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India's first dinosaur, rediscovered

'*Reasoning from analogy at Jubbulpore, where some of the basaltic cappings of the hills had evidently been thrown out of craters long after this surface had been raised above the waters, and become the habitation both of vegetable and animal life, I made the first discovery of fossil remains in the Nerbudda valley. I went first to a hill within sight of my house in 1828, and searched exactly between the plateau of basalt that covered it, and the stratum immediately below; and there I found several small trees with roots, trunks, and branches, all entire, and beautifully petrified. They had been only recently uncovered by the washing away of a part of the basaltic plateau. I soon after found some fossil bones of animals.*'

–W. H. Sleeman[1]

So begins the history of Indian dinosaur studies. The bones that Sleeman collected from the beds underlying the Deccan Traps at Jabalpur would soon embark on 'rambles' of their own[2]. Sleeman sent two fossil bones to G. G. Spilsbury, a civil surgeon, who himself collected a third bone from the same bed. In 1832, Spilsbury sent all three to Calcutta antiquarian, James Prinsep. By 1862, these fossil bones were presented to Thomas Oldham, the first Director of the Geological Survey of India. Surgeon–botanist Hugh Falconer, co-discoverer of the Siwalik vertebrates[3], provided the first description of two bones, which he identified as caudal vertebrae, and presented illustrations of the better preserved element[4]. Falconer correctly identified the vertebrae as reptilian but refrained from coining a name for them, probably because the manuscript, published posthumously, was not intended for publication. It was not until 1877 that Sleeman's discovery was finally recognized as a new genus and species of sauropod dinosaur called *Titanosaurus indicus* ('Indian titan reptile') by Richard Lydekker[5]. He named a second species from Jabalpur, *T. blanfordi* ('Blanford's titan reptile'), just two years later[6]. At that time, only approximately 115 dinosaur species had been identified, less than 10% of the 1401 species known by 2004 (ref. 7).

After passing safely through many hands for over the course of half a century, the original remains of *T. indicus* went missing. It is not known exactly when this happened, or even who was the last to examine them, but we were not able to find mention of first-hand observation of *T. indicus* bones subsequent to Lydekker's last treatment of them[6]. A cast of the specimen is present in the Natural History Museum, London (NHMUK OR40867).

T. indicus holds a special place as India's first recorded dinosaur, discovered only four years after the discovery of the first-named dinosaur *Megalosaurus*[8] and 14 years before the name 'Dinosauria' was coined[9]. Like *Megalosaurus* and other early-named dinosaurs such as *Iguanodon*[10] and *Cetiosaurus*[11], *Titanosaurus* was based on limited material whose diagnostic features were eventually made obsolete by the discovery of more complete remains[12,13]. The first such discoveries were made by Charles Matley and Durgasankar Bhattacharji in the early 1900s (refs 14 and 15). Excavations near the probable location of Sleeman's original site in Jabalpur produced the braincase and partial skeleton of *Antarctosaurus septentrionalis*[16] (whose genus name has since been changed to *Jainosaurus*[17]), a partial postcranial skeleton of a second, smaller individual of the same genus[18,19], as well as many isolated bones. Many of the theropod remains were shipped to London for preparation and description in 1922 and 1925; most of them were returned to India in 1936, along with a plaster cast of the partial hind limb of *Jainosaurus*[2]. There is no manifest for this shipment, so it is not known exactly which specimens made the trip to and from London. Barnum Brown visited Bara Simla and made additional collections of theropod[20] and sauropod[21,22] remains, which are housed at the American Museum of Natural History. More recent excavations elsewhere in India have added to the initial discoveries of Matley and Bhattacharji at Bara Simla and Chhota Simla (Jabalpur). One of most important was an accumulation of several hundred bones[21,23–25] in strata just below a prolific egg-bearing horizon[26,27] in Rahioli, western India. Another such locality was Dongargaon in central India, some 335 km south of Jabalpur. The Dongargaon locality produced the most complete skeleton of an Indian dinosaur, *Isisaurus colberti* (formerly known as '*Titanosaurus*' *colberti*), which is known from a braincase, presacral, sacral and caudal vertebrae, girdle bones and limb bones[28,29]. The more recent discovery of scores of dinosaur bones in Balochistan, Pakistan[30–32] also represents an important source of information on dinosaurs of the Indian subcontinent.

Beyond its historical and patrimonial significance, what is the relevance of *T. indicus*, if the species was based on limited material, now missing, deemed insufficient to distinguish it from other dinosaurs[13]? The material is relevant for several reasons. First, *Titanosaurus* provided an initial glimpse at, and eventually became the namesake for, the diverse, late-surviving sauropod lineage Titanosauria[33]. Titanosaurs comprise more than 40 genera[34], which have been recorded from all continental landmasses, including Antarctica[35]. They are morphologically distinctive sauropods with elongate skulls bearing narrow tooth crowns[36,37], presacral vertebrae with complex lamination[38] and limbs that were slightly angled outward in a wide-gauge posture[39]. Some titanosaurs even possessed dermal armour[22,40] that may have functioned as a mineral store that allowed them to survive in stressed environments[41]. In addition, *Titanosaurus* provided the first indications of what Lydekker[42] called a 'remarkable community of type which undoubtedly exists between the faunas of southern continents of the world'. Recast in today's mobilist palaeogeographic paradigm, the Indian subcontinent takes on special significance as a large dispersal vector[43] that began the Mesozoic interlocked with other southern landmasses and ended it in isolation prior to docking on Asia sometime in the early Tertiary. Large continental tetrapods like *Titanosaurus* and other dinosaurs can provide insight into India's relationship with other landmasses, both southern and northern. Last, and perhaps most significantly, inability of the scientific community to access and study *T. indicus* is symptomatic of a larger issue. There are several Indian dinosaur specimens that are currently missing, including both small and large specimens of sauropod and theropod dinosaurs. Notable missing specimens include the partial postcranial skeleton of the stocky-limbed, large theropod *Lametasaurus indicus*[44], skull materials of both *Indosaurus matleyi* and *Indosuchus raptorius*, parts of *Jainosaurus septentrionalis* and the small noasaurid theropod *Laevisuchus indicus* and many theropod limb bones[16] (Figure 1). The nonavailability of these elements has seriously hindered efforts to understand the evolutionary history of Indian dinosaurs and to decode their palaeobiogeographic connections to other southern landmasses[45,46]. But are these bones lost, or merely misplaced? Are efforts best directed at retrieving these bones in collections or finding new bones in the field?

The Geological Survey of India (GSI) and the University of Michigan have recently embarked on a programme to recover missing fossil bones in museum collections and to collect new bones from field sites. Efforts at the Indian Museum (Kolkata) and GSI repositories have resulted in the recovery of the misplaced holotypic caudal vertebra of *T. indicus* (Figure 2). The *T. indicus* holotype was stored together with bones of *T. blanfordi* and with Triassic vertebrates of the 'Lydekker collection'[47], also presumed missing. The bones were recovered from the vast fossil vertebrate and

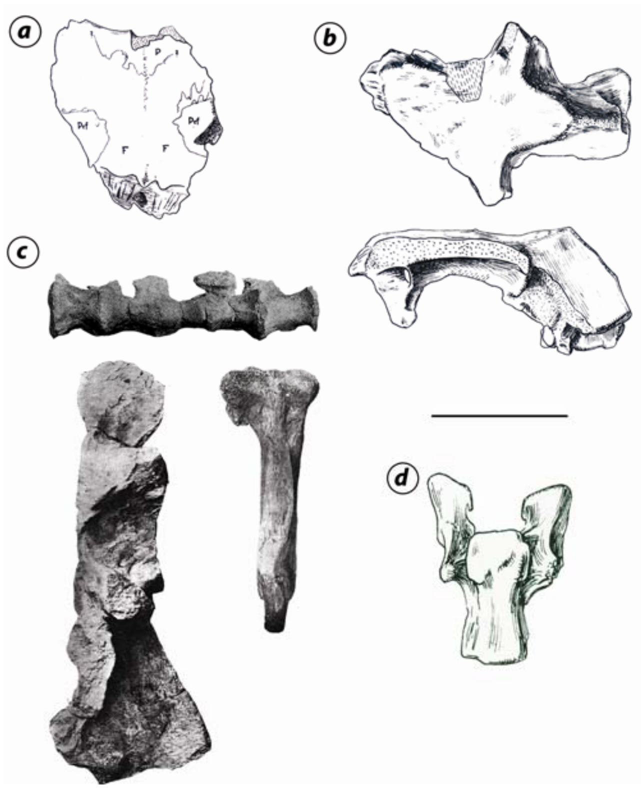

Figure 1. Currently missing Indian dinosaur fossils. ***a***, ***b***, Syntypic skull elements of the large theropod *Indosuchus raptorius*. ***a***, Skull roof K20/350 in dorsal view. ***b***, Skull roof and braincase K27/685 in dorsal and left lateral views[16]. ***c***, Holotypic partial skeleton of the large theropod dinosaur *Lametasaurus indicus*, including sacrum in ventrolateral view, right ilium in ventral view (anterior towards bottom), and left tibia in lateral view[44]. ***d***, Holotypic cervical vertebra (K20/614) of the noasaurid *Laevisuchus indicus*[16]. Scale equals 10 cm for (***a***) and (***b***), 30 cm for (***c***) and 5 cm for (***d***).

Figure 2. Rediscovered holotypic caudal vertebra of India's first dinosaur, *Titanosaurus indicus*, in left lateral view. Roman numerals inked on the bone refer to plate and figure numbers; the other two numbers (GSI '2191', '2194') represent serial numbers as recorded in the Specimen Register of the Curatorial Division, GSI. Scale equals 5 cm.

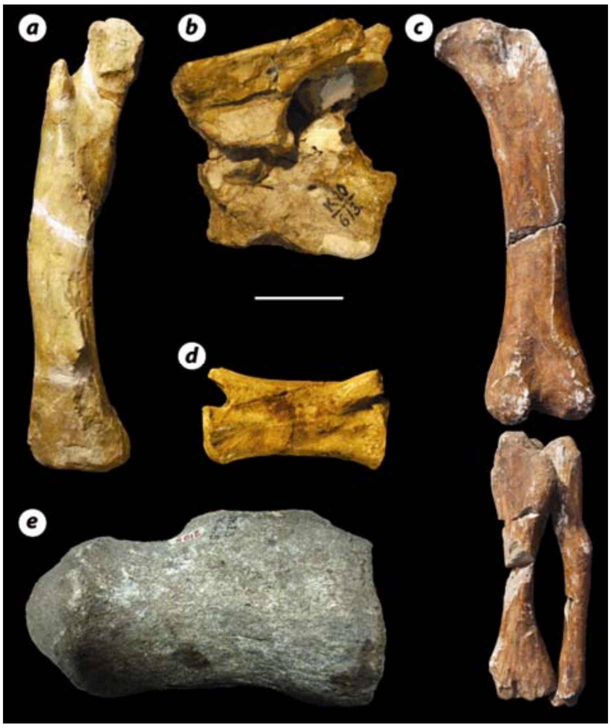

Figure 3. Other rediscovered Indian dinosaur specimens. ***a***, Abelisaurid femur (GSI K27/569) in anterior view. ***b***, Holotypic cervical vertebra of *Laevisuchus indicus* (GSI K20/613) in left lateral view. ***c***, Cast of *Jainosaurus* cf. *septentrionalis* hind limb from Chhota Simla[18,19], presented by Natural History Museum (London) to Nagpur City Museum[2] in 1936. The original specimens are labelled as NHMUK 5903. ***d***, Undescribed noasaurid caudal vertebra from the Matley Collection (GSI K20/612) in right lateral view. ***e***, Holotypic caudal vertebra of *Titanosaurus blanfordi* (GSI 2195) in right lateral view. Scale bar equals 10 cm for (***a***), 2 cm for (***b***), 30 cm for (***c***), 1.5 cm for (***d***) and 5 cm for (***e***).

invertebrate collection of the Curatorial Division of GSI Headquarters at Kolkata. The *T. indicus* caudal vertebra is preserved intact, based on comparisons with drawings by Falconer and Lydekker[4,5], save a small portion of its cotylar rim that is now broken. Recovery efforts have also turned up several other bones (Figure 3). The original syntypic caudal vertebrae of *T. blanfordi* (one of which later was removed from the type[16]) were found with the *T. indicus* holotype. The holotypic humerus of *J. septentrionalis* (GSI K27/497) was found in several pieces atop tall display cases in the Siwalik Gallery of the Indian Museum after having gone unnoticed for decades[48]. One of the holotypic cervical vertebrae of the small theropod *Laevisuchus indicus* (GSI K20/613)[16] was recently found in three separate pieces in unmarked boxes, together with other unnumbered fragments in the Invertebrate Gallery of the Indian Museum. A complete abelisaurid femur (GSI K27/569)[16] was found in five pieces in the Siwalik Gallery of the Indian Museum. In that same cabinet, a collection of theropod cranial, caudal, and limb elements collected by Matley but never described was found, along with undescribed rib fragments of the Chhota Simla specimen of *Jainosaurus*[19], still in their original wrappings. In each of these instances, the specimen had no accession number – either because it never received one (e.g. *T. indicus*, *T. blanfordi*) or because the number had been separated from it by breakage (e.g. *Laevisuchus*, *Jainosaurus*). Recovery of these specimens was more difficult because individual specimens (often fragments), rather than numbers, had to be recognized. In several cases (e.g. *T. indicus*, *T. blanfordi*, *Jainosaurus*), the specimen had been shifted outside the designated collection space, which had been searched repeatedly.

Recovery of *T. indicus* and other misplaced fossils bodes well for retrieval of other important missing specimens, such as *Lametasaurus indicus*, *Indosaurus matleyi* and *Indosuchus raptorius* (Figure 1). The circumstances associated with the loss of the bones in Figures 2 and 3 – no accession number, stored outside the 'normal' area – suggest that future rediscoveries may rely on visual recognition of unlabelled specimens that may be stored apart from other collections.

These results emphasize the importance of fossil repositories as secure storage for historical objects that form the basis for scientific research. These objects constitute the primary record of the evolutionary history of Greater India and its past and present connections to other landmasses.

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Mass stranding of pilot whale *Globicephala macrorhynchus* Gray, 1846 in North Andaman coast

Pilot whale is a carnivorous marine mammal described under the order Cetacea, suborder Odontoceti (toothed whales). Though commonly called as 'black fish' or 'pothead whales', these mammals are named as 'pilot whales' because it was believed that pods were piloted by a leader[1,2]. They are gregarious and frequently found with other small cetaceans. Pilot whales are one of the largest members of the family Delphinidae. Two extant species of pilot whales reported in the world oceans are long-finned *Globicephala melas* (Traill, 1809) and short-finned *Globicephala macrorhynchus* Gray 1846. General appearance of short- and long-finned whales is similar. However, the fin of the long-finned whales is one-fifth or more of their body length and one-sixth for that of short-finned whales. Short-finned pilot whales have fewer teeth, i.e. 7–9 short, sharply pointed teeth in the front of each tooth row, whereas it is 8–13 for long-finned whales[3]. According to IUCN Red List, both the species are insufficiently known. Pilot whales are found in waters nearly worldwide with long-finned pilot whales living in temperate waters, and short-finned pilot whales living in the tropical and subtropical waters generally in deep offshore areas of Indian, Atlantic and Pacific Oceans. Both the species live in groups of 20–60 individuals or more. The population of *G. macrorhynchus* has been estimated as 150,000 in the eastern tropical Pacific Ocean and about 30,000 in the western Pacific, off the coast of Japan[2]. Normally they prefer the waters of the shelf break and slope[2]. Although they primarily feed on squid[4], pilot whales consume fishes, including Atlantic cod, Greenland turbot, Atlantic mackerel, Atlantic herring, hake, blue whiting and spiny dogfish[2,5]. These whales are habituated to migrate seasonally inshore and offshore in response to the dispersal of their prey[2]. Pilot whales are often