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Dyke Swarm at Vaijapur-Gangapur, Aurangabad District, Maharashtra, India - Field Characters and Deformations

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Abstract: ***In addition to the three major dyke swarms from Deccan Volcanic Province, the Dyke swarm is reported from Central Deccan Volcanic Province from Aurangabad region recently. Small size dyke swarm is also reported from South East Deccan Volcanic Province, Nanded. In this paper we study the Dyke Swarm from NW of Aurangabad region in Maharashtra. These basaltic dykes have intruded the host basaltic rocks. The length of the dykes varies from 1.8 to 6.5 km and in width dykes vary from 1.5 to 18.0 m. The dominant orientation of the dykes is NE-SW which matches with the trend of Narmada-Tapi Dyke Swarm. The study describes the evidence of 'deformations (off-set)'. The deformations in the dykes are 'non-tectonic' (the off-set in dykes is attributed to the mechanical contrast of the associated rock types) as well as 'tectonic' (displacement along fractures). The deformations observed at Aurangabad and present study area, are primary (non-tectonic) and secondary (tectonic) deformation. This zone, a stretch of ~ 65 km is designated as Central Deccan Volcanic Province Deformation Zone (CDVPDZ).***

Keywords: Dyke swarm, deformation, Deccan basalt, Vaijapur-Gangapur, Aurangabad

1. Introduction

Deccan Volcanic Province (DVP) is studied by various researchers earlier and found three major dyke swarms in Deccan traps (Auden 1949; Vanderkluysen et al.2011). In addition to these three major dyke swarms in DVP recently mini-dyke swarm' is reported from South East Deccan Volcanic Province from Nanded region by Kaplay and Wesanekar (2014). Small feeder dykes are also reported from Nanded region (Kaplay et al. 2017c). Karmarkar and Muley (1977 and 1978) also reported occurrence of dykes from Aurangabad region in a brief manner. Recently, the dyke swarm is reported from Central Deccan Volcanic Province near Aurangabad by Babar et al (2017a). Dykes from Deccan trap are reported from Nandurbar (Gautam Gupta et al 2012 and Wagh et al 2013) and Dhule (GSI 2001; CGWB 2009, Pawar, et al 2009).

Aurangabad dyke swarm consists of seventeen dykes, these dykes are mostly vertical and are arranged almost parallel to one another. They are trending in NE-SW direction. These dykes are probably intruded along the pre-existing sets of joints (Babar et al.2017a). Babar et al (2017a) reported that Aurangabad dykes show primary deformation in the form of offset of dykes and deformed vesicles. Secondary deformations in the form of kinking and offset along fractures are also reported from Satara dyke in Aurangabad region. This formed the motivation to carry out the work on the similar lines in the vicinity of Aurangabad region. We selected Vaijapur region from where dyke swarm (Fig. 1) is reported earlier (Chande 1985).

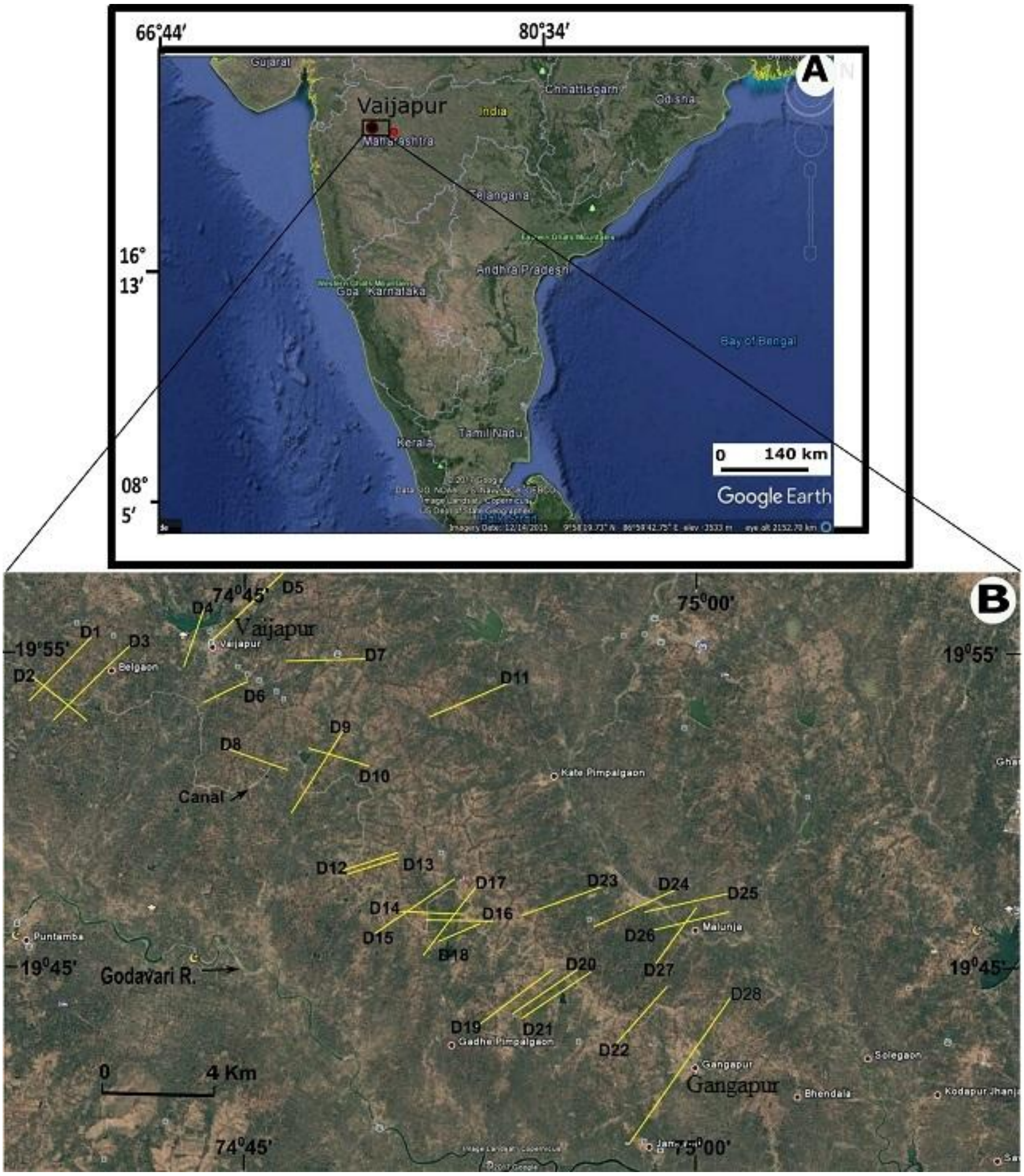

Figure 1 A: Location map of the study area. Dark black circle is the study area – Vaijapur-Gangapur. Small red circle is Aurangabad city in the state of Maharashtra. Fig.1B. Trend of dyke swarm in the study area – Vaijapur-Gangapur of Aurangabad district (modified after Chande, 1985).

Field features of dykes

We observed as many as 28 dykes in Vaijapur-Gangapur region of Aurangabad district (Fig.1 and Table 1). The dykes vary in width from 1.5 m to 18.0 m. The length of the dyke varies from 1.73 Km to 6.27 Km (Table 1). The dykes trend in NE-SW as a dominant direction (i.e. out of 28 dykes, 23 dykes trend in NE-SW direction, 1 in E-W and 4 in NW-SE direction). The dykes run sub-parallel to one another. The trend of the dyke matches with that of the dykes from Aurangabad Dyke Swarm (Babar et al 2017a), Narmada-Tapi dyke swarm (Bhattacharji et al.1996; Melluso et al.1999; Ray et al. 2007) and Nandurbar dykes (Deshpande, 1998 and Wagh et al 2013).

All the dykes show horizontal columnar jointing pattern, which is typical of dykes. Joint sets are developed perpendicular to the cooling surfaces this is attributed to the tensional stress developed during contraction of the magma. These type of joints spread inward from the cooling surface (Grossenbacher and McDuffie 1995; Cas and Wright 1996; Robert and Allen 1997; Simon and Conrad 2008). Hence, these joints are ‘cooling joints’.

Almost all the dykes show sharp contact with its host rock, although the contact surface is irregular in many cases. As the basaltic dykes have intruded basaltic host rock, hence the identification becomes difficult. We could identify these dykes with ease as all these dykes show horizontal and closely spaced columnar jointing pattern. During fieldwork around Vaijapur area, we observed that some of the dykes show offset which are described below.

At Tidi village a compact basalt (porphyritic) dyke (D7; marked as 'a' in Fig.2) in compact basalt host rock (b) is showing offset at the contact of compact basalt with red tachylite (c). The offset (0.6 m) of dyke is towards its left. As the offset has occurred along the contact of two different types of rocks it is attributed to different mechanical properties of two different types of basaltic rocks. It may be noted that red tachylitic basalt (c) is soft as compared to compact basalt (b). The offset is considered as primary deformation. Horizontal columnar joints are developed within the dyke however owing to weathering they are not prominently seen, particularly at the top portion of the dyke.

Table 1: Information of dykes at Vaijpur and Gangapur areas of Aurangabad district (modified after Chande 1985)

Dyke No.	Locality	Trend direction	Thickness (m)	Length (Km)	Lithology
D 1	Canal at Belgaon	$N40^0E$	10.20	3.33	Coarse grained CPB
D 2	Canal at Belgaon	$N40^0W$	3.00	2.40	CPB
D 3	Canal at Belgaon	$N45^0E$	5.00	4.05	Black CPB
D 4	Chandgaon	$N10^0E$	4.40	2.13	CAB
D 5	Vaijapur to Rotegaon	$N30^0E$	4.00	3.98	CPB
D 6	Gahegaon	$N60^0E$	6.00	1.73	CPB
D 7	Tidi	E-W	2.50	2.80	CPB
D 8	Canal at Mhaski	$N65^0W$	2.50	2.32	Black CPB
D 9	Chor Vaghalgaon	$N30^0E$	3.00	3.46	CAB
D 10	Near Sirasgaon	$N80^0W$	3.50	2.26	Fine grained CPB
D 11	Bhagur-Palkhed road	$N70^0W$	2.50	3.07	CPB
D 12	Canal at Mahalgaon	$N60^0E$	18.00	2.10	CGD
D 13	Canal at Mahalgaon	$N60^0E$	15.00	1.92	CGD
D 14	Canal at Panvi	$N80^0E$	4.00	2.67	CAB
D 15	Canal at Wakti	$N60^0E$	2.00	3.40	CPB
D 16	Canal at Wakti	$N80^0E$	1.50	2.38	CAB
D 17	Canal at Varkhed	$N70^0E$	2.40	3.95	CPB
D 18	Canal at Varkhed	$N60^0E$	2.00	1.60	CPB
D 19	Canal at Wahegaon	$N60^0E$	1.60	3.32	CPB
D 20	Canal at Wahegaon	$N60^0E$	1.80	2.75	Compact basalt
D 21	Canal at Wahegaon	$N60^0E$	3.00	2.90	CAB
D 22	Manjri	$N50^0E$	3.60	2.86	CPB
D 23	Shingi	$N80^0E$	12.80	3.02	CPB
D 24	Branch II of canal SE of Shingi	$N70^0E$	2.20	3.12	CPB
D 25	Branch II of canal SE of Shingi	$N80^0E$	15.20	2.92	CPB
D 26	Branch II of canal SE of Shingi	$N80^0E$	1.80	2.72	CPB
D 27	Branch II of canal SE of Shingi	$N30^0E$	12.50	2.44	CPB
D 28	Nawabpur village near Gangapur	$N45^0E$	13.00	6.27	CPB

CPB= Compact porphyritic basalt CAB= Compact aphanitic basalt CGD=Coarse grained doleritic

One more compact basalt dyke (a) is displaced towards its right by an amount of about 0.2 m at the contact of compact basalt (b) with green tachylitic basalt (c). The displacement of dyke No. D10 (Fig.3A and B) is not along any fracture hence cannot be considered as secondary deformation. However, it may be noted that dyke (a) has cut through the green tachylitic basalt (c) and after crossing the green tachylitic basalt dyke is displaced. It is primary deformation. The dyke (a) shows development of horizontal columnar joints within it (Fig.2 B).

The dyke (D15, marked as 'a' in Fig.4) at Wakti shows offset of 0.5 m at f1-f1 and 0.2m at f2-f2. The compact basalt (porphyritic) dyke (a) has intruded the amygduloidal basalt (b). At f1-f1 irregular curvilinear fracture has cut through the entire dyke and propagated into host rock. Similar feature is observed at f2-f2, here almost straight regular fracture has cut through the entire dyke and continued into host rock. Hence, this deformation may be considered as secondary and attributed to tectonic activity.

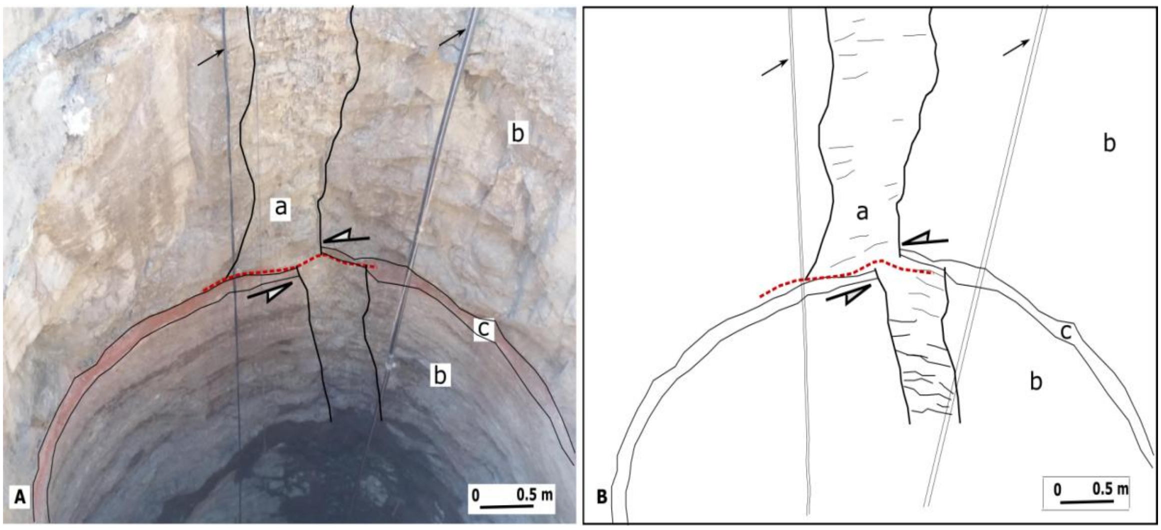

Figure 2 A: Basaltic dyke (a) in compact basalt ('b') showing deformation along the 'Paleosol' (c). Well section at Tidi, Vaijapur. White half headed arrows indicate offset. Small black headed arrows shows cables and wires used for pump in the well. B – Sketch of Fig.A, shows horizontal sets of joints within the dyke (a). Please note that the joints are not prominently seen, particularly at the top, as the section is weathered.

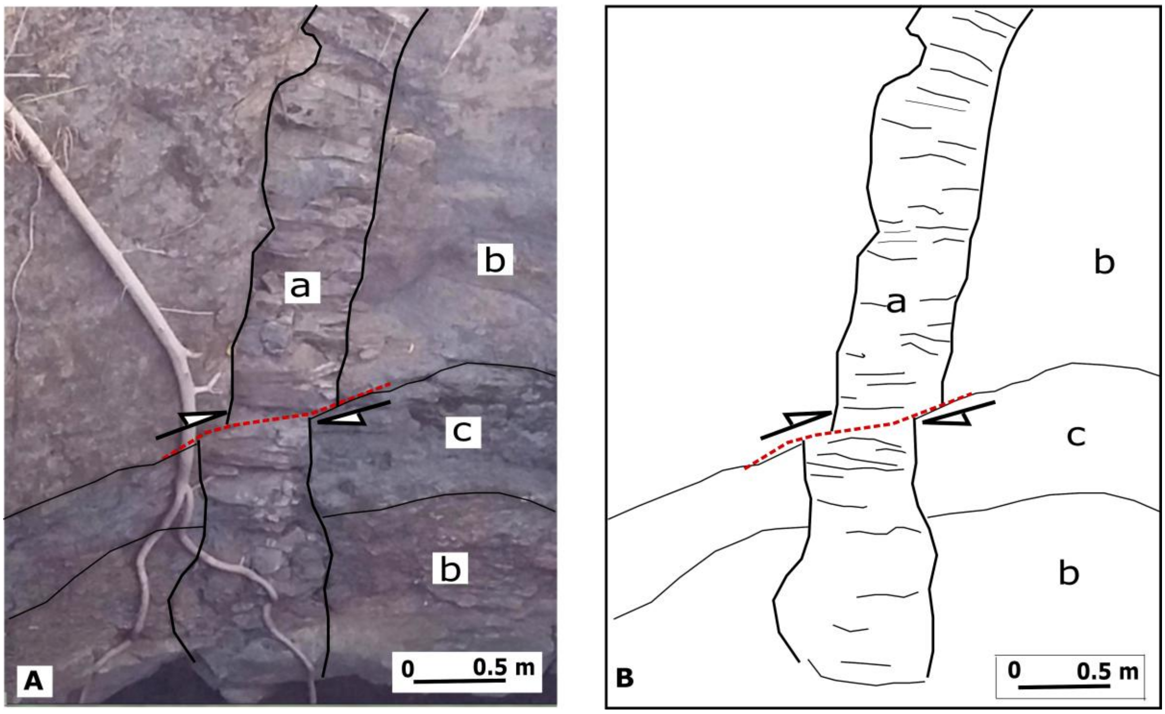

Figure 3 A: Off-set in dyke D10 (a) in the host rock compact basalt ('b'). 'c'- Dark green Tachylitic basalt. B – Sketch of Fig. A. Dyke (a) showing horizontal columnar joints within it observed at Chorvaghalgaon village

Most of the dykes show horizontal sets of columnar joints but the direction of the columnar joints within the dyke from Wakti changes from ~ horizontal to 40° (dotted ellipse in Fig.4 A and B). This change in direction point out that the there is shift in the orientation of the cooling front. Similar type of change in the direction of columns within the dyke is observed in Aurangabad dyke (Fig.6 of Babar et al 2017a).

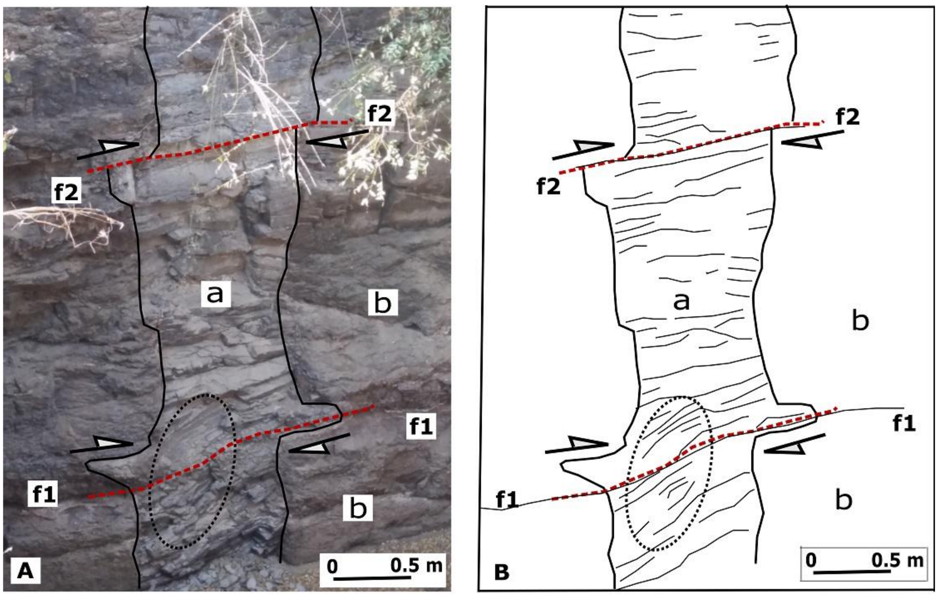

Figure 4 A. Compact porphyritic basalt dyke (a) in host rock amygdulodal basalt (b) showing offset at 'f1-f1' and f2-f2. At f1-f1 dyke has sent offshoot (initiation of sill) in opposite direction. Change in orientation of horizontal column to dipping column (40°) is shown in dotted ellipse. B – Sketch of dyke (a) showing horizontal dykes within it. Dotted ellipse shows shift in the direction of columnar joints from horizontal to inclined (40°) in nature. Well section at Wakti village in Vaijapur Taluka

One more dyke No. D9 (a) intruded in compact basalt (b) shows offset (Fig.5). The top portion of the dyke is found shifted towards left. However, the offset is not along the contact of two different rocks. In fact, in this case host rock is single host rock i.e. compact basalt. The offset is seen to have taken place along a fracture (f-f in Fig.5) that runs through the dyke entirely; hence, this deformation can be called as secondary deformation and may be attributed to tectonic activity. The dyke, like all earlier dykes, shows typical horizontal columnar joints within it (Fig.5B).

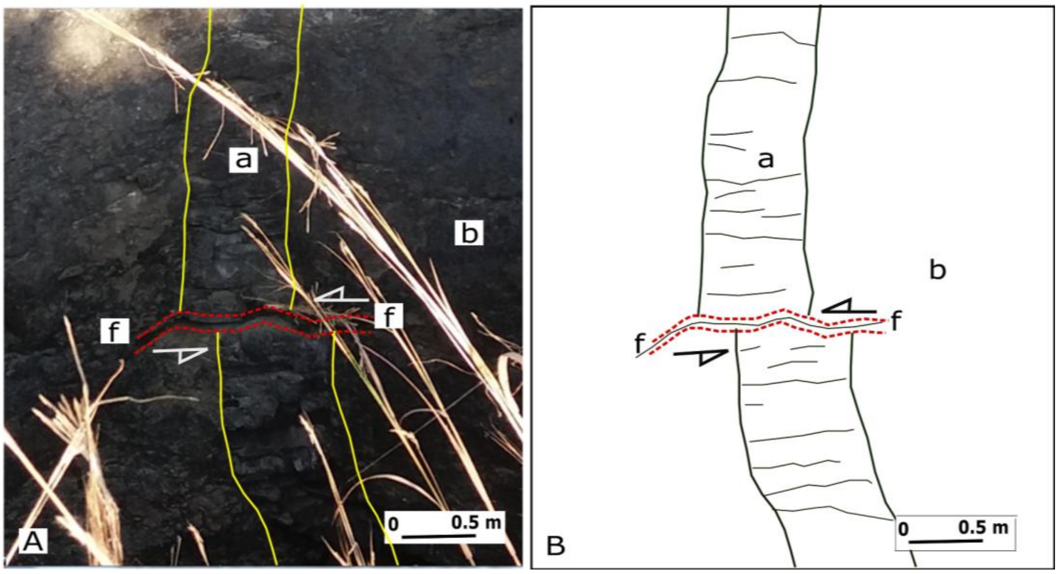

Figure 5 (a): Compact basalt dyke D9 (a) within compact basalt host rock (b) shows offset along a fracture that cuts through the dyke entirely. B – Sketch of the displaced dyke showing horizontal columnar joints within the dyke found at Chorvaghalgaon village

2. Discussion

We designate the group of dykes at Vaijapur-Gangapur as 'Vaijapur-Gangapur Dyke Swarm'. This dyke swarm is the part of 'Central Deccan Volcanic Province. The field features and the provincial en-échelon distribution of most of the dykes suggest that the 'Vaijapur-Gangapur dykes', like 'Aurangabad dykes', were injected along pre-existing fractures. Majority of the Vaijapur-Gangapur dykes (i.e. >82%) trend NE-SW direction. These dykes, like Aurangabad dyke swarm, are basaltic in composition. Just like Aurangabad dyke swarm, these dykes also show typical horizontal sets of columnar joints. The boundary of the dyke with the host basaltic rock is sharp. Most of the dykes are well exposed in 'dug-wells' and 'canal sections'.

Dykes usually get displaced across the layers of contrasting mechanical (rheological) properties (Gudmundsson and Brenner 2004). We observed similar type of displacements (offset) in dykes at many places in Vaijapur area (e.g. Fig. 2 and Fig. 3). Such type of displacements is probably related to the mechanical weakness along the contact of two flows. The displacements of dykes therefore, is attributed to abrupt change in rigidity of two different flows of basalts like the one in Fig.2 where the stiffness of red tachylitic basalt (c) and compact basalt (b) is abruptly changed. Fig.3 also show offset of dyke as the dyke crosses the green tachylitic basalt. In this case, like in Fig.2, one rock (green tachylitic basalt) is soft as compared to the other rock (compact basalt). This type of offset is attributed to contrasting mechanical properties of two different types of rocks. Such types of stress variation at local level are usually unfavourable for the propagation of dyke arrest (Gudmundsson and Brenner 2004). However, dyke arrest is not observed in the study area. Dyke arrest was also not observed at Aurangabad (Babar et al 2017a).

Babar et al (2017a) reported primary structures in the form of offset in dykes, bent pipe-vesicles, feeder dykes and finger like projections of dykes from Aurangabd dyke swarm, which is about 65 km East of the present study area. They also reported secondary deformations, in the form of kinking, offset along fractures from Aurangabad dyke swarm. We observed primary deformations in the form of offset of dykes in the study area along the stratigraphic break, similar to that of the Aurangabad dykes. However, we did not observe bent vesicles, feeder dykes and finger like projections of dykes in the study area. The occurrence of ‘feeder dyke’ in Aurangabad region (Fig.16 of Babar et al 2017a), perhaps suggest that Aurangabad region (~ 65Km east of present study area) was also one of the ‘eruptive centre’ for the formation of Deccan Trap. Feeder dykes are also reported from other parts of Deccan trap like Nasik (112.3 km west from present study area), Pune and coastal region (Widdowson et al.2000; Bondre et al.2006; Hooper et al. 2010; Vanderkluysen et al. 2011). We tried to find out such feeder dykes in Vaijapur region, but we did not come across any such feeder dyke. Probably Vaijapur region is not the eruptive centre like Aurangabad region.

The dykes in Vaijapur area, unlike Aurangabad dykes which show kinking in horizontal column (Fig.18 of Babar et al 2017a), show horizontal columns without any development of kink. However, we did observe displacement of dykes along fractures (Fig.4 and Fig.5). The deformation is not observed along the contact of two rocks of contrasting mechanical properties. In fact, in these cases, the host rock is of only one type. This is secondary deformation, which is attributed to tectonic activities, as the displacement in these two cases is observed along the fractures that cut through the dyke. Therefore, the study carried out so far does suggest that Vaijapur region has witnessed episode of tectonic deformation too.

Nanded region (SEDVP and margin of SEDVP with EDC) shows evidence of tectonic deformation (Fig. 6). The study carried out in recent times (Kaplay et al 2017a,b,c and 2018) suggests that the Kinwat, Bhaisa, Adampur region is tectonically deformed. The study carried out by Babar et al (2017b) suggests that Degloor region is tectonically deformed. Thus the region in and around Nanded and along the boundary of SEDVP with EDC (from Kinwat to Degloor) is tectonically deformed. Similarly, study carried out by Sangode et al (2013) near Kaddam and study carried out by Rajendran (1997), Sukhija et al. (2006) and Babar et al. (2012) near Killari suggest that the Kaddam region and Killari region are tectonically deformed. Thus Killari-Nanded-Kinwat-Kaddam-Degloor region can be categorised as ‘Tectoncially Deformed Zone’ (marked as white dashed ellipse in Fig.6). Nevertheless, a structural geology study along the patches from Killari to Nanded, Kinwat to Bhaisa and Degloor to Killari (marked as question marks in Fig.6) need to be carried out. In this tectonic deformation zone (in and around Nanded region), no evidence of primary deformations are reported so far.

Apart from these, there are no reports of tectonic deformations from CDVP and SEDVP. It may be noted that one noteworthy normal fault structure is observed in the crater wall of Lonar Crater (Adam et al 2010) near Lonar village in Central Deccan Volcanic Province (marked as red arrow in Fig.6), however it is not certain whether this normal faulting occurred immediately after formation of crater or subsequent to the formation of a crater. Adam et al (2010) also reported recumbent folding, parasitic folds, and reverse stratigraphy in Lonar. However, these structures (folding and faulting) are attributed to meteorite impact rather than tectonic activity.

The CDVP near Aurangabad and Vaijapur shows evidence of primary deformation (in the form of offset of dykes along stratigraphic break) and few secondary deformations (in the form of ‘kinking of horizontal columns in dykes’ and ‘offset of intrusions’ along fractures from Aurangabad region by Babar et al (2017a) and displacements of dykes along fractures in Vaijapur region). We choose to call this zone, a stretch of ~ 65 km, as ‘Central Deccan Volcanic Province Deformation Zone’ (CDVPDZ). This zone shows evidence of both ‘primary’ and ‘secondary deformation’. This zone is different than ‘Tectonic Deformation Zone’ near Nanded where tectonic deformations are reported with no evidence of primary deformations. At Lonar deformations are attributed to meteorite impact.

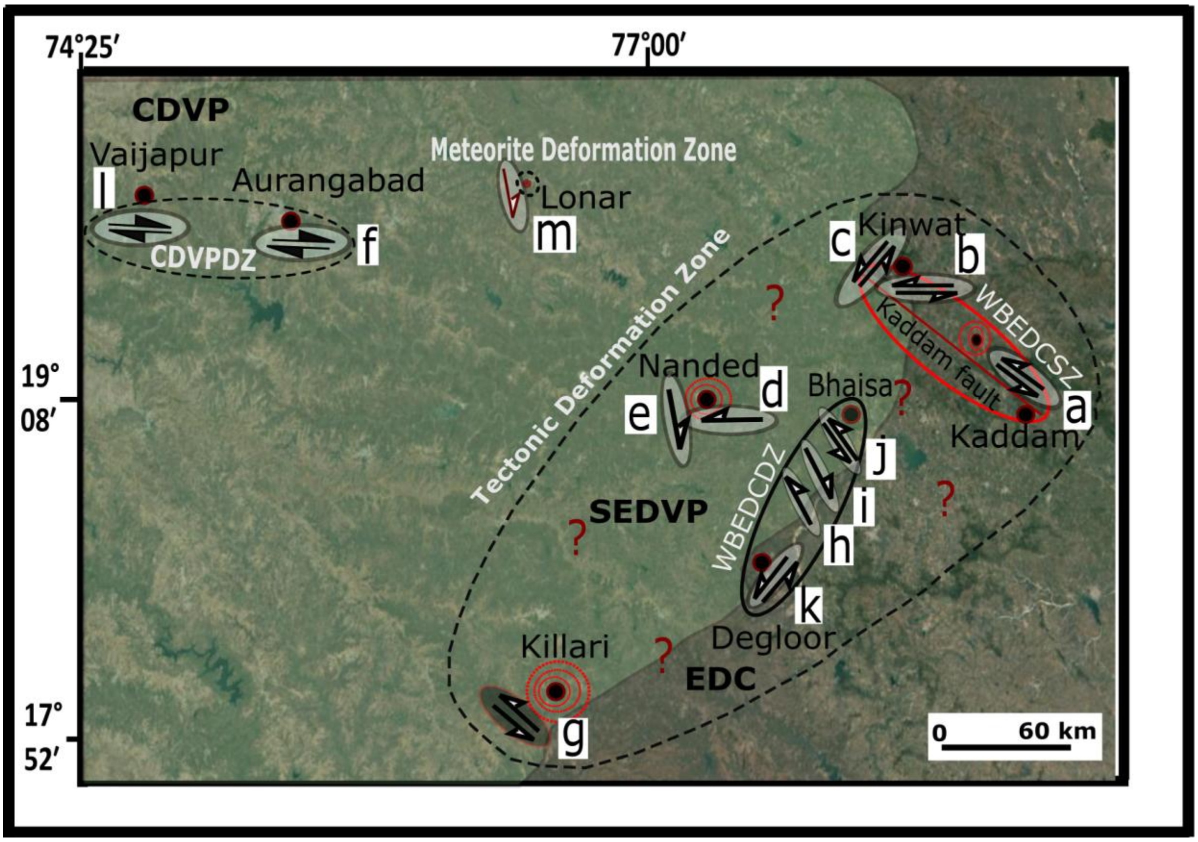

Figure 6: Summary of our recent structural geology work ('b', 'c', 'd', 'e', 'f', 'g', 'h', 'i', 'j' and 'k')) in and around Nanded and related work ('a' and 'g') carried out by other workers. 'a' – NW-SE strike-slip faults near Kaddam (Sangode et al.2013), 'b' - ~E-W trending Strike-slip faults in granites near Kinwat (Kaplay et al. 2017b), 'c'- NE-SW trending Strike-slip faults (in granites) NW of Kinwat (Kaplay et al. 2019), 'd' - West verge thrusts (in Deccan trap) in intracratonic microseismically active Nanded city (Kaplay et al 2013), 'e' – steeply dipping normal faults (in Deccan trap) in Nanded (Kaplay et al 2017a), 'f' – offset of dykes (in Deccan trap) presumably caused by local stress in Aurangabad city (Babar et al 2017a) and 'g' – a 'slow-deforming non-rifted zone (intracratonic seismicity) (Rajendran et al 1996). 'SEDVP' – South East Deccan Volcanic Province. 'EDC' – East Dharwar Craton. 'WBEDCDZ' – West Boundary East Dharwar Craton Deformation Zone (Kaplay et al 2017b), which includes 'EDMDZ' where 'EDMDZ' indicates East Dharwar Margin Deformation Zone, reported by Kaplay et al (2017b). White half headed arrows indicate deformation style of the faults. Black half headed arrow indicates offset direction of dykes in Aurangabad and Vaijapur region. 'h' – NW-SE reverse faults, 'i' – Normal faults, 'j' - NW-SE trending strike-slip faults, 'k' – NE-SW trending strike-slip faults near Degloor, 'l' – primary deformation at Vaijapur, 'm' – meteorite deformation (normal fault) at Lonar (Adam et al 2010). Red dash circles indicate seismicity/microseismicity. 'CDVPDZ' – Central Deccan Volcanic Province Deformation Zone marked as black dashed ellipse. White dashed ellipse – tectonically deformed zone.

3. Conclusion

The 'Vaijapur-Gangapur Dyke Swarm' is located in the 'Central Deccan Volcanic Province. The field features, the provincial en-échelon distribution of most of the dykes suggest that the 'Vaijapur-Gangapur dykes' were injected along pre-existing fractures. The dykes near Vaijapur show offset along the contact of the stratigraphically two different types of basalt i.e. compact basalt and amygduloidal basalt.

The general direction of these dykes (i.e. NE-SW) match with the orientation of the 'Aurangabad Dyke Swarm', 'Narmada-Tapi Dyke Swarm' and 'Nandurbar Dykes.

The offset of the dyke along the vicinity of the stratigraphic joint is the major one. This offset possibly developed due to stress barriers related to abrupt variations in rheological properties between porphyritic basalt and amygdaloidal basalt, compact basalt and red tachylitic basalt and compact basalt and green tachylitic basalt.

The Vaijapur Dykes like Aurangabad dykes show offset, which is a primary deformation. It also shows evidence of tectonic deformation zone therefore the zone is designated as Central Deccan Volcanic Province Deformation Zone (CDVPDZ). This zone is different from the 'Meteorite Deformation Zone' around Lonar and 'Tectonic Deformation Zone' in SEDVP region around Nanded and SEDVP contact with EDC.

Detailed structural, petrographic, petrochemical studies of Vaijapur-Gangapur dykes are warranted to bring out the complete geological picture of the region.

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