by Kiran Shanker Misra

Comment on “Emplacement history and evolution of the Deccan Volcanic Province, India” by Kale et al. (2020)

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This paper is most welcome as it reviews the chemo-stratigraphic work done in western part of Deccan volcanic province. Significantly it highlights the futility of establishing chemo-stratigraphic units and their long-distance correlation. The paper is also a step forward to remove certain misconceptions such as, the idea of hot spot related volcanism during northerly movement of Indian plate. Furthermore, the authors agree with the (unreferred) series of earlier publications (Misra, 1981, 1999, 2001a, 2004, 2005, 2007, 2008a, 2008c, 2009b, 2013, Misra and Misra, 2010, 2016b), that the volcanism seems to be related with the major rift and grabens. These publications, describe the geological details obtained by extensive field mapping, assisted by aerial photographs and high-resolution satellite images, integrate with the interpretation of aeromagnetic and seismic data sets along with the logs of several hundred drill holes. This comprehensive study has enumerated several manifestations of prolonged extensional tectonics in peninsular India. The significant ones are development of rift and grabens, formation of pull-apart sedimentary basins, decompression melting, magma generation, widespread effusion and transportation of lava along with emplacement of dyke swarms and dykes. This has also brought out, that in time, the Cretaceous period is conspicuously marked by rampant and spasmodic volcanism in the entire Phanerozoic history of peninsular India. Most important information has come from the subsiding basins, where volcanic units are inter-layered with sediments and form unique volcano-sedimentary succession. This succession is represented by robust fossil record from the beginning to the end of Cretaceous. Since most of these basins are producing hydrocarbons and others have very high perspective, they have been explored in detail by innumerable seismic profiles, profusely drilled and logged by dozens of well site geologists (Fig. 1). The details of these logs, geological interpretations and compilations have been published and are available in public domain (Berger et al., 1983, Jagannathan et al., 1983, Roybarman, 1983, Misra, 2005, 2007, 2008c, 2018, Misra and Misra, 2010, 2013, Raju and Misra, 2009).

These drill hole logs have played very significant role in establishing the volcanic stratigraphy. Total thickness of volcano-sedimentary sequence, ranges between 250 to 350 m in different basins. Individual volcanic units are 20 to 35 m thick. However, the top most unit, before the end of Cretaceous is thickest and is best exposed in western India and is generally described as Deccan Traps. Since all the units are part of the same package of Cretaceous period, (Misra, 2001a, 2004, 2004b, 2005, 2007, 2008a, 2008b, 2008c) grouped all the units in time and space

and described them as Cretaceous volcanics. (Valdiya, 2010) also included all the volcanic outcrops exposed in different regions as Cretaceous volcanism.

Evidences suggest that the lava forming the volcanic units was generated due to successive decompression melting due to down ward propagation of vertical faults and eruption along developing rift and grabens. Room created by effusion of lava caused repeated subsidence and accompanying sedimentation. Cessation of profound extensional tectonics terminated rampant volcanism just before K-T boundary. In sedimentary basins and oceanic regions, the volcano-sedimentary sequence is well recognized by very prominent seismic signatures. Interpretation of innumerable seismic profiles demonstrated not only invariable presence of this sequence (Misra, 2016a, 2018) but also it forms the subsiding re-laid floor over which complete succession of Tertiary rocks has been deposited (Fig. 2).

Apart from this, detailed work (Misra, 2008c, Misra and Misra, 2010, 2016b, 2018) has highlighted the significant role played by the volcanism in formation, migration and preferential accumulation of hydrocarbons. During pre-eruption stage the upwelling heat distilled the source sediments, later developing cracks, fractures and inter-connected vesicles provided required porosity and permeability for migration and subsequent flows acted as important trapping mechanism by sealing the joints and fractures. Furthermore, these units have generated lot of interest, as they are themselves very good reservoir rocks and prolific producers of hydrocarbons. Padhra and Ingoli fields in Cambay, Raggeshwari in Barmer and Mandapetta in K-G basin are some of the best examples. The other important basins underlain by volcanic units and have giant oil and gas fields, are Barmer on land and Bombay High in offshore region.

On land, apart from the Deccan region of Maharashtra, prominent Cretaceous lava units are located in far off regions such as Saurashtra, Kutch and other parts of Gujarat; Malwa and Mandla regions of Madhya Pradesh; Rajmahal in West Bengal, Sylhet in Meghalaya, Rajahmundry in Andhra Pradesh and St. Mary's island in Karnataka, (Fig. 3).

From this distribution pattern it is clear that all these occurrences cannot be explained by the presence of a single hot spot, supposed to have moved linearly from north to south along the west coast of India, crossed over to Arabian Sea and passed through Maldives and Chagos group of islands, jumped over diverging Carlsberg ridge to Reunion island in southern Indian Ocean. Furthermore, to explain the Rajmahal and volcanic units on the eastern side of Peninsular India, one more

Figure 1. Generalized well logs of different basins added and modified after (Berger et al., 1983), Fig. 1A Off-shore Kutch, 1B On-land Kutch, Fig.1C. Off-shore Saurashtra, Fig.1D. Lakshadweep basin, Fig.1E Krishna-Godavari basin, 1F.Off-shore Mahanadi basin, 1G. Cambay basin, 1H Bengal basin, 1I Andaman basin. The volcanic units are marked in black, can be seen confined within the Cretaceous period only.

Kerguelen hot spot was suggested. Continued work (Misra, 2001a, 2005, 2007, 2008c) found no geological or geophysical evidences to identify required trail left behind by the hot spot. A hot spot responsible for such vast volcanism, generate magma at great depths and pumps it up, is expected to have left behind lot many evidences along its path. On the contrary, no disturbance to continuous older rift and grabens, sedimentary basins with uninterrupted succession, along proposed path are observed. Furthermore, successively younger vol-

canic units are neither observed nor logged in southerly direction. Rather as stated earlier, evidences suggest that most of the volcanism has taken place from beginning to the end of Cretaceous period. Thus, long duration and spasmodic nature of volcanism does not support the prevailing idea of fast-moving Indian plate over a hot spot. Cretaceous volcanism was also accompanied with widespread emplacement of dyke swarms, dykes and igneous complexes with varied chemical composition. Parallel disposition of dyke swarms as well as alignment of

Figure 2. Interpretation of seismic profile across Kerala basin. Cretaceous volcano-sedimentary sequence, sandwiched between deformed Mesozoic and uninterrupted Tertiary successions can be seen. Nearly vertical faults mainly deform the rocks up to the top of Cretaceous and gradually diminish in lower portion of Tertiary succession.

Figure 3. Map of Peninsular India and surrounding oceanic region, showing distribution of Cretaceous volcanic units on land, sedimentary basins, off-shore and oceanic regions.

complexes along the rift and grabens, illustrates genetic relationship (Misra, 2008a, Misra and Misra, 2016b) and also contradicts the hot spot idea.

Chemo-stratigraphic units were identified on the basis of very subtle and inconsistent variations in ratios of trace elements and extended to far off regions. Systematic field mapping incorporating physical volcanic features, petrographic details and chemical analysis, was felt necessary for establishing the sequence of events. Innumerable geologists of Geological Survey of India (GSI) took more than four decades to establish the volcanic stratigraphy. Quite curiously the identified lava formations correspond very well with the chemo-stratigraphic units. Greater challenge has come from the vertical tectonics. The basement underlying volcanic units is composed of fragmented blocks with considerable relative vertical movement (Ravi Shankar, 1995).

Mapping by (Sharma and Vaddadi, 1996) and (Throat, 1996) made epoch making discovery by bringing out evidences of lava channels and tubes. An integrated system of lava channels and tubes, demonstrated how lava could have travelled to long distances (Misra et al., 2001b, Misra, 2002a). (Draiswami et al., 2004) and (Sen et al., 2012) also reported remnants of these lava channels and tubes from different parts of Deccan region. These features are mapped in entire region and are seen emanating from a common centre (Misra, 2002b). Earlier mapping of Kutch and Saurashtra regions by Misra (1999, 2009), suggested multi-central eruption with multi-tier volcanic fields, comprising innumerable plugs, cones and craters (Misra and Misra, 2010, 2013). These fields are present everywhere and have their local stratigraphy around them (Fig. 3). Empirically field mapping has revealed that, in approximately 80% of the any region the effusive centres and zones are covered by younger units, only in 2% area, where younger units are eroded and escarpment has receded recently, they can be identified with certainty and in remaining 8% terrain they are eroded beyond convincing recognition. Since there are no differences in chemical analysis, even in trace and rare earth elements, the futility of chemo-stratigraphy is quite obvious.

Important rift and grabens transacting the Peninsular India are Narmada-Tapti Tectonic Zone, Koel-Damoder, Mahanadi, Pranhita-Godavari and Kaladgi-Bhima grabens, Cambay Structure, East Coast Fault Zone, Kukdi-Ghod Lineament Zone and Manjeera Tectonic Zone (Misra, 2001a, 2005, 2007). They all have experienced extensional tectonics and several of them have developed as grabens. Their boundaries can best be identified by presence of lineament zones. Evidences suggest that lineaments are surface expressions of nearly vertical faults. Gondwana sedimentary basins with coal seams have formed within these subsiding rift and grabens. Relationship between these rift and grabens with the effusion of volcanic units in different regions of peninsular India is illustrated by (Misra, 2008c). Faster subsidence resulted in deposition of thicker sediments in inter-sectional regions due to compounding affect. Similarly, the volcanism has also been much more pronounced in the intersectional regions. Most of the volcanism has taken place along down-ward propagating faults and repeated decompression melting at critical levels. Keeping pace with emplacement of dyke swarms and dykes in several pulses related to spasmodic volcanic activity, represents only ephemeral period, during prolonged Mesozoic and Tertiary extensional tectonics. Location of several giant hydrocarbon fields along dyke swarms, marks important understanding in planning exploration strategies (Misra, 2016a).

Figure 4. Typical volcanic units and their mode of eruption can be seen. Upward bifurcating conduits have given rise to volcanic fields at different levels.

Cretaceous volcanism in initial phase was of felsic nature and inter-layered rhyolite and obsidian flows have erupted. Accompanying explosive activity has given rise to rhyolite bombs embedded in obsidian flows (Misra, 1981, 1999). This sequence shows moderate to steep dips and is best exposed in coastal belts of Saurashtra, Maharashtra and Karnataka. Several igneous complexes such as Alec-Barda, Osam, Chamardi-Chogat in Saurashtra; Union territories of Daman, Dadra-Nagar Haveli and St. Mary's Island; came into existence due to decompression melting of shallower sialic lithosphere. With progressive downward movement of nearly vertical faults it became quartz normative tholeiitic in composition. Alkaline phase is found in areas where faults could reach to further deeper levels (Misra, 2009b).

Volcanic units exposed in the vicinity of Rajmahal and Sylhet areas are part of enormous volcanism, which has taken place in eastern part of peninsular India. (Roybarman, 1983) reported colossal and spasmodic Cretaceous volcanism in entire sub-surface Bengal basin. Similarly, Mahanadi off-shore volcanic units are logged in the drilling for hydrocarbon exploration (Jagnathan et al., 1983).

In conclusion, the long duration study has led to suggest that the Cretaceous volcanism was rampant in spatially wide spread areas, basins and oceanic regions. Continued extensional tectonics resulted in development of rift and grabens, decompression melting, magma generation and multi-central eruption. Large scale transportation has taken place by lava channels and tubes. Several units interlayered with complete Cretaceous sedimentary succession further suggest that the entire volcanism was in pulses.

References

- Berger, P., Cerny, P., Hook, J.V., Jaffex, Kabir, C.S., Kumar, R., Minne, J.C., Pinnington, D.J., Serra, O., Shukla, S.N., and Sibbit And Visvanath, S.N., 1983, Petroleum Geology of India in Schlumberger, Well Evaluation Conference, pp. 1–36.
- Duraiswami, R.A., Bondre, N.R., and Do, le G., 2004, Possible lava tube system in a hummocky lava flow at Daund, western Deccan Volcanic

- Province, India. *Proceedings of Indian Academy of Science*, v. 113, pp. 813–829.
- Jagannathan, C.R. Ratnam, C., Baishya, and Das Gupta, U., 1983, Geology of the shore Mahanadi basin. *Petroleum Asia Journal*. Special Issue, *Petroliferous Basins of India*, pp. 101–104.
- Misra, K.S., 1981, Tectonic setting of Deccan Volcanics in southern Saurashtra and northern Gujarat. *Memoir Geological Society of India*, pp. 81–86.
- Misra K.S., 1999, Deccan Volcanics in Saurashtra and Kutch, Gujarat, India. *Memoir Geological Society of India*, pp. 352–334.
- Misra K.S., 2001a, Lineament fabric and its relation to the eruption of Deccan Volcanics and Seismicity of west-central India, *Geological Survey of India. Pub.*, v. 64, pp. 209–221.
- Misra, K.S., Sable, A.B., and Bhutani, R., 2001b, Lava channels and tubes in the western part of the Deccan Volcanic Province. *Geological Survey of India, Special Publication*, pp. 503–510.
- Misra, K.S., 2002a, Arterial system of Lava tubes and channels within Deccan Volcanics of western India. *Journal Geological Society of India*, pp. 115–124.
- Misra, K.S., 2002b, Arterial system of lava tubs and channels within Deccan Volcanics of western India, Discussion, *Journal Geological Society of India*, v. 59, pp. 595–600.
- Misra, K.S., 2004, Seismogeology of the Kutch and Adjoining Region, with special reference to 26th January 2001 Earthquake in vicinity of Bachau, Gujarat. Discussion, *Journal Geological Society of India*, pp. 379–385.
- Misra, K.S., 2005, Distribution Pattern, Age, Duration and Mode of Eruption of Deccan and Associated Volcanics, *Gondwana Geological Magazine. Special v. 8*, pp. 53–60.
- Misra, K.S., 2007, Tectonic history of major geological structures of peninsular India and development of petroliferous basins and eruption of Deccan and associated volcanics, *Journal Geophysics*, v. 27, pp. 3–14.
- Misra, K.S., 2008a, Dyke Swarms and Dykes within the Deccan Volcanic Province, India. *Indian Dykes*, Narosa Publishing House Pvt. Ltd. New Delhi, India, pp. 57–72.
- Misra, K.S., 2008c, Cretaceous Volcanic Sequences and Development of Hydrocarbon Pools in and Around Peninsular India. *Petroview*, v. 2, September, 2008, pp. 3–20.
- Misra, K.S., 2009b, Magma generation and Eruption of Cretaceous Volcanism Sequence in and Around Peninsular India, *Magmatism, Tectonism and Mineralization*, Macmillan Publishers India Ltd. pp. 29–46.
- Misra, K.S., and Misra, A., 2010, Tectonic Evolution of Sedimentary Basins and Development of Hydrocarbon pools along the Offshore and Oceanic Regions of Peninsular India. *Gondwana Geological Magazine. Sedimentary Basins of India*, v. 12, pp. 165–176.
- Misra, K.S., and Misra, A., 2013, Hydrocarbon Exploration in Sub-Basalt Basins around Peninsular India. *AAPG, Search and Discovery, Article#50804*.
- Misra, K.S., 2016a, Extensional Tectonics, Rifting, Formation of Sedimentary Basins, Cretaceous Volcanism, Emplacement of Dyke Swarms and Development of Hydrocarbon Pools, Case Studies from Peninsular India and Indian Ocean Region India, *Acta Geologica Sinica English Edition*, 90 supp. 1, pp. 59–60.
- Misra, K.S. and Anshuman Misra, 2016b, Emplacement of Dyke Swarms, Cretaceous Volcanism and Development of Petroliferous Basins in and around Peninsular India, *Acta Geologica Sinica English Edition*, 90 supp. 1, pp. 61–62.
- Misra, 2018, Geo-tectonic Evolution of the Paleogene Basins in and around Peninsular India as revealed by Seismic Sections and Deep Drilling, *Springer International Publishing Co.* pp. 113–133. doi.org/10.1007/978-3-319-7443-5-3
- Ravi Shankar, 1995, Fragmented Indian shield and recent earthquake. *Geological Survey of India Special Publication*, v. 27, pp. 41–48.
- Raju, D.S.N. and Misra, R., 2009, Proterozoic and Phanerozoic Integrated Stratigraphy, *ONGC Bulletin* v. 44, pp. 1–532.
- Roybarman, A., 1983, Geology and Hydrocarbon Prospects of West Bengal. *Petroleum Asia Journal*, Spl. Issue *Petroliferous Basins of India*, pp. 51–56.
- Sharma, R.K. and Vaddadi, S., 1996, Report on lava tubes/channels from Deccan Volcanic Province. *Gondwana Geological Society Magazine, Special Publication*, v. 2, pp. 457–460.
- Sen, B., Sabale, A.B., and Sukumaran, P.V., 2012, Lava channel of Khe-drai Dam, Northeast of Nasik in Western Deccan volcanic province: Detailed morphology and evidences of channel reactivation. *Journal of Geological Society of India*, v. 80, pp. 314–328. doi.org/10.1007/s12594-012-0150-8->doi.org/10.1007/s12594-012-0150-8
- Thorat, P.K., 1996, Occurrence of lava channels and tubes in the western part of Deccan Volcanic Province. *Gondwana Geological Society Magazine, Special Publication*, v. 2, pp. 449–456.
- Valdiya, K.S., 2010, Cretaceous Volcanism, Chapter 14, *Making of India, Geodynamic Evolution*, Macmillan Publishers India Ltd., pp. 321–346.

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