Field geology, petrography, and orthopyroxene clusters of the Dhule–Parola dike, Tapi valley, central Deccan basalt province

S. Keshav[1], H. C. Sheth[1] and D. Chandrasekharam[1,2,*]

[1]Department of Earth Sciences, Indian Institute of Technology, Powai, Bombay 400 076, India
[2]Centro di Studio per la Mineragenesi e la Geochimica Applicata, via La pira 4, 50121 Florence, Italy

The >40 km-long, E–W-trending Dhule–Parola multiple dike marks the southern limit of the Tapi rift. It is made up mainly of an aphyric and a plagioclase (pl)-phyric dike, with large loose boulders of dioritic gabbros. Unlike a previous report, we have found no clearcut basement xenoliths in it. In the pl-phyric dike, the groundmass plagioclases are more calcic (An_{89-92}) than the phenocrysts (An_{82-85}). This unusual phenomenon indicates contamination or magma mixing. An interesting observation is the presence of orthopyroxene clusters in the pl-phyric dike. Each of these clusters comprises hundreds of microscopic, individual orthopyroxene crystals. Except from Shirpur, in the same general area as that of the present study, the development of such puzzling clusters is not yet reported from basalts of the entire Deccan province.

WE have mapped and sampled a >40 km-long Deccan Trap dike between Dhule and Parola in northern Maharashtra, parallel to the Narmada–Satpura–Tapi regional tectonic trend (E–W). This dike is apparently the southernmost member of the major E–W-trending dike swarm in this region, and thus marks the southern limit of the Tapi rift. The presence of basement xenoliths in this dike has been briefly mentioned by Guha[1], who however did not mention their lithology. Over vast areas of the Deccan the basement is completely covered by the basalts; and hence xenoliths, if found in the Deccan flows or dikes, would provide invaluable information. At present such confirmed xenolith occurrences are few (e.g. lithospheric mantle xenoliths from Kutch[2,3] and from Murud–Janjira[4]; crustal xenoliths from near Mahabaleshwar[5] and Mandaleswar[6,7]). Suspected basement xenoliths in dikes of Shahada and Shirpur[8] were later indicated to be of Deccan age (~ 65 Ma) based on ^{40}Ar–^{39}Ar radiometric dating[9]. With careful field observations they are now known to be simply the weathered remnants of a major, multiple Deccan dike[10]. Thus, as the scarcity of basement xenoliths in the Deccan has made them highly valuable, we made a detailed field and petrographic study of the Dhule–Parola dike, the results of which are reported here.

The physiographic expression of this dike is a ridge which begins 3 km north of Dhule town (20°54′N, 74°25′E) and runs for > 40 km eastward up to Parola (20°53′N, 75°07′E) (Figure 1). This dike is multiple and consists mainly of an aphyric dike and a plagioclase (pl)-phyric dike, intruded into a compound flow of pl-phyric basalt (Figure 2) which is *areally extensive* and shows an exposed thickness of up to 70 m near Dhule and near Parola. The dike is segmented. It appears that it was originally continuous, but right-lateral strike-slip faulting and erosion have produced its present segmented configuration. Right-lateral strike-slip displacement of older, E–W-trending faults and E–W dikes; along younger, N–S-trending cross-faults, has been previously noted and discussed by Guha[1]. Our observations match with those of Guha in this regard.

All along the dike large loose boulders are exposed and apparently these were described by Guha[1] as base-

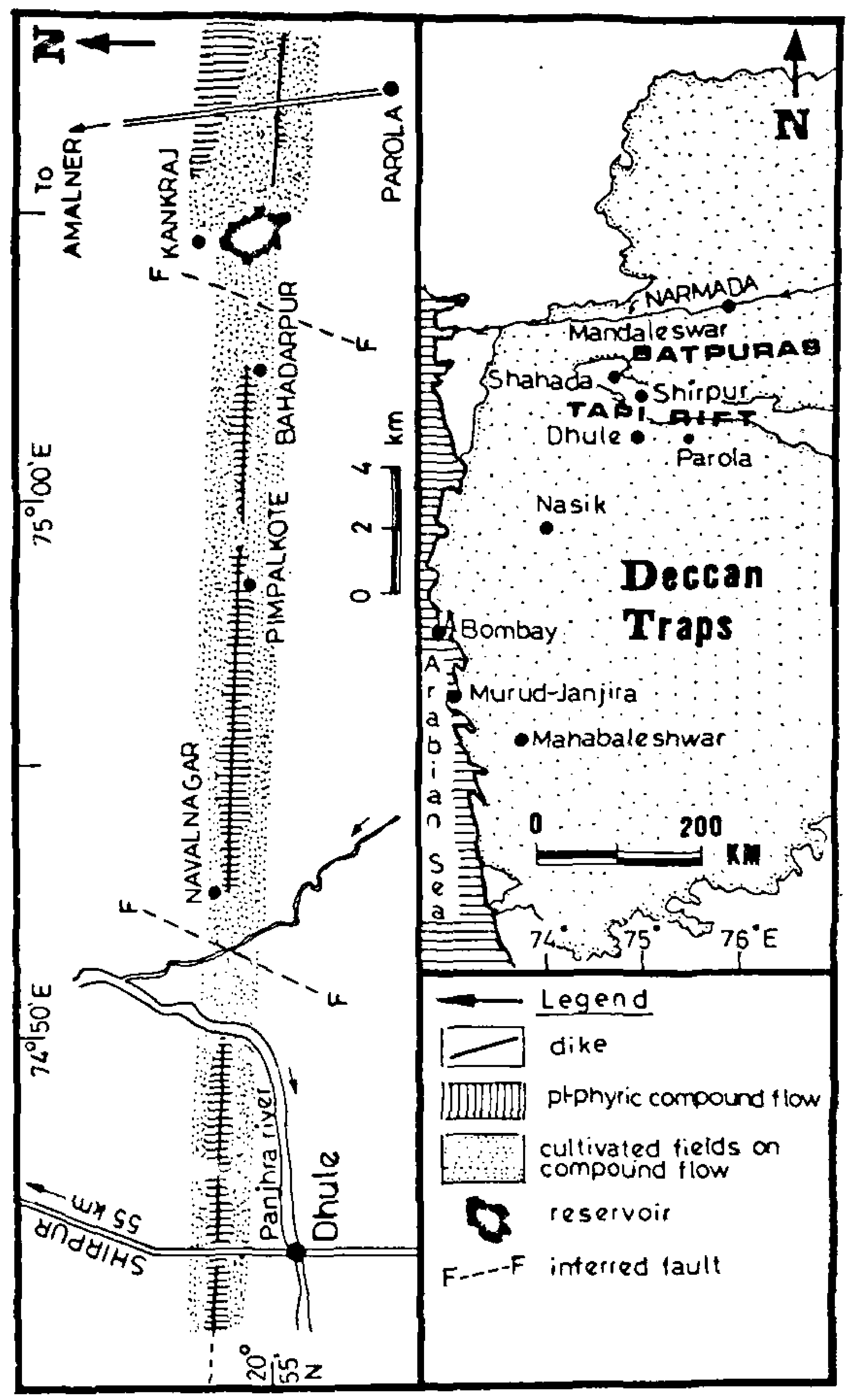

Figure 1. Geological map of the study area with the Dhule–Parola dike shown in black. The locations of Dhule, Shahada, Shirpur and Parola and some other important localities in the Deccan province, and the Tapi rift and the Satpura range, are also shown.

*For correspondence

ment xenoliths. However, petrographic studies[11] reveal that they are dioritic gabbros. This causes a doubt: are they real basement xenoliths of dioritic gabbro composition, contained in Deccan Trap dikes of crudely the same (doleritic–gabbroic) composition? (If so, how were they identified as older basement xenoliths, since to our knowledge, no radiometric dates exist for them?) Or, by analogy with a similar documentation from Shahada and Shirpur[10], do these doleritic boulders simply represent the weathered remnants of a Deccan Trap dike? (Note that the Dhule–Parola dike, like the Shahada–Shirpur dike[9,10], is a multiple one.) We consider this possibility as highly likely. Therefore, though in the absence of age data, the Dhule–Parola boulders cannot be ruled out as being basement xenoliths, we have still found no real evidence to designate them as basement.

Figure 2. Road cut near Navalnagar exposes the contact between the plagioclase–phyric flow (f) and the pl-phyric dike (d). The flow is distinctly compound, made up of a number of flow units. The dike shows crude, large blocky jointing in the interior part, but more perfect and smaller-scale blocky jointing along its chilled margin (shown by arrows). Keshav provides a scale.

Petrographically, the boulders are mainly composed of plagioclase (oligoclase-andesine, An_{10-50}), augite and titanaugite, with minor opaques. They are coarse grained with ophitic texture. The aphyric basalt dike has the same mineral assemblage as the boulders and differs from them in its fine grain size. The evolved plagioclase compositions suggest that the boulders and the aphyric dike can be termed dioritic gabbros. The Shahada–Shirpur dike[9,10] is precisely of this composition.

Mineral chemical studies were performed on samples of the pl-phyric dike (N4; Navalnagar segment) using an energy-dispersive spectrometer (EDS) coupled to a scanning electron microscope (SEM) at IIT. The studies showed that the groundmass plagioclases are more calcic (An_{89-92}) than the phenocrystic plagioclases (An_{82-85}). The phenocrystic plagioclases have the percentage composition $Na_2O = 1.36$, $Al_2O_3 = 24.67$, $SiO_2 = 59.23$ and $CaO = 14.74$, with negligible K_2O. The groundmass plagioclases have $Na_2O = 1.31$, $Al_2O_3 = 22.42$, $SiO_2 = 56.72$, $CaO = 16.70$, and $K_2O = 0.76\%$. This defies the general rule that in a solidifying magma the (early-formed) plagioclase phenocrysts are more calcic than the (late-formed) groundmass plagioclases. The phenocrysts appear to reflect some sort of contamination. They are either xenocrysts from the wall rocks (earlier basalt flows or

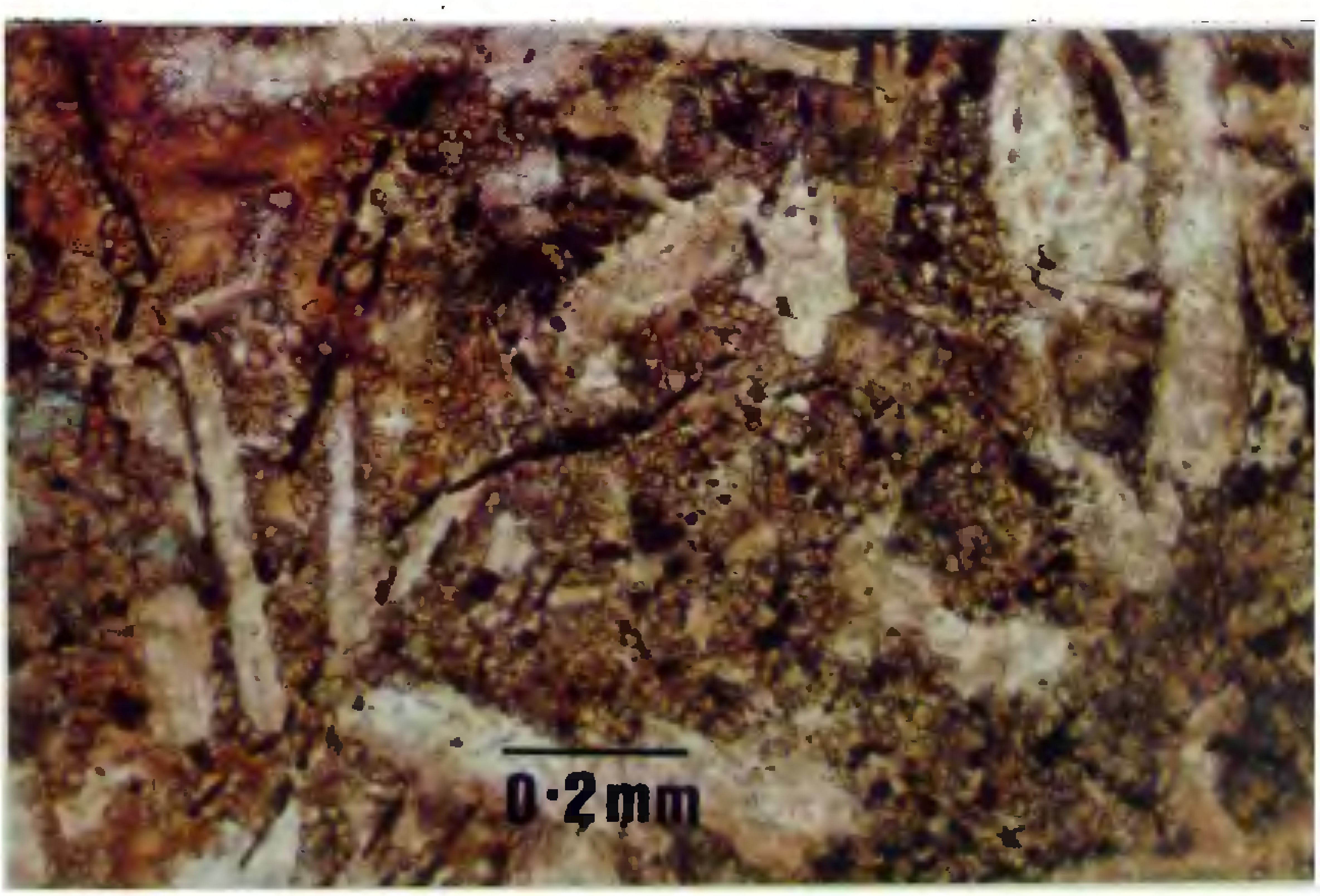

Figure 3. Innumerable microscopic, tubular grains of orthopyroxene-forming clusters (plane polarized light). White laths are of plagioclase, and black grains are opaque minerals. Sample N2 (plagioclase–phyric dike from Navalnagar).

basement rocks like anorthosites), picked up by the host basalt dike magma during ascent; or they represent magma mixing, wherein a primitive liquid with plagioclases having relatively high An content mixed with the evolved phenocryst-rich dike magma.

However, petrographically the most important finding has been the presence of microscopic clusters of apatite-like crystals. These clusters are mainly found in the interstices between groundmass plagioclase grains or sometimes within these grains. Each cluster contains hundreds of such crystals (Figure 3). Interestingly, very similar clusters have been recently known from a Shirpur area basalt dike[8,10]. The crystals forming these unusual clusters in the Shirpur dike and the Dhule–Parola dike were earlier thought to be apatite[8,11] on the basis of their needle- or tubular shape, transparency, and first order gray interference colour and straight extinction between crossed polars. However, ongoing electron microprobe studies at the Consiglio Nazionale Delle Ricerche (CNR) Laboratory, Italy, indicate that these crystals are *orthopyroxenes*[12], with which identification, the above-mentioned optical characteristics are consistent. To our knowledge, occurrence of such unique orthopyroxene clusters has not been reported from anywhere else in the entire Deccan province till date.

1. Guha, S., *Indian Miner.*, 1995, **49**, 61–78.
2. De, A., International Geological Congress Report, 22nd session, 1964, New Delhi, Pt. VII, pp. 126–138.
3. Krishnamurthy, P., Pande, K., Gopalan, K. and Macdougall, J. D., in *Deccan Flood Basalts* (ed. Subbarao, K. V.), Memoirs of the Geological Society of India 10, 1988, pp. 53–67.
4. Dessai, A. G., in *Deccan Basalts* (eds Deshmukh, S. S. and Nair, K. K. K.), Gondwana Geological Magazine, Special Volume 2, 1996, pp. 201–212.
5. Mahoney, J. J., in *Continental Flood Basalts* (ed. Macdougall, J. D.), Kluwer, Dordrecht, 1988, pp. 151–194.
6. Subbarao, K. V., Ramasubba Reddy, N. and Prasad, C. V. R. K., in *Deccan Flood Basalts* (ed. Subbarao, K. V.), Memoirs of the Geological Society of India 10, 1988, pp. 225–233.
7. Chandrasekharam, D. and Viladkar, S. G., Abstract in Geological Survey of Finland Special Paper, 1989, No. 8, p. 25.
8. Chandrasekharam, D., Mahoney, J. J. and Sheth, H. C., Abstracts, Vol. of Deccan'96 International Conference, 1996, p. 3; and Sheth, H. C., verbal comm. therein.
9. Sheth, H. C., Duncan, R. A., Chandrasekharam, D. and Mahoney, J. J., *Curr. Sci.*, 1997, **72**, 755–757.
10. Sheth, H. C., Ph D thesis in preparation, IIT Bombay.
11. Keshav, S., Unpublished M Sc thesis, IIT Bombay, 1997.
12. Chandrasekharam, D., Vaselli, O., Sheth, H. C. and Keshav, S., MS in preparation.

ACKNOWLEDGEMENTS. K. V. Subbarao and B. B. Rao provided valuable discussions, and K. Sundar and J. Talluri helped with SEM-EDS (to S.K.). The DST provided financial support to H.C.S. and D.C., and an anonymous referee made very helpful comments.

Received 6 August 1997; revised accepted 18 December 1997

Mud eruption in Elagiri region, Tamil Nadu, South Indian peninsular shield

SM. Ramasamy, C. J. Kumanan, R. Sivakumar, R. Mani*, E. B. Joyce[†] and Ian Bishop[‡]

Centre for Remote Sensing, Bharathidasan University, Tiruchirapalli 620 024, India
*Department of Geology, Annamalai University, Annamalainagar 608 002, India
[†]School of Earth Sciences, Melbourne University, Australia
[‡]Department of Geomatics, Melbourne University, Australia

The recently occurred mud eruption in Elagiri region, Tamil Nadu appreciably signifies the active tectonic movements along N-S trending lineament systems in South Indian peninsular shield. Such mud eruption warrants further detailed studies in the context of active tectonics and mid-plate seismicities in this area.

On 28 January 1997, Attanavur village (lat. 12°35′N, long. 78°36′E) located in the close proximity of the Elagiri plateau Tamil Nadu, South Indian peninsular shield was affected by thundering noise and fracture development for nearly 50–60 min in North–South direction (Figure 1). This activity was associated with an eruption of brownish mud. After three days of such activity, Ambur, Vaniyambadi and Tiruppatur (Figure 1) area felt mild earth tremors. The National Geophysical Research Institute, Hyderabad recorded earth tremors ($M = 3$) on 31 January 1997 in the above areas[1].

A field visit was undertaken by us nearly one month after the event. Most of the fracture length was filled, but a fracture length of 15–20 m in N–S direction with a number of branches (Figure 2 *e*) remained open. In and around the crack, mud-eruptive craters of varying dimensions (radius of 20–70 cm and a depth of 30 cm to 3 m) were present (Figure 2 *a–d*). In and around the craters, the mud was usually soft and loose and on applying pressure over the dry skin of the erupted mud with hands in one crater, the pressure was released with a bubble in the other nearby craters, which indicates their interconnections. In addition to the brown mud, there was a coating of blackish material, giving expression of burnt appearance (Figure 2 *c*), and also the mud had white clay particles.

The fissuring and eruption was located at the western fringe of the Elagiri Syenite plug (750 Ma), which stands raised as a plateau to an elevation of 1121 m above MSL. The slopes were filled with colluvial fill and debris wash material derived from the above syenite plug. As the source for the colluvial fill has been the Syenite, which is rich in feldspar, obviously such colluvial fill contains mostly whitish and brownish clay with pebbles and boulders. Further, the occurrence of a number of springs indicates the shallow water table conditions or the aquiclude behaviour of the groundwater.