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Spectacular Basalt columns of Panhala-Masai range, Maharashtra: a potential geoheritage site in the Deccan Traps

The ~65 Ma old Deccan Traps cover about 0.5 million km^2 in western and central India. The Deccan Traps region has huge geotourism potential with several potential geoheritage sites[1–3]. We report here the occurrence of spectacular columns in basalt near Bandivade village (16°49′18″N and 74°01′0″E), in Kolhapur district, Maharashtra (Figure 1). The locality is situated on the Panhala-Masai Range, about 22 km west of Panhala Fort and ~43 km from Kolhapur. At Bandivade, the stout, pentagonal basalt columns in different stages of disintegration are present (Figure 2 *a*). The columns rise above an east-west oriented low ridge (~850 m ASL), connecting two laterite-capped tablelands. Thick ferricrete (laterite) duricrusts cap the tablelands[4]. The tableland on the east is known as the Masai Plateau/Tableland (>950 m ASL). Stratigraphically, the columnar-jointed basalt flow occurs below the early Paleogene ferricrete duricrusts. This flow is nearly 80–90 m thick and consists of stout (diameter >1.0 m), pentagonal columns. The *in situ* ferricretes occurring on top of the Masai Tableland are developed in a protolith of Panhala Formation basalt of the Wai-Subgroup[5]. The basalt flow, with well-developed colonnade, thus, belongs to the Panhala Formation, one of the youngest formations of the Deccan Traps. Recently, the base of the Mahabaleshwar Formation of the Wai-Subgroup has been dated to 65.6 Ma (ref. 6). The flows of the Panhala Formation are younger than the Mahabaleshwar Formation and were emplaced during early Paleocene (Paleocene 56–66 Ma). Unlike Deccan flows in central India, well-developed, strikingly contrasted colonnade-entablature tiers are rare in the nearly ~2 km thick lava flows of Western Ghat Escarpment[3]. The Bandivade site, therefore, deserves greater attention from earth scientists.

Due to their remarkable polygonal pattern, columnar-jointed volcanic rocks have fascinated geologists in general and volcanologists in particular for a long time. To understand the process of their formation, field studies, laboratory experiments, and modelling have been undertaken by several workers and different

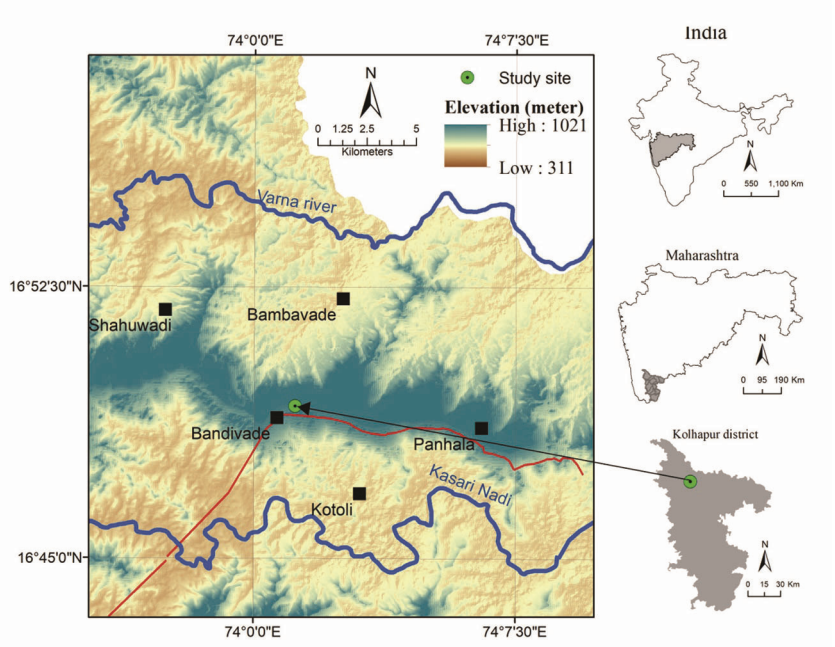

Figure 1. Map showing the location of the Bandivade site with the spectacular columns.

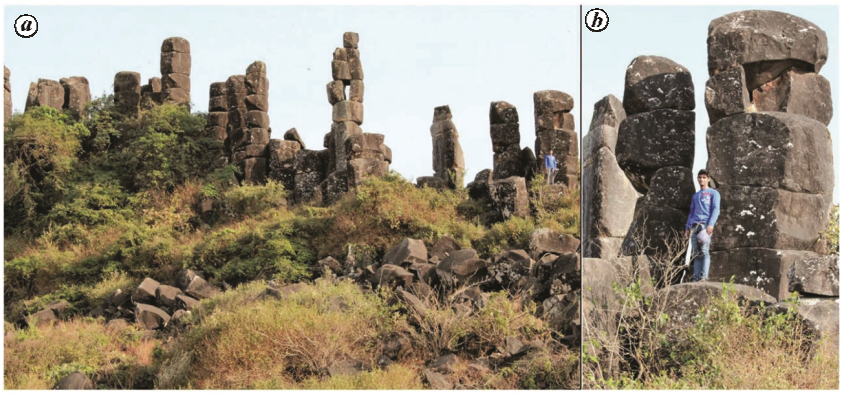

Figure 2. ***a***, A view of the pentagonal columns that have been isolated due to prolonged weathering and erosion along vertical joint planes. Toppled blocks of other columns are seen in the foreground. ***b***, Photograph of the pentagonal columns divided into distinct blocks due to secondary weathering and erosion along horizontal joint planes.

Figure 3. ***a***, Photograph showing the pentagonal shape of the column. ***b***, Photograph of the exposed unweathered pentagonal columns (~40–50 m in general) that are still connected and have undergone comparatively less weathering and erosion along vertical joint planes.

hypotheses have been offered[3,7–15]. The present understanding is that the polygonal or columnar jointing is favoured by non-equilibrium and inhomogeneous cooling[12]. Conductive cooling leads to thermal contraction and formation of polygonal joints[13]. The vital role of water in the formation of polygonal structures has also been recognized[12,14]. A recent experimental study has demonstrated that columnar jointing in volcanic rocks takes place well within the solid state[14]. Apart from differential cooling in sub-aerial lava flows, the magma chemistry is also considered critical in determining the stoutness of the columns[15].

To get some idea about the size (diameter) of the Bandivade basalt columns, the perimeter of more than a dozen pentagonal columns (Figure 3 *a*) was measured in the field. The perimeter was used to calculate the circumcircle radius and the incircle radius. The results show that the circumcircle radius varies from 0.65 to 0.92 m, and the incircle radius ranges between 0.52 and 0.74 m. The results indicate that the columns occurring at St Mary's Islands in Karnataka and exposed at many places in Deccan Traps are slenderer then the stout columns of Bandivade. This is the second reason why this geomorphosite deserves greater attention from earth scientists.

It is evident in the field that, erosion and stripping of the duricrust has exposed the underlying basalt flow with 'colonnade' with horizontal joints. The 'entablature' also appears to have been entirely eroded. Weathering and erosion was primarily concentrated along vertical joint planes, resulting in the widening of the joints. Unstable columns have intermittently collapsed, leaving behind isolated standing columns of different heights (1 m and >10 m). The exposed un-weathered columns further east are even taller, about 40–50 m in general (Figure 3 *b*). Due to secondary weathering along horizontal joints, some of the isolated columns appear to be made up of vertically stacked blocks (Figure 2 *b*). Some of the unstable blocks have slightly shifted or have toppled down and accumulated at the base of the low ridge on either side. The Bandivade site is as remarkable and scenic as the world famous Giant's Causeway[7] in Northern Ireland and St Mary's Islands[3] in Karnataka.

Needless to say, more studies are required to understand the site-specific characteristics of basalt flows and geomorphic factors responsible for differential weathering and erosion. Geological or geomorphological features of profound aesthetic appeal and geological importance or of intrinsic geological value fall under the umbrella of geoheritage. According to Brocx and Semeniuk[16], 'geoheritage encompasses global to local features of geology, at all scales that are intrinsically important sites or culturally important sites offering information or insights into the evolution of the Earth; or into the history of science, or that can

be used for research, teaching, or reference'. ProGeo, the European Association for the Conservation of the Geological Heritage, defines geoheritage as *in situ* elements (geosites) or *ex situ* elements (collections of geological specimens) with paleontological, geomorphological, mineralogical, petrological or stratigraphical significance, among others[17]. Thus, given the high aesthetic, touristic, educational and scientific value of these spectacular columns, this geologically significant site has all the potential to be recognized as a geoheritage site and deserves to be declared as a National Geological Monument.

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