DISCUSSION


S. Viswanathan, 10, Bapuji Apts., Rajendra Prasad Raod, Dombivli (East) - 421 201, comments:

I wish to offer a few comments on the above paper:
1. The exhaustive and painstaking exercise of Dr. K.S. Misra is commendable though it definitely needs a re-look to propose a sort of an arterial system of transport for the emplacement of the voluminous Deccan lava pile.
2. The image interpretation maps (Figs.1, 2, 3 and 5) do not indicate the details of the data source. Study area is not indicated in Fig.1. Latitudes, longitudes and major topographic contours could have been incorporated for better appreciation. At least part of the studied imagery could have been reproduced.
3. Does the author believe that the so-called tubes and channels are missing in areas outside the study area?
4. Around Dhule, the lava tubes are found at 650 m elevation in the west, 500 m in the centre and 300 m towards east (p. 117). For the same Dhule region, it is also mentioned (p.121) that tubes occur at 290 m and gradually get down to 228 m towards southeast. The author suggests step faulting towards east. If so, can the base of lava tubes be taken as a marker horizon? Then, how do these observations match with the detailed chemostratigraphy established for this region by earlier workers?
5. Lineaments indicated in the air photos or the imagery may represent fractures, faults or even dykes in the Deccan Trap terrain. This differentiation has not been attempted except for the lone appearance of a dyke in Fig.3. Some of the lineaments are perhaps prominent form lines.
6. Field photographs (Figs.4D & 4F) suggest pillow-like structures and the unique textures referred to are perhaps spilitic or non-spilitic pillow lavas.
7. The author mentions (p. 121) that the N-S large tube of Sutarvadi has formed along a zone of closely spaced oblique lineaments (fractures). Were these fractures formed earlier to the tube-formation or vice versa?
8. Are not the so-called tubes or pipelines of lavas just the large elongate cavities of escaping steam and gases?

K.S. Misra, Geological Survey of India, Alandi Road, Phule Nagar, Pune - 411 006. Email: gsi_pune@vsnl.com, replies:

1. I thank Dr. Viswanathan for finding this work to be an exhaustive and painstaking effort.
2. Data source for preparation of image interpretation maps Figs.1, 2, 3 and 5 on pages 116, 118, 119 and 122 respectively, were Indian Remote Sensing satellite images and aerial photographs and are described in the introduction section. Major rivers and localities are given in the maps and as suggested a part of image depicting typical remnant of lava tube/channel is reproduced (Fig. 1A) here.
3. No, the remnants of lava tubes and channels can be found within, as well as outside the studied area. Present work describes those remnants which have been identified during this study. Later work by the Geological Survey of India team has identified similar remnants within Malwa traps, north of Narmada river (Thorat, 2001).
4. Yes. The base of lava tubes and channels has been taken for elevation purposes. I am not aware of any chemostratigraphy established in Dhule area, so it cannot be correlated or commented.
5. The purpose of the paper was to describe the arterial system and only those lineaments and dykes which were relevant to the theme were discussed.
6. No. The field photographs (Fig.4D and F on page 120) do not display pillow structures and their details are described in the figure captions. A mosaic of micrographs depicting texture of tube filling material is presented (Fig.1B)
7. The lava tubes/channels appear to have formed along pre-existing topography which was also largely controlled by the faults and lineaments.
8. Steam and gases are expected to take shortest vertical route and will not form horizontal tubes and channels with vertically disposed levee portions.
Fig. 1. (A) Indian Remote Sensing satellite imagery of area NE of Ahmednagar near Satarwadi. Gently meandering ridge in the central part of imagery is a typical remnant of lava tube/channel within the Deccan volcanic terrain. (B) Mosaic of photomicrographs of nodular structure within the lava tube filling material. Large laths of plagioclase can be seen converging towards a common center with tapering ends. The central portion is occupied by small grains of plagioclase, pyroxene, olivine and opaque iron ores. Shearing along discrete planes can be observed. This unique texture has formed due to slow cooling of lava within the insulated lava tubes. (C) Field photograph of vertically disposed volcanic rocks representing levee portion of lava channel on the western side of Asoliya Dongar near Chandvad. (D) Field photographs of volcanic rocks forming the levee portion of lava channel. Fragments of different shapes and sizes can be seen agglutinated together. (E) Field photographs depicting thermal erosion. Flowing, hot molten lava has formed bowl shaped channels in the horizontally disposed solidified lava flow unit. Younger flows have occupied these depressions. (F) Field photograph showing lava channel emanating on the eastern side of the Asoliya Dongar. The lava channel has cut through the horizontally disposed flow unit. Indurated and reddened lava representing the levee portions of the channel is seen forming a ridge.
Gauri Dole, 238, Narayan Pehlu, Pune, 411 030. Ninad Bondre, 114 Shideler Hall, Department of Geology, Miami University, Oxford, Ohio 45056 USA. Raymond A. Duraiswami, A/6 Gurusud Housing Society, Srinagar, Kalewadi Phatta, Rahatani, Pune - 411 017 and Vivek S. Kale, Kalyani Neu Ventures Ltd., Pune, comment:

This interesting paper is a welcome addition to the sparse knowledge of the physical volcanology of lava flows in Continental Flood Basalt (CFB) provinces, particularly the Deccan Volcanic Province (DVP). In ancient provinces like the Deccan, the high degree of dissection and erosion makes it difficult to identify and study the structure and morphology of the lava flows. In the DVP, exposures of flows are restricted to low exhumed surfaces or vertical sections in almost inaccessible cliff faces; adding to the difficulties in documenting the morphological features of the individual flows and consequently on their emplacement mechanism. We compliment the author for the exhaustive and widespread observations recorded in this publication which obviously represent very extensive field studies supported by meticulous remote sensing interpretations.

While respecting the observations recorded in this paper, we differ on many aspects of the interpretations made. The following points need clarifications and we submit them with a hope that they will generate a discussion that will benefit not only us but also the geological fraternity at large.

The sinuous tube-like features, described in the paper seem to have been identified by remote sensing on the basis of their topographic expression. Having visited several of the “tube” exposures in question, we differ with the author. It is common to detect ghost patterns that appear like sinuous ridges caused by resistant spurs, originating at the footwalls in the Deccan uplands. These may be purely erosional features resulting from differential erosion of flows or may be related to flow emplacement (e.g. as at Songiri).

The larger dimension of the tubes/channels has been correlated to ‘very high effusive rate’ by the author. One would certainly wonder what the author implies by the interpretation of “high rates”. High rates of effusion will encourage erosion of the base of the tube and tubes may cut across several flows units. No such evidence has been presented in the paper. If such observations exist, they would be worth recording.

It is to be noted that most of the tubes recorded by the author in this paper are from an area which is known to be dominated by compound pahoehoe flows (Deshmukh, 1988). In fact, most of the key areas covered (barring the southern parts around Satara and Koyananagar) expose typical compound pahoehoe flow units. Pahoehoe flows are invariably emplaced at low effusion rates by endogeneous processes through the mechanism of inflation (Hon et al. 1994). Units in pahoehoe flows are therefore almost always preserved intact due to slow rates of lava influx so that heat loss is negligible (Cashman et al. 1994; Keszthelyi, 1994, 1995). Observations consistent with low volumetric effusion rates and endogeneous lava transfer have been recorded from the pahoehoe dominated parts of the DVP (Bondre et al. 2000; Duraiswami et al. 2001). Higher rate of lava effusion (Rowland and Walker, 1990) causes continuous disruption of the flow crust and allow the exposed core to lose heat quickly giving rise to “aa” type flows, analogous to the simple flows observed in the southern and eastern fringes of the DVP. The interpretation of ‘rapid’ emplacement by the author is therefore erroneous, unless it is in context of the large volume of eruptions recorded in the province in a small time frame of a few million years. The evidence for such an interpretation comes from geochronology, not physical volcanology.

The author is right when he points to the fact that in the DVP lava tubes are rare in the simple flows. However, he has provided a photograph of a lava “tube” within simple flows from near Koyananagar. From the photograph we decipher that this structure represents a ‘war bonnet’ structure. Similar structures are quite common in simple flows from other places too. The road section from Satara-Sajangad-Thosegarh exposes at least seven such structures varying in dimensions from a few metres to about 10 m across. Observations of such several complete and partial structures reveal a closely spaced, radiating jointing pattern towards the periphery with a massive or brecciated central region. Since most of the radiative cooling in the tube is towards the upper surface, a radial arrangement of the cooling joints is most unlikely.

Although the structure was previously believed to represent filled tubes (Waters, 1960), subsequent studies suggest that these structures represent either radial zones of quenching through isotherms wrapped around a linear point (e.g. water filled fracture) or a point cooling source (Justus, 1978; Long and Wood, 1986). Alternatively, they may also represent inward cooling of the last mobile portion of the lava flow (M. T. Murphy, as quoted in Greeley et al. 1998). In contrast, filled tubes are generally identifiable by their lenticular or elliptical cross sections and show a concentric
.variation in vesicularity and crystal size (Keszthelyi and Self, 1998). No such records have been made by the author in the present paper. The inference of the radially jointed sections as tubes is consequently not tenable. Such features are primarily cooling features and not lava transfer channels or tubes.

While describing the morphology of the tubes, no mention is made on the relationships of tubes with flow units/lobes in the area. As most of the above described areas are dominated by sheet lobes and are constituted of compound pahoehoe type lavas, the exact relationship of the lobes/flow units with these so-called tubes will be interesting to know. It is necessary to note at this stage that such lavas are characterised by “inflated” and updomed crusts of variable dimensions, not to mention the large and small tumuli (Keszthelyi and Self, 1999; Keszthelyi et al. 1999; Bondre et al. 2000; Duraishi et al. 2001). The author mentions the nodules and megacrystic material filling the tubes, but their origin, in terms of specific processes, has not been discussed.

The author has recognized lava “tubes” in the field by tabular outline and by the presence of reddened fragmentary material. Our observations (e.g. Mangave, 2001) suggest that reddened fragmentary materials (flow-top breccias in most cases) are encountered at several places in the Deccan and are closely associated with the ‘simple’ flows. Most of the ‘tubes’ recorded by the author are dominantly from compound (pahoehoe type) flow fields where such fragmentation of flow crust is almost negligible due to the slow rates of effusion. Localised duricrust of such weathered flow units can often be mistaken for ‘fragmentary material’, but the fragmentation is not the inherent character and may be a result of weathering.

The dykes and lineaments mentioned in the paper add to the confusion. If the intention is to use them for tectonic interpretations (e.g. for proving block faulting), it would have been better to have delimited them from the “tubes”. In the present context, one is left wondering whether the author wishes to imply that the emplacement mechanism and the tectonism went hand in hand. If so, the case is not convincingly made out.

It is weird to co-relate en echelon block faulting of the basement on evidences of (a) “tubes” having very low gradient in continuous outcrops, and (b) “tubes” are exposed at higher elevation in the western part of the study area and at successively lower levels in the east. We are sure that a better explanation can be offered to account for a general east-west direction of the tube-like features. One possible explanation to account for this typical pattern could be the general west to east slope of the palaeotopography due to the plume impact and the subsequent north south migration of the plume tract. This is well complimented by the disposition of the lava flows and the easterly flowing western drainage. Moreover, it suggests that the elusive vents or ‘source’ of the tubes could be in the western parts.

The area around Sangamner (in Fig.3 of Misra, 2002) is dominated by two sets of lineaments trending in NW and NE directions. According to the author, dykes are absent in this region. Our studies in this region indicate that number of dykes are present in this area. All dykes trend in NE-SW direction (Fig.1) and the fracture zones are oriented in NW-SE direction. The rose diagram (Fig.2) depicting the orientational distribution of all the lineaments in this area indicates that NW-SE orientational class forms the maxima. The NE-SW orientational class on the other hand is far less than sub-maxima. The NW-SE trending lineaments are fracture lineaments while those trending NE-SW are dyke lineaments (Bondre, 1999). Since the presence of dykes and their orientation reflects the syn- and/or post eruptive tectonic configuration at the time of eruption of the DVP, caution should be taken while mapping the lineaments using satellite data or aerial photos. It is very important to classify the lineaments either as fracture zone, dyke or fault, since each one of these structural features has its own implication.

We agree that the remnants of tubes may be affected by later tectonics, but the fact that dykes intrude the tubes (as mentioned in the paper) appears a bit out of place. It is likely
D I S C U S S I O N

Fig.1. Rosette diagram depicting the orientational distribution of all the dyke lineaments in the Sangamner area. N% is the upper half represents the number frequency of the lineaments and L% in the lower half depicts the length frequency of lineaments.

that a tube may develop within depressions along pre-existing lineaments and these very lineaments can be locales of dyke intrusion. If such were the case in the DVP, then it calls for closer examination and detailed investigation, because it would have serious implications on the eruptive history of the Deccan lava flows. If such were the case in the DVP, then it calls for closer examination and detailed investigation, because it would have serious implications on the eruptive history of the Deccan lava flows. While we do not discount the possibility of existence of tubes in the DVP, rather they are expected to be present, the descriptions given in the present paper (and our studies at some of the sites discussed by the author in this paper) do not appear convincing.

The issue of lava channels, lava tubes, emplacement mechanisms and the physical volcanology of the Deccan Traps deserve a lot more serious and dedicated effort. We record our appreciation of the efforts made by the author towards this goal, but fail to accept some of the conclusions drawn. Even a single, unambiguous, well-defined and studied tube would be of more importance than the regional brush used by the author.

K.S. Misra, Geological Survey of India, Pune, replies:

I am glad for the profuse appreciation of the work. The work is not only interpretation of remotely sensed data and topographic expression, but also backed by exhaustive field work which is described in figures and text. Geomorphic features which have no relevance to the theme have been eliminated during interpretation and ground truth collection. Differential erosion of flows will not give rise to induration, reddening and other physical volcanological features such as agglutinated levees, etc.

Very high effusive rate is believed to be responsible in formation of certain tubular structures having large dimensions and should not be construed for the huge sequence of compound flows or for the entire volcanic province. Evidences of thermal erosion at the base of lava tubes/channels is indeed recorded in the proximity of effusive centre (Fig.1E).

Converging pattern of columnar joints is seen along elliptical tubular outlines for quite some distances and upward converging columnar joints have also been observed not only along ‘war-bonnet’ structure, but also in other tubular structures described in the paper (Fig.4E on page 120).

Theme of the paper was to describe remnants of lava tubes and channels and their bearing on transportation of Deccan lavas. The author believes that a large portion of lavas forming compound (pahoehoe) flow units have been transported to long distances through these structures. Simple ‘aa’ flows have travelled to long distances through conduits, remnants of which are now present in the form of elliptical tubular outlines with converging columnar structures and they are described as ‘war bonnet’, (Waters, 1960)

The outline of lava tubes is tubular and not ‘tabular’ as understood by Dole et al. Ropy structures, lava toes, lobes and squeeze ups are features associated invariably with all the remnants of lava channels and tubes particularly in their basal portions. The huge thickness of fragmentary material associated along the lava channels and tubes negate the proposed contention of them being localized duricrust. The levee material described in the paper is hardened, reddened, agglutinated material which will not result from weathering.

Lineaments, faults and dykes are important tectonic features in the Deccan volcanic terrain. The development of geomorphological landscape including channels etc. is closely associated with them. The lineaments provide paths of least resistance to flowing water thus forming channels. These channels were later occupied by flowing lavas forming lava channels and some have later developed arched roofs forming lava tubes. This intimate relationship is described in the paper.

Differences in the levels of the base of the lava tubes and channels is reported since it forms an additional
evidence to support en echelon faulting. The analysis of lineaments and tectonics is discussed in detail separately (Misra, 2001).

Detailed description of single well studied tube is already given by Thorat (1996) and Sharma and Vaddadi (1996). The purpose of this paper was to report similar structures which are quite common within extensive Deccan volcanics.

Mapping of these remnants has helped in locating effusive center at Asoliya Dongar near Chandwad, where several lava tubes/channels are found to be emanating in different directions (Misra et al. 2001a). One such tube coming out on the eastern side is shown in Fig.1F.

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References


