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Extinct plants, evolution
and Earth's history

Birbal Sahni
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The Deccan traps

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'At this distance of time we can see only a dim outline of the world as it was and the exact language of science is ill suited to the description of visions.'

The above lines are excerpts from Birbal Sahni's presidential address to the Indian Science Congress at Madras in 1940, while speaking on the Deccan Volcanics, a topic to which he contributed significantly. In this his centenary year, this note pays tribute to his remarkable capacity of arriving at a scientific synthesis based on his vast experience and intuitive perception but playing it down as 'a fairy tale'. Many of the questions that he posed then on the age, biotas and affinities of the Deccan intertrappean assemblages are still relevant today and are still being asked. This note attempts to recapitulate four issues raised in the original paper and give an update on the progress that science has made during the last five decades.

It is now well known that the Deccan Traps (Figure 1) rank as one of the major volcanic events in Gondwanaland and straddle the Cretaceous–Tertiary Boundary (KTB). During the last decade, accelerated research has led to a better understanding of the stratigraphy of the flows, particularly those of the Western Ghats, sourcing of the magmas and the isotopic signatures related to the degree of crustal contamination, geochronology and magnetostratigraphy[1–5]. Great advances have been made in the study of the biotas recovered from the Deccan volcano-sedimentary sequences (informally referred to as the infratrappeans and the intertrappeans, Figure 2) and in deciphering the palaeoenvironments of the sedimentary basins[6–8].

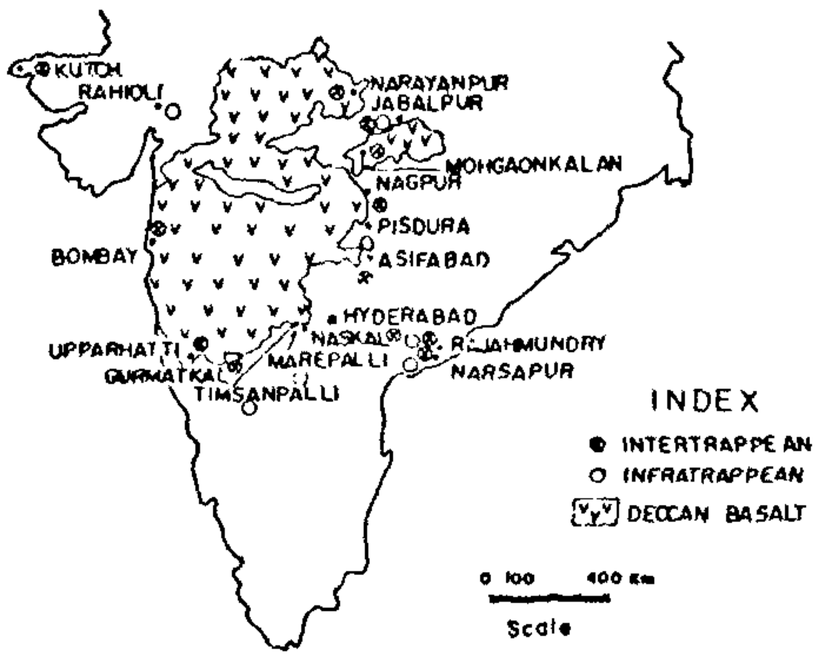

Figure 1. Distribution of the infratrappean and intertrappean beds in relation to the outcrops of the Deccan traps.

The issues that I would like to discuss here, after quoting passages from the original text, concern the biotas and age of the Deccan intertrappeans, the latest stratigraphic record of Indian dinosaurs, the direction of the younging of the flows and lastly, the palaeobiogeography of the Indian region in the context of Gondwanaland reconstructions. These aspects reflect the breadth and depth of some of the themes discussed by Birbal Sahni in his 1940 address which are still burning issues today.

1. *The age of the Deccan traps has now been a matter of discussion among geologists for over seventy years. The main point at issue was whether the volcanic period began during the decline of the Mesozoic era or at the dawn of the Tertiary.*

For well over a century, opinion has been divided on this issue. Several lines of converging evidence now suggest that the volcanic eruptions occured at the KTB and were of limited duration. Several of the taxa on which Birbal Sahni worked have now been shown to have temporal ranges extending at least down to the latest Cretaceous, for example the various palm genera, the water fern *Azolla* and the algal charophytes. In addition, several of the animal fosssils recovered from the Deccan intertrappeans mentioned by Sahni (fishes[9] and ostracodes[10]) have now been recorded from the Maastrichtian[6,7]. The new information would seem

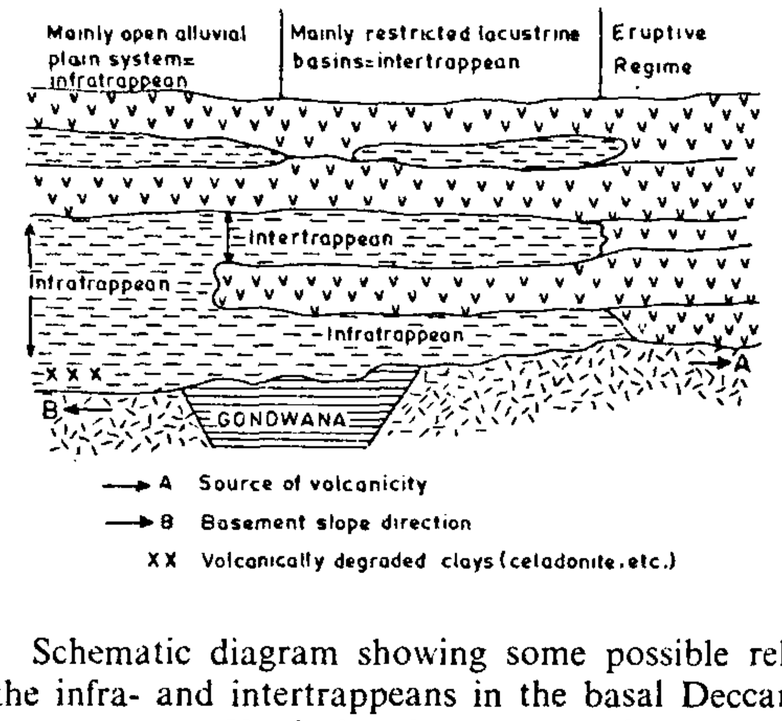

Figure 2. Schematic diagram showing some possible relationships between the infra- and intertrappeans in the basal Deccan volcano-sedimentary sequences. Vertical scale exaggerated.

to set at rest the old controversy but there are still some dissenting opinions which deserve due weightage[11].

Deccan intertrappean palaeobotany has steadily progressed with the documentation of several taxa in which Birbal Sahni would have been most interested: *Musa* sp. (the banana plant) and *Eucalyptus*[11]. Recently, palynofossils, including *Aquilapollenites*, *Diporoconia*, *Araednisporites*, *Azolla cretacea*, and *Gabonisporis*, have been recorded from the Jabalpur intertrappeans and the Naskal intertrappeans (near Hyderabad)[12–14]. Palynoassemblages suggest a Late Cretaceous age for these widely separated intertrappeans.

Vertebrates have also added greatly to the establishment of the age and palaeoenvironment of the Deccan volcano-sedimentary sequences. Several new taxa of fishes, frogs, lizards, snakes, turtles, crocodiles, dinosaurs and mammals are now known[6,7]. The dinosaurs represented by limb bones, teeth and eggshell fragments are particularly useful in assigning a latest Cretaceous (rather than Tertiary) age for these beds[15].

Based on biotas, the age of the Deccan intertrappeans is best interpreted as terminal Cretaceous, close to the KTB.

2. *Amongst the denizens of the land, dinosaurs ... are rapidly running out of their race. The last of the Indian dinosaurs lie buried in the Lameta beds near Jabalpur and at the village of Pisdura near Warora, to the southeast of Wardha.*

The latest stratigraphic record of dinosaurs is indeed considered to lie in volcano-sedimentary sequences associated with the Deccan Traps. The relationships of the Indian dinosaurs, as pointed out by Birbal Sahni, lie with similar forms from the Cretaceous of Madagascar and South America, though now similarities have been detected with the titanosaurids of the northern Mediterranean Province, especially in the eggshell morphotypes and nesting sites recorded from these two regions[16]. It has been suggested that dinosaurs may have survived into the Tertiary, because of lack of competition in an oceanically isolated landmass as India drifted away from Madagascar in the west after severing its physical bonds with Australia and Antarctica. However, this does not appear to be the case as the biotas from the volcano-sedimentary sequences are no different from those known globally at the same time, thereby implying bilateral migration from the Indian landmass[7]. The newly acquired palynological data[18–20] are of great importance in determining the latest record of Indian dinosaurs and, represent three distinct geological settings: the inland continental intertrappean beds of Jabalpur and Naskal, the paralaic shallow water marine deposits of the Cauvery Basin and the offshore subsurface sediments of the Godavari Delta[18–20].

One of the sections where the latest record of dinosaurs is probably preserved is the Gaur River Section at Ranipur, southeast of Jabalpur. Here, a large pelvic girdle probably belonging to a titanosaurid sauropod occurs in a cherty limestone underlain by an *Aquilapollenites*-bearing shale[13]. This intertrappean has also yielded fish scales of the type described from Deothan and Kheri[9].

3. It appears that vulcanicity began in the eastern part of the Deccan and gradually spread to the west.

This is still a debatable issue and has considerable importance in establishing the relative direction of the younging of the basaltic flows as a means for determining the movement of the drifting Indian landmass. There are basically three hypothesis (i) an east to west younging advocated by Birbal Sahni[21] and several others, (ii) a general southward younging[2] and (iii) a near synchroneity of the basal basaltic flows, unresolvable temporally at least by existing biostratigraphic and physical dating methods[4].

At present, the bulk of the data (palaeontological, palaeomagnetic, Ar/Ar geochronology) suggests that the Deccan Traps were of short duration with an initial event in the 30 N chron and the bulk of the eruptions occurring in the 29 R chron which includes the KTB. These data, together with the radiometric evidence, would tend to support alternative 'c'. That the Deccan activity was temporally limited, was a viewpoint also adhered to by Birbal Sahni. The only distinguishing feature is that while he considered this event to be restricted to the earliest Eocene ('Palaeocene' as it is understood today), scientific consensus places the volcanic eruptions at and cross the KTB.

4. *Professor Wegener, who died a hero's death in Greenland a few years ago in the pursuit of science,...*

Birbal Sahni was one of the staunchest and earliest adherents of the continental drift hypothesis in India and applied the theory to explain the distribution of landmass and the floras (and faunas) that they supported as well as to explain the uplift of the Himalayan Chain. In India, Wegener's hypothesis did not receive general acceptance for several decades in the

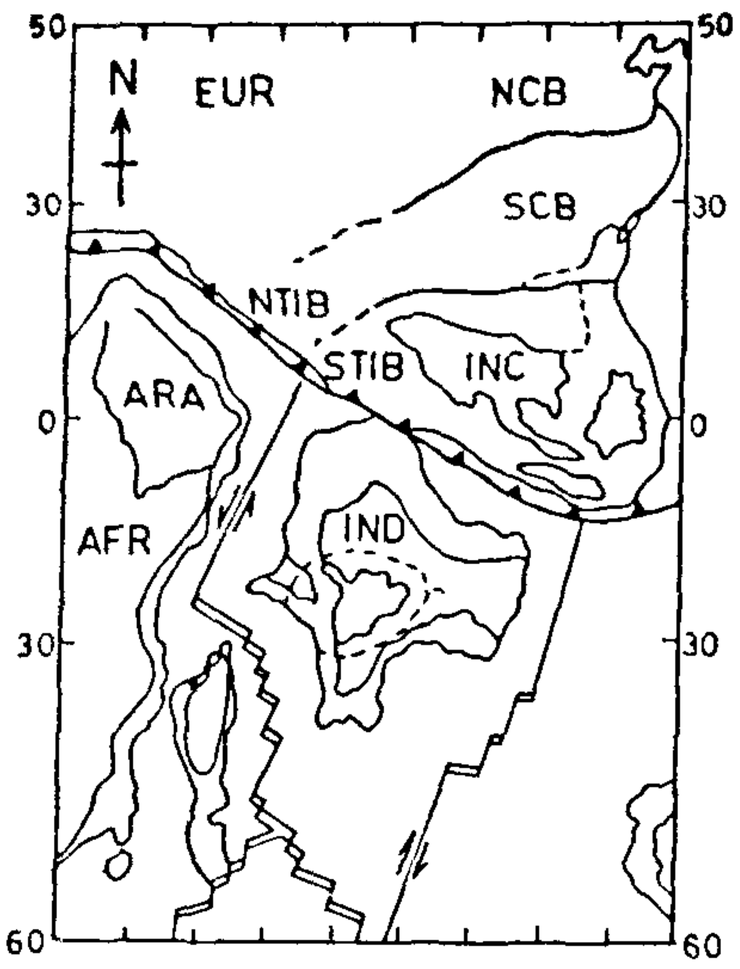

Figure 3. Jaeger *et al.*[22] model to explain the Laurasiatic affinities of the Deccan intertrappean biotas and the India–Asia collision.

forties, fifties and sixties. In fact, global tectonics, a later version that now dominates geological thought, also faced the same fate initially. The remarkable foresight of Birbal Sahni invoked the concept of drifting landmasses to explain palaeobiogeographical phenomena. To use his own expressive and picturesque phraseology, the events relate to the approach of 'the two great landmasses' (namely the Indian and Asiatic blocks) 'narrowing the width of the intervening sea, parts of the ocean floor were caught up as between the jaws of a gigantic vice, and they have been squeezed, crumpled and uplifted into the chain of the Himalaya'. This idea expressed half a century ago, is similar to a recent attempt (Figure 3) to relate the affinities of the Deccan intertrappean biotas to the India–Asia collision[22].

The foregoing account on the Deccan Traps illustrates that Birbal Sahni was far ahead of his times in conceptualization because he cared to use *all the available evidence* (morphotectonic, sedimentological and geodynamical) and did not exclusively rely on information provided by his first passion, fossil plants.

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