical structures are exposed along the depression surfaces. The extension lineation (X) acts as the bisector to the apical angle of the MSF and makes the elliptical structures as eye-fold patterns (Fig. 5e), which are symmetrical about the medial surface. The apparent asymmetric ellipses are inferred to be due to oblique

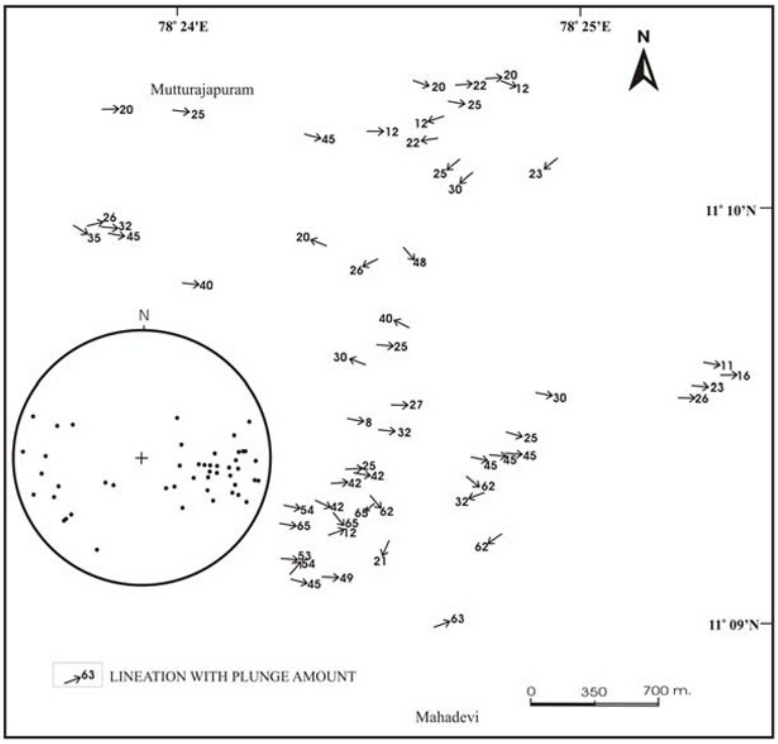

Fig.8. Map of the exposed MSF showing the plot of extension lineations with Stereodiagram displaying two maxima in the east and west with plunge values ranging between 20°-40°.

section of the surface. The structural basin (morphologically at higher elevations), in the NE-corner of the MSF has a tear drop shape with consistent inward dipping gneissosity at its margins. The dips of S1 become steep in the central part of the basin. A highly elongated elliptical structure is also mapped in the northern part outside the MSF. These structures are also recorded in the southern sector, which forms a part of the MSF. However, another isolated elliptical structure is well exposed in the eastern part (Fig. 5f). The shape, size and orientation of domes and basins are variable. Majority of elliptical geometries show near E-W elongation including the tear drop shaped structural feature in the NE-part of the MSF. Some mesoscopic features possess the appearance of a crescent-shaped dome and basin with rectangular to elliptical shapes, but trending in the same direction as those of larger ones.

STRUCTURAL CROSS - SECTION

A structural section has been constructed across the general E-W trend and subparallel to assumed YZ- plane of the bulk strain associated with the MSF (Fig. 9a). Two synformal structures (depressional surfaces) are separated by an antiformal structure (culmination surface) brought out nicely by the pattern of BIF bands in the central part. Closed elliptical structures occur along the depressional surfaces showing mirror like images on either side of the culmination surface. The F1 isoclinal folds were refolded giving rise to F2 folds and are well depicted in the northern part of the section. From the attitude of foliations, it is interpreted that they close upwards, forming a broad elliptical structure along YZ-plane (Fig 9b). There seems to have been further deformation in the form of continued compression and the shortening along Y direction, where only the lower limbs have been affected giving rise to two well defined similar synformal structures on either side. The entire fold structure seems to have been affected on all sides resulting in the constrictive deformation except the direction along the extensional transport X-direction. The entire section is also bound by two converging thrust surfaces in an E-W trending shear zone.

DISCUSSION

The detailed structural map of Mahadevi Hills, prepared from the present study, reveals paraboloidal forms and typical sheath fold geometries as described by Minnigh (1979). The geometry of the Mahadevi sheath fold structure closely resembles a model of three dimensional group of sheath folds (Fig. 9b) depicted by Henderson (1981) with the horizontal X-axis. The other axes perpendicular to X –axis are referred to as Y (horizontal) and Z (vertical) respectively. The Mahadevi sheath fold (MSF) displays near symmetrical geometries about the X-Z mirror plane. The XZ-medial (culmination/depression) surface bisects the parabolic fold nose (Fig. 10). These fold structures can further be subdivided into tubular folds, since their apical angles are less than 20°. The limbs of the MSF are inferred to lie parallel to the XY-plane and accordingly, the XZ- section in the limbs form upward curving. The X-axes of the MSF are nearly coincident with the exposed surface of the antiformal culmination surface in the central part with complementary synformal depressional surfaces on either side. The YZ- cross section constructed for the MSF exhibit upward convexity-crescents on both sides of the depressional surface (Fig. 3). Since the assumed X-axes of bulk strain ellipsoids associated with these folds are slightly inclined, a variety of elliptical, crescent shaped and isoclinally folded sections occur at the same level of truncations, which, were described as elliptical map patterns in the earlier section.

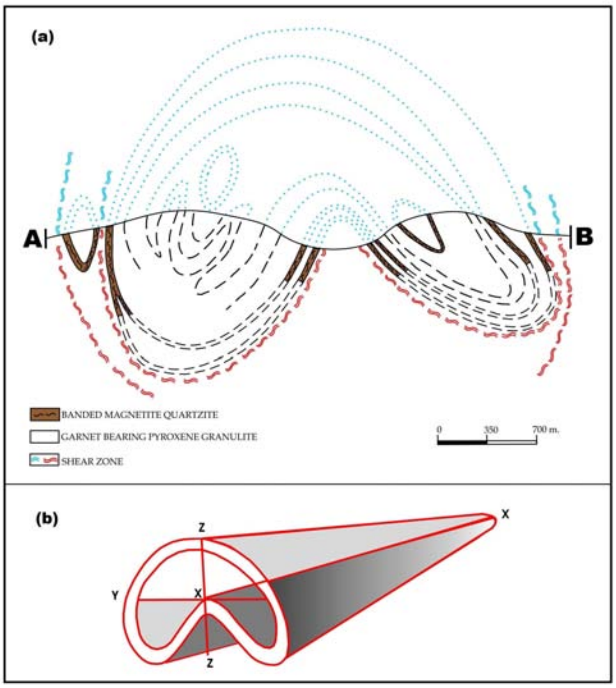

Fig.9. (a) Structural cross section along YZ- plane showing crescent shaped and elliptical structures. Notice the shear zone all along the lower limbs leading to high strain development; **(b)** Schematic block diagram showing the Mahadevi sheath fold.

The well exposed mega sheath fold in Mahadevi hills (MSF) is interpreted to have originally developed locally south verging recumbent fold with E-W axis and got overprinted by E-W trending open folds. These folds could be the result of simple rotations of the layers containing them into the inverted limb of a major recumbent fold anticlinorium, as obtained from the structural cross-section. We interpret that these recumbent folds must have formed as a consequence of ductile thrusts and nappe emplacement. South verging thrust–nappe tectonics and the generation of a stack of imbricate structures have been recently established in the proximity of the MSF (Chetty et al. 2011). The exposed section of the MSF could represent the lower limb of a larger recumbent structure, which, must have been deformed during modest shortening in near N-S direction. This also produced dome and basin structures, which, have buckled the flat lying gneissosity on the limbs of the folds. Shortening along Y-axis is to produce flattening of the sides of the sheath and thereby, increasing the area of sub-vertical foliation along the sheath fold hinge.

The MSF forms a part of a sequence of back thrust in the crustal-scale ‘flower structure’ model envisaged by Chetty and Bhaskar Rao (2006). The MSF also marks the central and axial zone of the CSZ and separates the north verging frontal thrust and the south verging back thrust. The later comprises an imbricate stack of E-W trending parallel thrusts/duplex structures (Chetty et al. 2011). The MSF may represent a well defined ‘horst’ bound by converging thrusts. Several other E-W trending antiformal fold structures occur to the south in the region in the form of ridges for over a distance of 30 km upto the Cauvery river course. About 80 km west of the MSF along the strike, a remarkable domal structure around Perundurai, associated with small scale domes and basin structures was described as a resultant product of constrictive deformation in a transpressional tectonic regime (Chetty and Bhaskar Rao, 2006,). Such domal structures marked by characteristic radiating lineations can also be treated analogous to sheath fold structures (Fowler and Kalioubi, 2002). Mesoscopic sheath folds in the MSF are rarely noticed and such deficiency particularly along the limbs of macroscopic sheath folds is not a surprising phenomenon (Henderson, 1981; Lacassin and Mattauter, 1985). These features may be due to the mechanically active behaviour of folded layers and strong extensional strain associated with them.

The shortening of the MSF along its Y-axis and the ellipticity of the cross – sections seem to be dependent on the nature of refolding. If this ellipticity (Y/Z ratio) is large, then the sheath buckles after a style similar to type-2 refolding where the axial plane buckles. If the ratio is lower, then type-1 refolding styles appear to be preferred (Ramsay and Huber, 1987). Our results show that the MSF is a refolded and deformed structure with type-1 refolding style and is consistent with Y/Z ratio. It is also well established that the ancient high-grade terranes were characterized by recumbent orientations (eg. Enderby Land, Sandiford,1984; Rayner

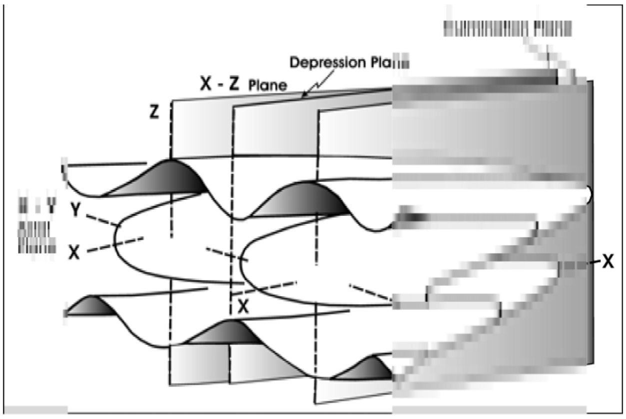

Fig.10. A cartoon showing a typical sheath fold structure showing the orthogonal axes X, Y, Z and the culminations and depressional surfaces (modified after Alsop and Holdsworth, 2004).

complex, Clarke,1987), whereas, most modern orogens are dominated by inclined to upright structures (Alps, Himalayas, Appalachians). Tectonic models for recumbently deformed terrains employ either compressional (very low angle, ductile overriding, Park, 1981) or extensional (collapsing crust, Sandiford, 1989) tectonics. But the deformational structures of an inclined orientation and predominant flat lying gneissic foliation (S1), partial melt segregations within the orthogneisses from the CSZ can be interpreted as having comprised a recumbent terrain during D1-deformational event, related to regional northward verging frontal fold thrust tectonic regime. The transpressive tectonic regime during D2 is responsible for rotating recumbent gneisses into inclined orientations on a local scale (i.e., on a macroscopic fold scale) and the development of a less steeply inclined nappe and thrust sheet stacking on a regional scale.

Sheath fold, particularly mega-scale sheath fold structure such as those in Mahadevi have important implications in understanding the regional tectonics. Recently, Searle and Alsop (2007) described mega-scale sheath folds of km-scale from northern Oman, representing highly curvilinear folds developed by hinge rotation towards the transport direction during intense deformation. Sheath folds have long been known to be typically linked with accretionary tectonics associated with subduction-collision zones (e.g., Hibbard and Karig, 1987; Drury, 1993). The area of present study is considered to mark the trace of the Cambrian Gondwana suture, and defines the zone along, which, Himalayan-scale collision occurred subsequent to a prolonged subduction-accretion history in the Neoproteorzoic (Santosh et al. 2009). The mega-scale sheath fold described in the present study, defined by rocks that have undergone high pressure and high to-ultrahigh temperature metamorphic history, thus supports the model of subduction-accretion-collision history prior to the final assembly of the Gondwana supercontinent.

CONCLUSIONS

1. The Mahadevi hills are defined by a mega sheath fold structure which is spectacularly well exposed with strong curvilinear hinges and typical parabolic fold geometries.
2. The MSF is characterized by strong extensional strain exhibiting well developed extension lineations and bound by sub-horizontal ductile shear zones.
3. The MSF is likely to have been initially developed in a regional fold-thrust tectonics and later modified under constrictional deformation related to a major transpressional tectonic regime.
4. The spectacular exposures and the accessibility make the MSF a classic example of sheath fold structure that provides the best opportunity to understand the processes of accretionary tectonics and hence warrant further detailed investigations.

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