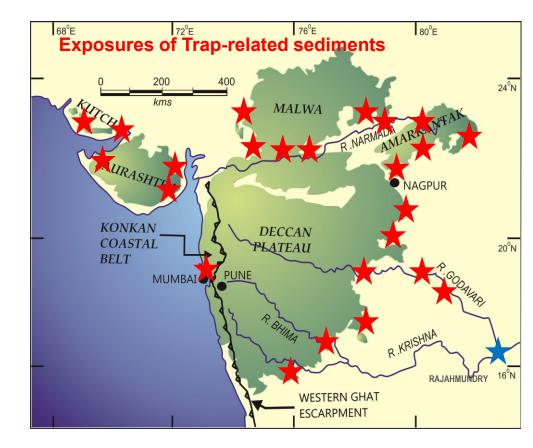
POLYCENTRIC MULTI-PHASE DECCAN VOLCANISM: IS CAUSATIVE LINKAGE TO K-Pg BOUNDARY VALID?

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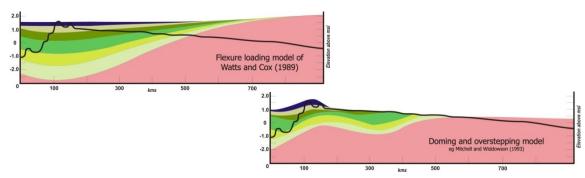
Deccan Traps

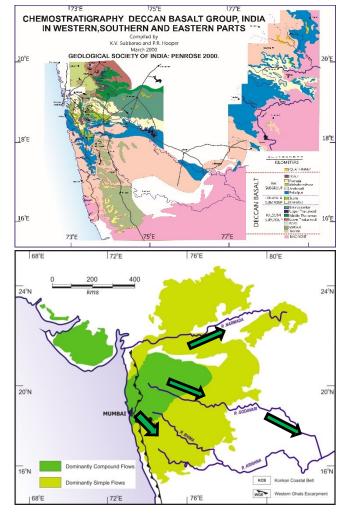
- Earliest stratigraphy used ages of Trap -related sediments to divide the Traps into Lower, Middle & Upper (Pascoe, 1959; Krishnan, 1968) successively from east to west.
- Chemical analysis of the western sections laid the foundation of the Chemostratigraphy of the Traps (Cox and Hawkesworth, 1985; Srineevasa Rao et al, 1985; Subbarao (ed) 1988; Mitchel and Widdowson, 1991...).
- Individual flows were shown to be traceable across more than 100 km in different parts (West, 1961; Chobey, 1973), although some doubts remained.
- Geochronology showed that they were erupted very close to the K-Pg boundary.



Deccan Traps

- Chemical indices were used to correlate packets of flows / flow fields classified in the western part of the province to other parts of the province.
- Comparison of these basaltic flows from the province with the Hawaiian volcanics (West, 1961; Walker, 1969, 1981) was elaborated to develop a classification into 'simple' v/s 'compound' flows (Deshmukh, 1988) and map their distribution.
- To a large extent they contributed to the monocentric model of eruptive history linked to the passage of the Indian plate over the Reunion Hotspot.





Basic critique:

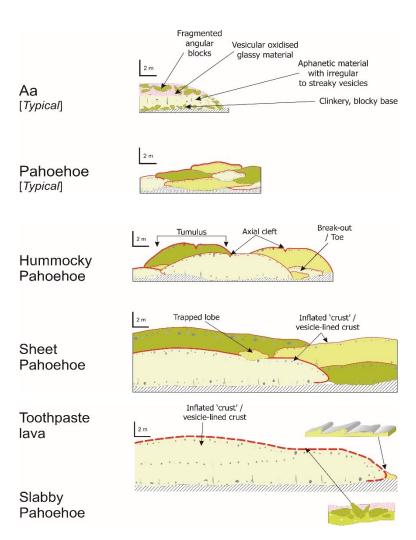
Some questions:

- > Do these models and data stand the test of volcanological considerations?
- > Are the chemical parameters diagnostic to establish the correlations?
- Is there an oversimplification based on lop-sided data ?
- Assumptions of simple v/s compound flow types dominating a particular formation tend to discount *lateral changes* in the volcanological characters of the flows leading to confusing identifications.
- Chemical classification is essentially parametric and probabilistic. Chemostratigraphic correlations based on a combination of chemical parameters (*leading to bizarre results*) are at best '*indicative'* not deterministic.
- \rightarrow > 80% data is from only ~10% aerial extent from the western parts.
- The N-R-N; N-R; and other paleomagnetic sequence in different parts may not necessarily belong the same magnetic chrons.
- Sub-Trappean structural features of the basement unaccounted for.

Flow geometry

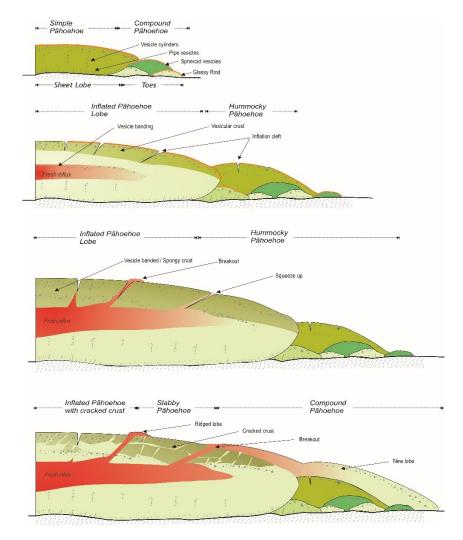
- Individual flows / flow-fields do not have uniform thickness.
- Change their character laterally (pāhoehoe / áā or simple / compound) making it difficult to establish continuity, in absence of inter-flow horizons (~ red beds / red boles).
- Large areas of the DVP exposes what appear to be 'sheet flows' but show mixed character of pāhoehoe flows and yet have flow-top breccias (akin to áā flows). Most 'flows / flow-fields' can be established to have been created due to multiple pulses of emplacement. Truly 'simple flows' are exceptional.

In many ways Hawaiian analogy (Walker, 1969, 1981) has limitations in the Deccan. **Icelandic analogy** (Oskarsson, et al., 2014; Eibl, et al., 2015) **appears more apt.**



Flow geometry

- Recognition of **endogenous emplacement** of lava as an efficient mechanism of lava transfer across large distances led to the understanding of how the different varieties evolve from the same lava type.
- Pulsed emplacement and inflation (with or without crust disruption yielding flow-top breccia) enables lava transfer across long distances, but with variable release of vapour phases.
- Based on this, it is possible to classify the Deccan lavas into two end-member types and a continuous series of variations between them.
- Designated as A-type and B-type (for the Deccan, to avoid terminological confusion: Kale, 2016) flows.



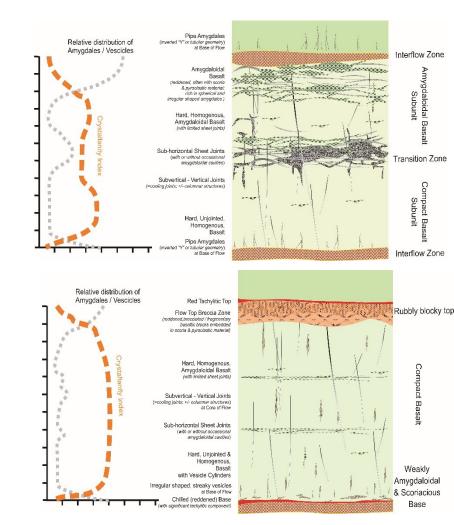
Flow Types

The "A-type : Lobate" flows are

- characterized by a lobate geometry, with several component lobes;
- manifest rapid emplacement of successive phases where loss of volatiles is also swift, thereby rendering the lava viscous;
- ✓ tend to remain close to the eruptive focus.

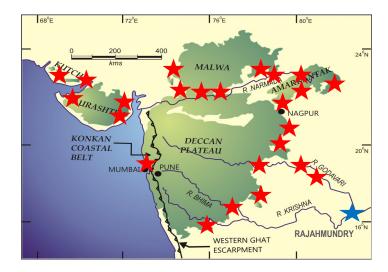
The "B-type : Sheet" flows have

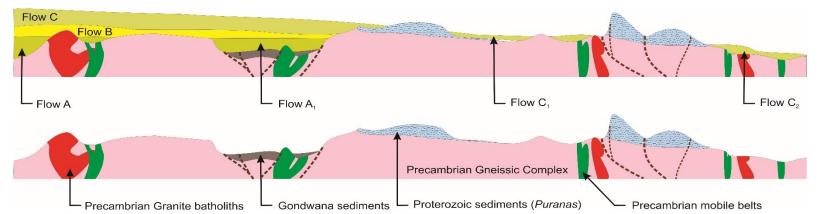
- ✓ lateral spread much larger than thickness;
- suggest that early developed crust allowed the volatiles to remain trapped retaining fluidity;
- enabling longer distance of transport from the eruptive focus



Trap – Basement relations

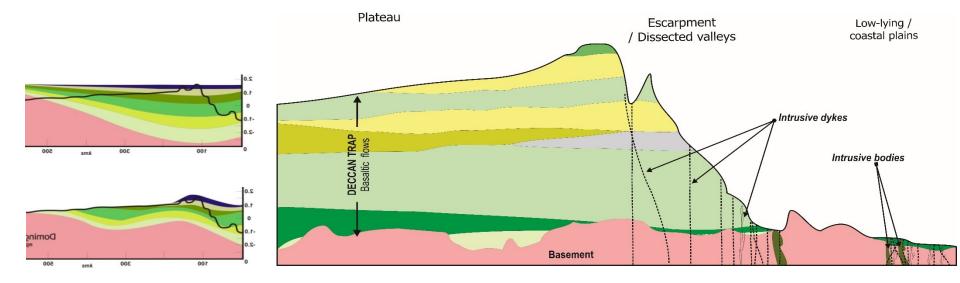
- The contact between the Deccan basalts and their basement is **not smooth**.
- The undulations of the pre-Trappean topography recorded all around are of the order of 100 – 200 m, and in some cases ~ 350 m.
- Individual flows / flow-fields do not have a uniform thickness across their length.
- Correlations of 'lowermost' flows assume that they have been emplaced from a singular edifice and are not derived from diverse sources.





Lateral continuity

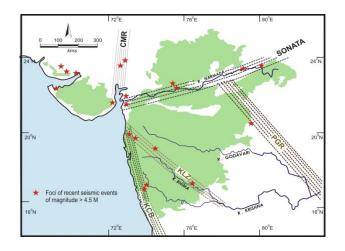
- Assuming that early flows filled up the undulations **does not ensure** that elevations are proxies for **correlations**.
- Vertical sections show intrusives (dykes) at lower levels, but rarely in the upper flows.
- Dykes are dominantly oriented parallel to **SONATA**, **KCB**, **KLZ** and (*northern*) **PGRZ** zones.
- More importantly, the warp / flexure models of the Deccan stratigraphy are open to reinterpretation.

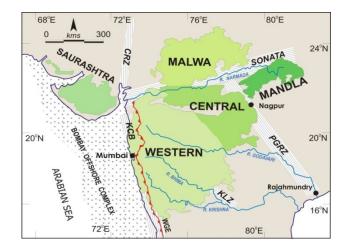


Lateral continuity

- **Dislocations** across faults have been recorded across the Traps (including in the western Deccan Province) along discrete zones, which host **Neotectonic movements** and **recent seismic activity.**
- These zones have a close orientational relationship with **basement trends**.
- Geophysical studies (gravity, magneto-telluric, DSS) have shown these zones to have thinner crust than the adjoining parts of the DVP.
- Several instances of 'eruptive foci' had been earlier recorded by earlier workers along them.

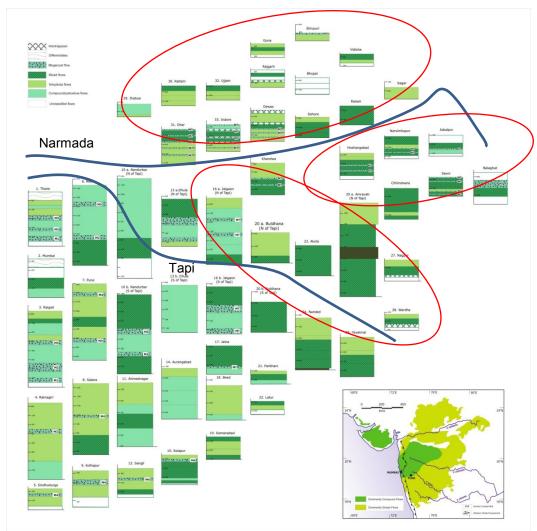
We propose that the **DVP is constituted of subprovinces** that display lithological and structural contiguity; and <u>is not</u> a single volcanological province in terms of its surface eruptive history.





Distribution

- Flow-by-flow mapping across the province by Geological Survey of India (*mostly unpublished reports through 1990's*). Was published as DRMs released between 1999 2003.
- We replotted the district-wise successions using the lobate / sheet / mixed types on an elevational control.
- Existing chemo-stratigraphy, paleomagnetic data and geochronological data cannot be reconciled across the province, if treated as a single volcanological unit.
- Logs of the Saurashtra subprovince not plotted pending field validations.

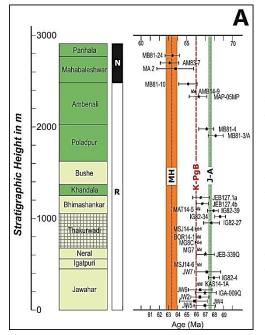


Zonal Lithostratigraphy

Western (= W Deccan Plateau, Western Ghats & Konkan Coastal Belt)			Central (= E Deccan Plateau, Satpura, S Narmada & Tapi Valleys)		Northern (Malwa Plateau & N Narmada Valley)		Eastern (Mandla Lobe)	
Group	Subgroup	Formation	Group	Formation	Group	Formation	Group	Formation
Sahyadri	Bombay	Borivali						
		Elephanta						
	Mahabal- eshwar	Mahabaleshwar	Satpura	Karanja		Singarchori]	
		ManaDalesi Wai		Ndidija		Bargonda		
	Diveghat	M4 (GPB)		Buldana	Malwa	Indore	Amarkantak	Kuleru
		Purandargad		Duidana				
		Diveghat		Chikhali		Kankaria - Pirukheri		Khamla / Khampla
	Lonavala	Karla		Ajanta		Kalisindh		Amarwara
		Indrayani				Mandleshwar		Multai
	Kalsubai	M3 (GPB)		Upper Ratangarh		Gaganwara		Linga
		Upper Ratangarh						Pipardehi
		M2 (GPB)						Dhuma
		Lower Ratangarh						Mandla
		M1(GPB)						
		Salher	Cretaceous Lameta & Bagh					
			Gondwana Supergroup					
Kaladgi Supergroup / Bhima Group			Mahakoshal Group		Vindhyan Supergroup		Sausar, Sakoli Groups	
Archaean Basement Complex								

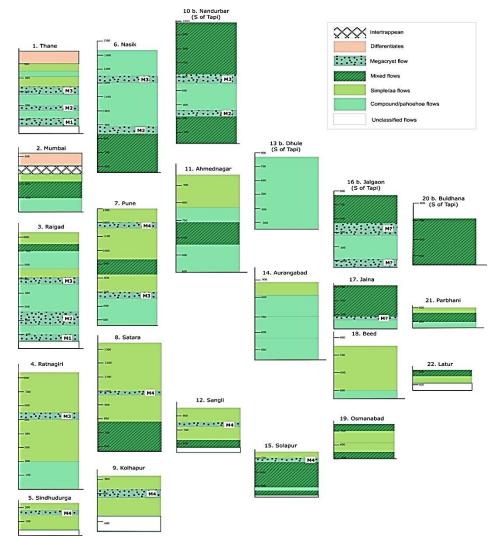
Western DVP

- Basement of Dharwarian shield and Kaladgi – Bhima sediments (exposed in south and west).
- Vertical thickness exceeds 1600 m.
- □ R-N magnetic polarity.



Recalculated Ar/Ar ages against the Fish canyon sanidine (FCs) age of 28.294±0.036 Ma using the method of Renne et al (2010, 2011).

- 67.5±0.2 Ma (J-A) for Reverse polarity flows.
 63.2±0.7 Ma (MH) for Normal polarity flows.
- 62.8+0.2 Ma. for the Bombay succession.

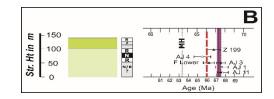


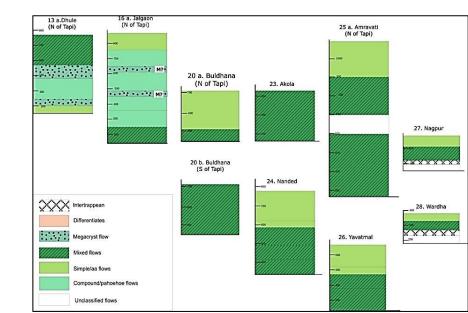
Saurashtra

- Basement of Mesozoic sediments.
- Vertical thickness less than 120 m. But, are capped by Tertiary sediments. [<u>As also the Bombay off-shore region</u>]
- Multiple polarity reversals (poorly constrained); apparently R-N-R.
- □ WMA age of 67.2<u>+</u>0.2 Ma (~ J-A)

Central

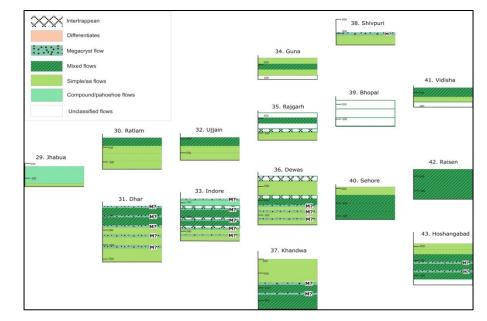
- Basement of Gondwana (in North); Dharwar + Gondwana + Infratrappeans (in East).
- Vertical thickness up to 800 m diminishes south-eastwards.
- Very little paleomagnetic or geochronological data. Has been mapped as extensions of the Wai Subgroup based on chemical characters.

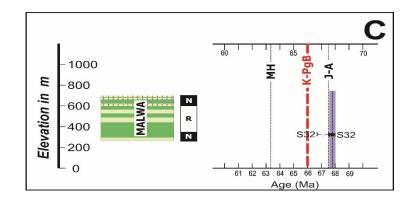




Malwa

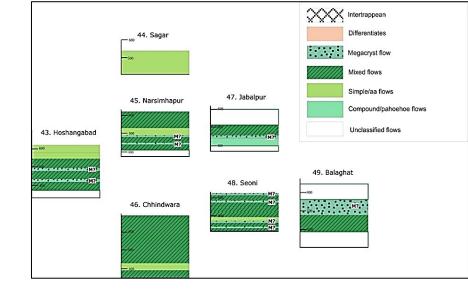
- Basement of Mahakoshal + Gondwana + Bagh / Infratrappeans (in South); Vindhyan + Bundelkhand Gneisses (in other parts).
- Hosts intertrappean fossiliferous beds in the lower parts.
- Vertical thickness < 750 m diminishes south eastwards.
- Three clear GPB horizons that help in correlations across this subprovince.
- Paleomagnetic & geochronological data restricted to its southern exposures only.
- Has a clear N-R-N paleomagnetic sequence.
- WMA age of 67.8±0.2 Ma (slightly earlier than the J-A).

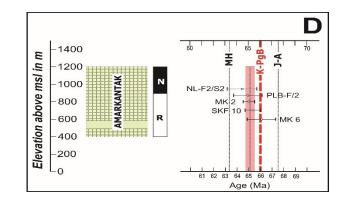




Mandla / Amarkantak

- Basement of Mahakoshal / Bastar Pc + Gondwana + Bagh / Infratrappeans.
- Hosts intertrappean fossiliferous beds in the lower parts.
- Vertical thickness ~ 500 m.
- At least 2 GPB horizons.
- Paleomagnetic data indicates several "mixed polarity" flows, but essentially appears to have a R-N on N-R-N sequence.
- WMA age of 65.1±0.4 Ma (younger than the K-Pg Boundary; and a different age than any other WMA cluster from other parts of the DVP).

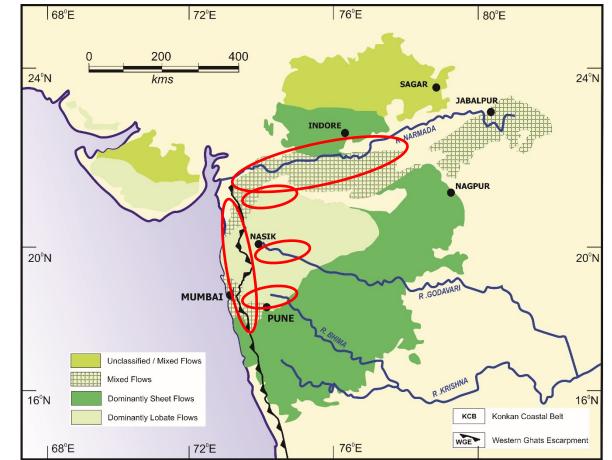




Distribution of flow types

- Taking into account the observations across much of the province, and the basic flow-types observed in different sections provides a new look at the province.
- The 'mixed flows' indicate regions of the eruptive foci of the Deccan.
- They coincide with occurrence of dykes swarms.
- Coincides with geophysically determined zones with thinner crust (sub-Trappean).

The Deccan must have **multiple eruptive foci.**



Modified based on the compilation by Deshmukh and Sehgal (1988)

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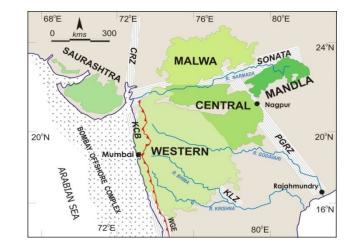
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Where does this new look take us?

- ✓ Volcanological factors are taken on board. Lateral correlations are more robust, repeatable and not 'indicative or probabilistic'.
- \checkmark Multiple eruptive centres allow efficient transfer of lava on to the surface.
- \checkmark ? Enable dispersal of (toxic) volatiles over larger areas faster.
- ✓ Rather than the Hawaiian analogy, an Icelandic analogy for the eruptive history of the Deccan is more apt.

- Eruptive histories across subprovinces may differ and are NOT synchronous.
- There have been at least 2 (perhaps 3) post K-Pg Boundary eruptive events in the Deccan, but in different parts.
- □ The N-R-N magnetic chrons are not the same in all parts of the province.



Conclusions:

Does this mean that Deccan is not a potential contributor to the K-Pg extinction events?

- > Yes, it still remains a potent event capable of creating the environmental crisis that could lead to mass extinctions.
- The Dinosaurian egg-clutches and other fossil evidence do point to a quick demise!
- But
- The fact that a major (if not larger) part of the erupted volume has a post-K-Pg Boundary age needs to be looked into.
- The coincidence of the Chicxulub impact and the early Deccan eruptions do provide a very potent mixture of environmental disasters.
- Lastly,
- > Existing models do not provide satisfactory answers to several questions.
- There is a need to relook at the Deccan both in terms of its linkages to this boundary, and also in terms of its being one of the largest continental large igneous province.





THANK YOU FOR YOUR ATTENTION



