Memorandum of Understanding for Joint Collaborative Programme for

STUDY OF LATE CRETACEOUS CONTINENTAL TETRAPOD FOSSILS FROM LAMETA FORMATION

Government of India, Ministry of Mines,

Geological Survey of India

University of Michigan Museum of Paleontology

February 2012

MEMORANDUM OF UNDERSTANDING

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This MEMORANDUM OF UNDERSTANDING is made on this date between Geological Survey of India, Kolkata (herein referred to as GSI) and University of Michigan and Museum of Paleontology, Ann Arbor, U.S.A. (herein referred to as UMMP) for the field work, preparation, and museum research on continental tetrapod fossils.

1. Background Information

1.1. The Geological Survey of India has been pursuing research on Indian dinosaurs and associated Late Cretaceous vertebrates jointly since 2001, in collaboration with Prof. Jeffrey Wilson of UMMP under MoU. As mentioned in the letter by Prof. Wilson, addressed to the Hon'ble Secretary Ministry of Mines (15 July 2010), New Delhi, these collaborative studies have produced excellent results having impact on the global research on dinosaurs and snakes. The recently completed MoU between GSI, C.R. and UMMP on "Study of Late Cretaceous Snake Fossils from the Lameta Formation of Kheda District, Gujarat' (initiated on 18 June 2004 at GSI, C.R., Nagpur) was very successful. The unique snake specimen that was the centrepiece of that MoU needed advance techniques for its preparation, and it was removed to UMMP for preparation by skilled professional with special techniques. The findings under this collaboration proved to be of global significance, not only for the origin and evolution of snakes but also for the unique evidence for predation by primitive snakes on sauropod dinosaur hatchlings and eggs. A paper was published in the high-impact journal PLoS Biology (http://www.plosbiology.org/article/info:doi%2F10.1371%2Fjournal.pbio.1000322). Following the publication of this paper, a press conference was realized in Mumbai on 12 March 2010. During this press conference, a life-sized reconstruction of the snake and hatchling dinosaur was presented to the GSI; it now resides in the Museum at GSI (CR) Nagpur. In addition, Prof. Wilson has also been studying the collection in the Indian Museum, Kolkata, GSI C.R. (Nagpur) and Indian Statistical Institute (ISI), Kolkata and has published quality papers on the Indian Late Cretaceous dinosaurs, which is a significant contribution to the Indian palaeontology and especially the Cretaceous stratigraphy and palaeobiogeography.

1.2. This MoU provides a framework for continuing joint GSI-UMMP study of Late Cretaceous **fossil reptiles** of India over the course of the next few years by conducting a (1) large scale field project that aims to bring to light new and important specimens and to place them in a precise chronological and phylogenetic framework and (2) extensive **museums collection research** that seeks to frame new discoveries within the context of previous finds. The goals of this MoU are to improve our understanding of the origin and palaeobiogeographic relationships of India's Cretaceous fauna by: (1) collecting and developing diagnostic latest Cretaceous continental tetrapods from infratrappean and intertrappean beds of India within a constrained chronostratigraphic framework and depositional context; (2) establishing the genus-level affinities of newly collected and

previously-collected taxa from India and Pakistan; (3) investigating the implications of these relationships for Gondwanan palaeobiogeography and KT biostratigraphy.

2.0 **Nature and Type of Study**

2.1 The Late Cretaceous was a pivotal time for continental tetrapods. Dinosaurs were reaching their acme before their end-Cretaceous demise and mammals were beginning an evolutionary radiation that would lead to their Cenozoic predominance (65 Ma to present). Biogeographic processes operated on various spatial scales to shape these and other evolutionary histories. Indo-Pakistan is a key landmass in palaeobiogeography because of its unique palaeogeographic history - early in the Mesozoic it was interlocked with other Gondwanan landmasses, but it later drifted 5,000 km northward to collide with Asia sometime in the early Tertiary. Although the timing and nature of its trajectory are disputed, Indo-Pakistan is predicted to have acted as a one-way dispersal vector that transported both its living and fossil biota from southern Gondwana to Asia, an event that may have profoundly affected the Asian and Indian biota. Despite its importance, the fossil record of Indo-Pakistan during this period remains poorly sampled. As a consequence, Indo-Pakistan acts as a "wild card" in palaeobiogeographical scenarios - it is indiscriminate to competing hypotheses explaining the processes shaping the past and present biota of Asia. Palaeontological prospection by GSI specialists (e.g., Dr. Dhananjay Mohabey), in some cases in collaboration with Prof. Wilson has produced diagnostic continental tetrapod fossils that show the potential of these horizons to shed light on Indo-Pakistani palaeobiogeography. Additionally, renewed debate regarding the timing and causes of the Cretaceous-Paleogene (KT) mass extinction event has refocused attention on the role of Deccan volcanism and the need for high-resolution KT vertebrate biostratigraphy outside of North America.

2.2 **Collections Work**: Hundreds of fossil bones and teeth of continental tetrapods have been collected from the Lameta Formation and intertrappean deposits of India since the late 19th century, including some of the earliest-discovered dinosaur fossils (Sleeman 1844). Despite the large number of bones collected, few associations between elements have been documented. Our joint collections work has sought to forge as many valid associations as possible, and has resulted the first clear inventory of fossil reptiles from the latest Cretaceous of India. A logical 'next step' would be to formalize these observations and interpretations by organising existing collection of dinosaur fossils in Indian Museum, Kolkata, as well as fossil remains housed in GSI Nagpur, Jaipur, and Gandhinagar. These specimens, which are of international importance, are in need of curation - as an expert in Indian dinosaurs, Prof. Wilson can put together long-lost specimens, repair and restore damaged specimens, and update the fossil catalogue. On similar lines, the preparation and description of the selected specimens from existing collection in GSI Nagpur and Jaipur, also need to be taken-up for the study. Needless to reiterate, the GSI collection is of international significance. Importantly, a part of the Indian collection of dinosaur fossils excavated in the early 20th Century (1930s) remains undescribed. Still other specimens reside in collections outside India (British Museum, London;American Museum Natural History, New York). Inventory of such Indian dinosaur fossils abroad is now available. The study of this collection is crucial for

understanding all about the Indian dinosaurs and is supplementary to the study the collection available in Indian Museum. Prof. Wilson has an edge over the other contemporary researchers on dinosaurs in a way that he has access to the Indian collection abroad and has extensively studied it.

Although there is still work to be done with materials previously discovered by C.A. Matley in 1933 (which is available in the Museum Collection of GSI at Kolkata), we are now nearing the end of this museum-related work. It is critical that we take the next step, which is to **begin new excavations** that will bring light to previously unknown or poorly known continental tetrapods that will shed light on India's pre-Himalayan connections to other landmasses. Field reconnaissance by Wilson and GSI personnel in 2007 has revealed "hot spots" in western and central India where additional globally significant fossils are likely to be found. These must be exploited in the near future before they are damaged, eroded, or found by amateur collectors and removed illegally. We have sought funding from the National Science Foundation (US) to support our project, which we hope will receive a positive response (pending December 2011). Our proposal would involve intensive prospection of field areas, collection of geological samples for magnetostratigraphic and chemostratigraphic characterization, and excavation of relevant fossil remains. **This latter point is an important one, because without excavating fossil specimens, we can do very little new work.** The way forward for a better understanding of pre-Himalayan India requires that new specimens come to light. We hope to conduct our field work in western India (Kheda District, Gujarat State) and in central India (Chhota Simla, pisdura, Dongargaon, Maharashtra State) under the auspices of the GSI Western Region and Central Region, respectively and also the Curatorial Division, Kolkata.

Vertebrate fossils require specialized development that includes (but is not limited to) preparation, molding, casting, and CT visualization

Preparation & facilities: certain new fossils that we turn up during proposed field work, as well as certain critical fossils discovered previously (e.g., from Matley collection) will need specialized preparation, which will require pneumatic tools in the hands of trained professionals. Currently no such facility exists in India (see below). The University of Michigan Museum of Paleontology has an excellent preparation staff that specializes in developing small fossils (http://www.paleontology.lsa.umich.edu/Resources/prepLab.html). Computed Tomography facilities are available through the University of Michigan Department of Radiology, which will provide access to a spiral CT scanning machine. The spiral CT scanner provides adequate resolution of fossil specimens of the size and preservation as the Dholi Dungri snake.

Advanced Vertebrate Preparation facility in India: this is a need of the hour. The facility can be established under the aegis of GSITI or RTI, and it can be extended including development of expertise and techniques in preparing fossils to both the GSI personnel and researchers and students from other organisations and academic institutes. The Advanced Vertebrate Preparation Lab. can be established involving expertise of Prof. Wilson and his team members and their expertise can also be utilized as and when

necessary for imparting training to the Indian scientists and students. Prof. Wilson is committed to helping with the fund-raising, if need be, but funds must come from India. Federal funds from US (e.g., National Science Foundation) are not only scarce, they are preferentially used to build US infrastructure.

2.4.3 **Time-Frame:** The Project will commence in the month of January, 2011 with a sabbatical visit of Prof. Wilson (for a period of three months) to GSI, Nagpur, Kolkata, Gandhinagar, and Jaipur. During this visit, Prof. Wilson and GSI personnel having leading expertise including will embark on field prospection of fossil hot-spots in central and western India identified on previous joint trips as well as trips by GSI alone. Localities include the Jabalpur site in Madhya Pradesh, Pisdura, Dongargaon, and Nand localities in Maharashtra, as well as the Rahioli and Dholi Dungri localities in Gujarat. As far as possible, the efforts would be made to prepare the fossil specimens generated at Palaeontology Laboratory, Nagpur and only relevant selected fossils that may need special preparation will return with Wilson to the UMMP for development at the end of March-April 2012. During this time, an opportunity can be created through GSITI for availing the expertise of Prof. Wilson in establishing the Advance Vertebrate Preparation Facility at Nagpur or any other center as may be identified. A visit for one expert collaborator from GSI (for a period of about one month) to the UMMP is planned to begin as soon as the preparation, imaging, technical illustrations, and molding/ casting of the dinosaur specimens are nearly finished. We tentatively schedule this visit for August 2012, with the understanding that timing may shift depending on how quickly development proceeds. At this time, GSI personnel and Wilson will develop descriptive papers and GSI personnel will be trained in preparation techniques. GSI personnel will return with the developed fossil specimens to India.

3.0 **Personnel**

3.1 This collaborative project will include only the GSI and the UMMP, as represented by Prof. J.A. Wilson. The GSI includes India's leading expert on Mesozoic reptiles and has been central to many key discoveries in central and western India, including the first notice of fossil dinosaur eggs (Dwivedi et al.1982; Mohabey 1984), the first notice of dinosaur eggs and bones (Mohabey 1987), and the first notice of giant snakes in India (Mohabey et al. 2011, in press). Prof. J. A. Wilson has spent the past decade studying the fossil reptiles of India (e.g., Wilson et al., 2001, 2003, 2009, 2010, in press).

4.0 **Proposed visits**

4.1 Three visits are proposed: two for Wilson to visit the GSI Nagpur and one for GSI personnel to visit the University of Michigan. Wilson's visit is essential for the proposed field research and for transport of key fossils to the University of Michigan. The GSI personnel's visit is essential for collaborative study, familiarization with preparation techniques, and transport of the fossil and casts back to GSI, Nagpur. Additional visits will be planned as necessary.

4.1.1 **1st year of Collaborative work (Phase-I)**: the first year of work will include both field research and museum research. This includes (1) assessing and making inventory of the

fossils in the Indian Museum, Kolkata and selecting specimens for their restoration and revised taxonomic and phylogenic description and organizing the specimens for display in the Museum; (2) study of specimens in the collection of GSI, Nagpur. The fossils to be removed for preparation to UMMP. This would be necessary until the facility is made available in GSI as part of the collaborative project; (O) excavation in the original fossil locality at Jabalpur and collection of new specimens. Study of the specimens as prioritized; (3) working out modalities for establishing Vertebrate Preparation Facility in GSI; (4) visiting fossil locality of Gujarat and working out plans for development of Dinosaur Fossil Park in consultation with CGM, Gujarat who are maintaining the site in consultation with GSI; (5) visit of GSI personnel to UMMP for learning special techniques in preparation and to other museums for study of classic and crucial dinosaur skeletons collected from all over the world and specially from the Gondwanan countries including Madagascar South America and Africa. Such visit are necessary for exposing Indian scientists to the international collection for research and comparative study and for developing expertise on dinosaurs. The expenses for the visit of GSI scientist can be borne by GSI with local guest facility to be provided by UMMP.

4.1.2. **IInd Year of Collaborative Work (Phase-II)**: the second year of work will also include both field research and museum research. This includes (1) continued study in Indian Museum, Kolkata. During this visit, the specimens prepared at UMMP can be restored back to GSI with description available; (2) excavation in fossil locality in Gujarat. The necessary preparation of fossils to be done in the newly established Vertebrate Preparation Lab in GSI, but some fossils may be removed for preparation at UMMP; (3) imparting training in vertebrate fossil preparation techniques including scientific casting and molding to GSI scientists and trainees from other organisation in the Vertebrate Preparation Lab. The facility to be established during the intervening period of Phase I and Phase II with the active co-operation of UMMP. The financial cost for establishing such facility to be borne by GSI; (4) visit to important Indian Late Cretaceous dinosaur associated fossil localities for review and for additional information.

4.1.3. **IIIrd year (Final phase)**: In the last and final phase of the collaboration focus will be on the final touches to the studies completed on the collection of Indian Museum, description and cataloguing. This will include (1) write-up of description, illustrations of the studies completed on the specimens; (2) imparting specialized training in the Vertebrate Preparation lab; (3) write-up of Report and publications. Visits may occur as needed

5.0 **Funding**

5.1 Expenses for this research programme will be offset one or more of the following funding sources: The University of Michigan, The National Geographic Society, and The National Science Foundation and would be arranged by Prof. J.A. Wilson.

5.2 Geological Survey of India or Government of India will bear costs for the travel expenses for the visit of GSI scientists to UMMP.

6.0. **Institutional Obligations**

6.1. **The UMMP agrees to the following terms:**

6.1.1. The UMMP will prepare, CAT scan, and produce high-quality casts of the vertebrate fossil specimens. This will require an institutional loan for specimens; upon completion of this process, the UMMP will return casts and loaned specimens to the GSI Nagpur. The UMMP will keep a set of casts for their collections.

6.1.2. Dr. Jeffrey A. Wilson will provide expertise in the study of Mesozoic reptiles.

6.1.3. Dr. Jeffrey A. Wilson and UMMP will help train GSI scientists in fossil preparation.

6.2. **The GSI agrees to the following terms:**

6.2.1. The GSI will loan the fossil specimens from its Central Region, Nagpur to the UMMP for preparation, CAT scanning, and cast making.

6.2.2. The GSI will provide logistic support for field, maps and geological sections and other information for study and publication.

6.2.3. GSI personnel will provide field expertise and other geological and locality information on the fossil continental vertebrates (including snakes and dinosaurs).

6.3. **The UMMP and the GSI Nagpur jointly agree to the following terms:**

6.3.1. Collaborators from both institutions will jointly study the material.

6.3.2. Collaborators from both institutions will jointly write and publish scientific results from these studies.

6.3.3. Collaborators from both institutions will jointly pursue additional fieldwork for study of Late Cretaceous continental vertebrates in Gujarat, Maharashtra, and Madhya Pradesh.

7.0. **Security of the Specimens:** Considering the importance of fossil specimen, the safe custody and security of the specimen would be ensured during the transportation of the specimen from India and back by both the collaborators.

Signature
Date 27. 2. 2012
Place KOLKATA.

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Signature
Date 27 FEB 2012.
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