Field evidence for deformation in Deccan Traps in microseismically active Nanded area, Maharashtra

Nanded city in Maharashtra is experiencing microseismic activity since 2006. It is located in the southeastern part of the Deccan volcanic province (DVP) spanning over more than 50,000 sq. km in the stable continental region (SCR) of India (Figure 1). SCR of India is not free from earthquakes, although they are rare. Two major earthquakes have occurred in the Deccan Trap region of Maharashtra, namely the Koyna earthquake of 1967 and Killari earthquake of 1993. While the fault plane solutions for the Koyna seismic fault indicate strike slip movement those of Killari are related to thrusting[1–6]. These events caution that the microseismic activity in the Deccan Trap region should not be neglected and geological and seismological investigations have to be pursued to understand the state of structural deformation in the region. Srinagesh *et al.*[7] have carried out microseismic study in Nanded area and suggested that the recent seismic activity is related to thrusting along a NW–SE fault that coincides with a stream that joins the River Godavari to the south of Nanded city.

Neotectonic activity is known both from the coastal and the Western Ghats regions of the Deccan Trap province[8,9]. Imprint of NW–SE Precambrian tectonic grain reactivated during the Tertiary in Deccan Trap terrain SE of Nanded has been reported[10]. In spite of the above studies, there is no detailed documentation of deformation structures in the Deccan Traps of Nanded region. Here we report ductile as well as brittle deformation structures in the Deccan basalts of Nanded and suggest their relation to the known principal horizontal compressive stress direction reported for this region by GPS studies[11].

The Deccan Traps of Nanded comprise thick, medium to fine-grained, greenish-grey and red basaltic flows. They may be compact, vesicular/amygdaloidal and tachylitic at places. The vesicles/amygdales may be circular and elliptical and segregated in bands. Pipe amygdales are common. The minerals in the amygdales comprise chlorite, calcite, zeolites and chalcedony. The traps are weathered by kaolinization and lateritization producing soil. On the river banks they are covered by alluvium.

We have examined the traps for deformation structures in the vicinity of River Asna, which is a tributary of Godavari, as this is the area related to microseismicity (Figure 1). Ductile as well as brittle deformation structures have been noticed. They include folds, ductile shears, brittle shears and thrusts. They are documented in brief in the following.

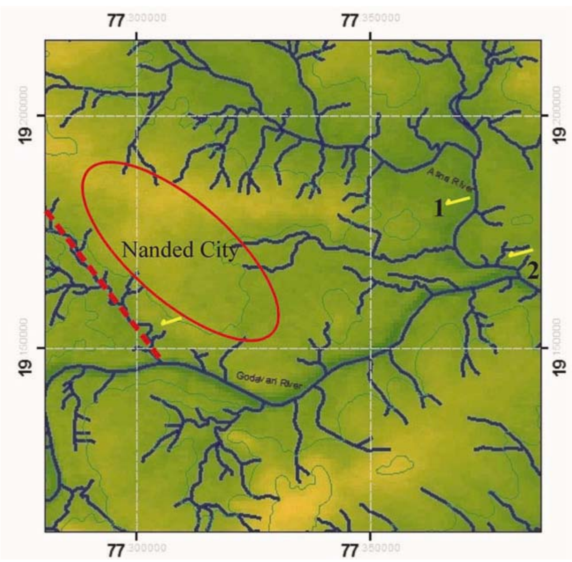

Figure 1. Location map of the study area overlaid on SRTM DEM of 90 m resolution. The region of microseismic activity is represented by an ellipse. Sites 1 and 2 are marked on the map and inferred seismic fault is marked by red dotted line. Arrows indicate the sense of movement of the 'thrust fault'.

A 2 m outcrop of green coloured basalt near Kamtha (19°10′45″N; 77°21′09″E), shows an asymmetrical open fold (Figure 2 *a*). Axial plane of the fold dips at 77° towards E. Dip of the western limb is steeper (16°) relative to the dip of the eastern limb (11°). Inter-limb angle is 156°. Nearly N–S orientation of axial plane and axis indicates E–W compression.

Brittle fracturing and displacement is particularly well documented by displaced pipe amygdales (Figure 2 *b*). Here the basalts are exposed in a vertical section. The face of the outcrop shows multiple small-scale faults. The fault planes dip at low angles (0° to 40°) towards west. The pipe amygdales are displaced by them in the range 0.2–0.5 cm (Figure 2 *b*). The hanging wall has moved up relative to the footwall indicating that these minor faults are of the nature of the thrusts.

Brittle thrust has displaced the eastern limb of an antiformal fold (Figure 2 *c*). The curvilinear fault plane runs for 3.62 m and dips towards east. The fault angle varies from 40° at the top to 20° nearer to the ground surface. The thrust is associated with en-echelon faults. In this case variation from brittle thrusting to brittle ductile thrusting is observed. Here, the limb shows slight bending before breaking, indicating brittle ductile nature of deformation. In this case also, the hanging wall has moved up relative to the footwall. Fault bend folding is particularly well documented in another outcrop at site 1 (Figure 2 *d*). Ramp and flat portion of thrust plane is also visible. Some amount of brecciation is seen in the footwall.

Instances of ductile shearing are seen as illustrated in Figure 2 *e* from site 2. Here a green basaltic vein has thinned out and got stretched in the shear zone, but not lost its continuity.

Reddy *et al.*[11] have suggested crustal field strain in Deccan Trap region using GPS data. Their studies show E to ENE orientation for the maximum horizontal compression at the present time. It is not known for how long this orientation of

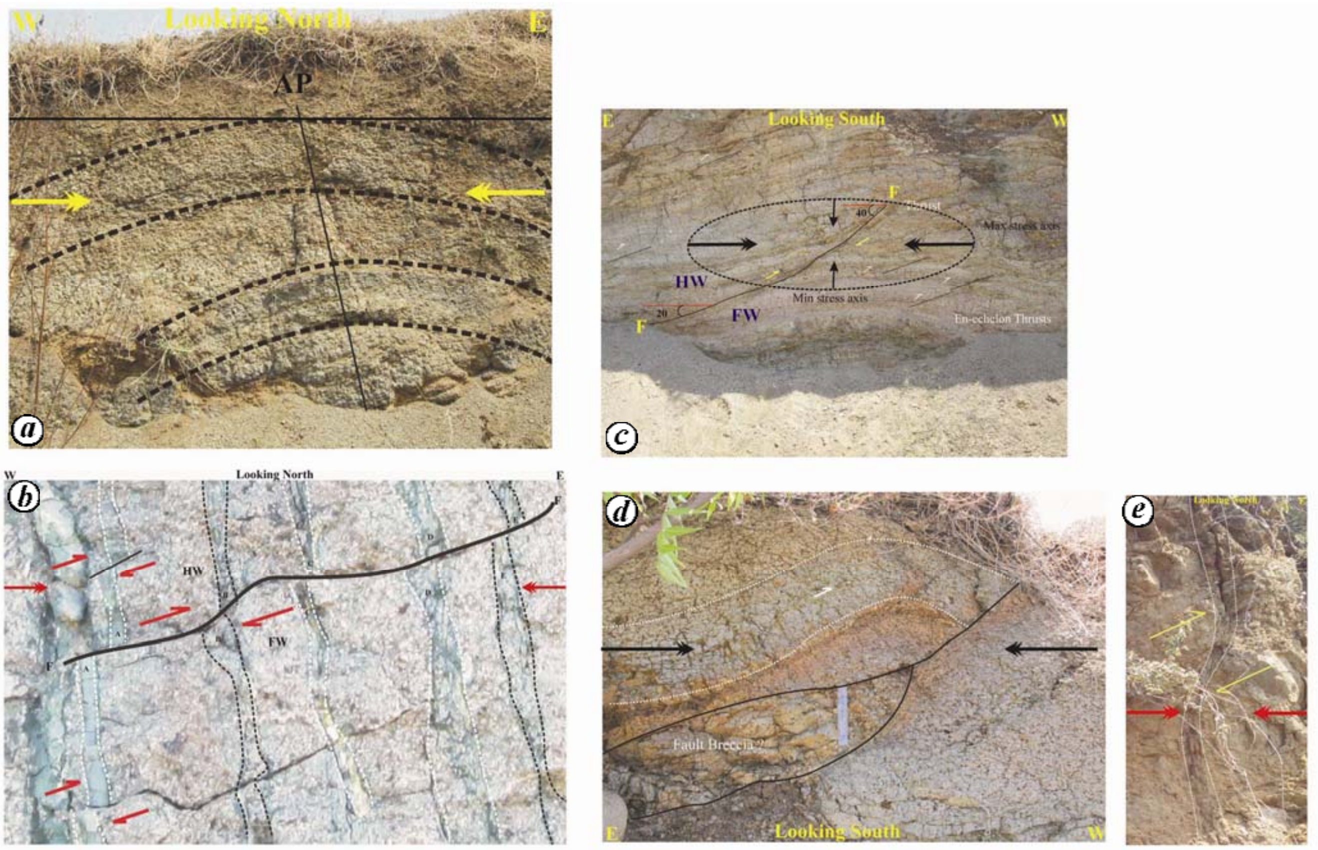

Figure 2. ***a***, Green coloured basalt showing broad 'anticline' of 2 m length (vertical cross-section from site 1). Arrows represents maximum horizontal stress direction trending EW. ***b***, Vertical cross-section of small-scale multi-faulting shown by pipe amygdules in basalt (site 2); → denotes maximum stress direction trending east-west. ***c***, Thrust associated with 'antiform' and 'en-echelon' small faults (site 1). ***d***, Ramp anticline (vertical cross-section from site 1). ***e***, Stretching and displacement of basaltic vein (site 2); → denotes the maximum stress direction.

horizontal compression been prevalent in the Deccan Trap region. The NW–SE-oriented lineament with which the reported microseismicity is associated being oriented at high angle to maximum horizontal compression axis, may be getting reactivated as thrust as evident from the seismological data. Upthrusting of the hanging wall towards west, as well as the easterly dip of the axial plane of the fold as observed in the minor deformation structures in Deccan Trap of Nanded, suggest greater compression from the east.

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