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Review of fossil records of prehistoric reptiles, their distribution, and paleobiogeographic evolution in Pakistan

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Abstract

Recent paleontological and geological research in Pakistan has found numerous fossils belonging to different groups of prehistoric organisms, including reptiles. Pakistan is rich in paleontological evidence of vertebrates, especially tracks/footprints of Mesozoic reptiles. These reptilian fossils are significant for paleo biogeographical studies because the region is connected to Asia in the north and east and Eurasia and Africa in the north and west. It was attached to Gondwana in the past (Jurassic and Pre-Jurassic), so Mesozoic vertebrates show distinct affinities with Gondwana, Cenozoic vertebrates show affinities with Eurasia and migrated from the Indo-Pak subcontinent via the ancient Indus system of the West Indus River (and vice versa). Neogene (Siwalik Age) deposits in India and Pakistan have produced prehistoric reptiles containing numerous fossils, many of which were named in the 19th century. Recent geological and paleontological research conducted in Pakistan at the beginning of the new millennium/third millennium (2000-2019) found more than 3,000 fossils divided into 45 biological groups (taxa).
Keywords: Fossil, Pakistan, Prehistoric, Paleobiogeography, Reptiles

Introduction

The Mesozoic was a significant paleontologically era for the dominancy of terrestrial vertebrate fauna. In addition to the occurrence of large explosions, especially in Africa and Asia, significant climate changes caused by heat and cold have also caused drastic faunal turnovers, and acted as a major biological extinction (Rögl, 1999; Böhme, 2003; Karl et al., 2021). The Siwalik age (Miocene-Pleistocene) is a group of fossils found in the Himalayan foreland basin extending from the Indus River (Pakistan) in the west to the Irrawaddy River in the east of Myanmar (Barry et al., 2013; Nanda et al., 2018) and in the central part of the subcontinent (e.g., Piram Island in the Gulf of Cambay, India, and along the Indus River, Sindh and Baluchistan, Pakistan). The fossil vertebrate fauna at Siwalik age has been studied for the last 150 years (Garbin et al., 2020).

Although extinct turtles in this region have been well described (e.g. Theobald 1877; Lydekker 1 885a, 1886a, 1889a, 1889b), little is known about the available material in terms of their taxono mic, phylogenetic and biogeographic impact, and most of the turtle species of the Siwalik Age are related to Indo-Pakistani extant taxa (Turtle Extinction Working Group (TEWG) 2015; Turtle Taxonomy Working Group (TTWG), 2017; 2021), thus providing high new access f or Neogene and Quaternary chronological dates. Pakistan's Indus Basin (Part of Gondwana) is i mportant for the discovery of dinosaurs as well as other Mesozoic land and marine strata and biot a. The Indus Basin covers Mesozoic and Cenozoic marine and continental sequences (Malkani , 2010a) (Fig**.** 1). Thanks to the latest geological and paleontological research, Pakistan is on the w orld dinosaur map for the first time. Dinosaur research in Pakistan began in 2000, and dinosaurs have been discovered in neighboring India since 1828. The fossils are outside the University of Michigan. All the fossils found so far are housed in the Museum of Geological Survey of Pakistan (GSP) Quetta, Pakistan, except some fossils sent to the University of Michigan, USA, for preparation. The Vitakri region of Pakistan is considered a paradise for dinosaurs due to its rich collection of fossils. The mass screen-washing method of paleontological examination is used to study amphibians (frogs), reptiles (Snakes, lizards, turtles, Dinosaurs, and crocodiles, etc.), mammals, birds, and fishes etc. to make an accurate assessment of the paleo-biogeographic affinities of Indo-Pakistan subcontinent (Malkani & Sahni, 2015; Malkani & Ge, 2016).

A joint paleontological expedition was built in 1955-1956 at the Institute of Paleontology and Historical Geology of the Ludwig-Maximilians-Universität Munich (Now the Department of Earth and Environmental Sciences, Paleontology and Geo-biology) and the Bavarian State Collection of Paleontology and Geology SNSBBSPG) lead by Prof. Richard Dehm explored northern Pakistan in search of fossils (Dehm et al. 1958). They returned to Munich with an extensive collection of fossil remains, coming from Neogene sediments exposed near villages of Chinji, Dhok Pathan, and Nagri (Siwalik Group) and now stored in the SNSB-BSPG. Research on a Munich group of fossilized mammals still found from this period and previous expeditions in the region have reported the presence of *Dinotheria* (Dehm et al., 1963), squids (Hussain, 1971), primates (Dehm 1983, 1984; Pickford, 2010), rhinoceros (Heissig, 1972) and traguliids (Guzmán & Rössner, 2021). Pickford (2010) mentions other taxa that have not yet been published. There is no amphibians site in Pakistan, as reported by SNSBBSPG, but crocodiles, turtles, snakes, dinosaurs, and squamates represent reptiles. Of these, only snakes were studied by Hoffstetter (1964), who described the spine of an obscure boa constrictor and a new large acrochordid, *Acrochordus dehmi* (Villa & Delfino, 2022).

The Siwalik belt forms the southern part of the Himalayas, extending from the Indus River in the west to the Brahmaputra River in the east, except for a small gap near Sikkim. The Siwalik Group is known for its rich collection of vertebrate fossils, ranging from 18.3 to 0.22 million years ago. In the Early Miocene, before the uplift of the Himalayas, a depression was formed, and freshwater molasses were deposited in the depression. These have mud/siltstone, sandstone, and conglomerate-like muds, with the overall lithology being coarser in the younger formations. Although the Siwalik Group is known for its rich mammalian fauna, some reptile fossils were described earlier since Cautley's time, following a more extensive paleontological study by Lydecker, 1885a, 1886a, 1889a & 1889b (Nanda et al., 2016) (Fig. 1).

Recent geological and paleontological research at the beginning of the new century/third millennium (2000-2019) has yielded more than 3000 fossils from Pakistan, divided into 45 biological groups (Malkani, 2019). Some reptilian fauna belonging to this prehistoric group are described here.

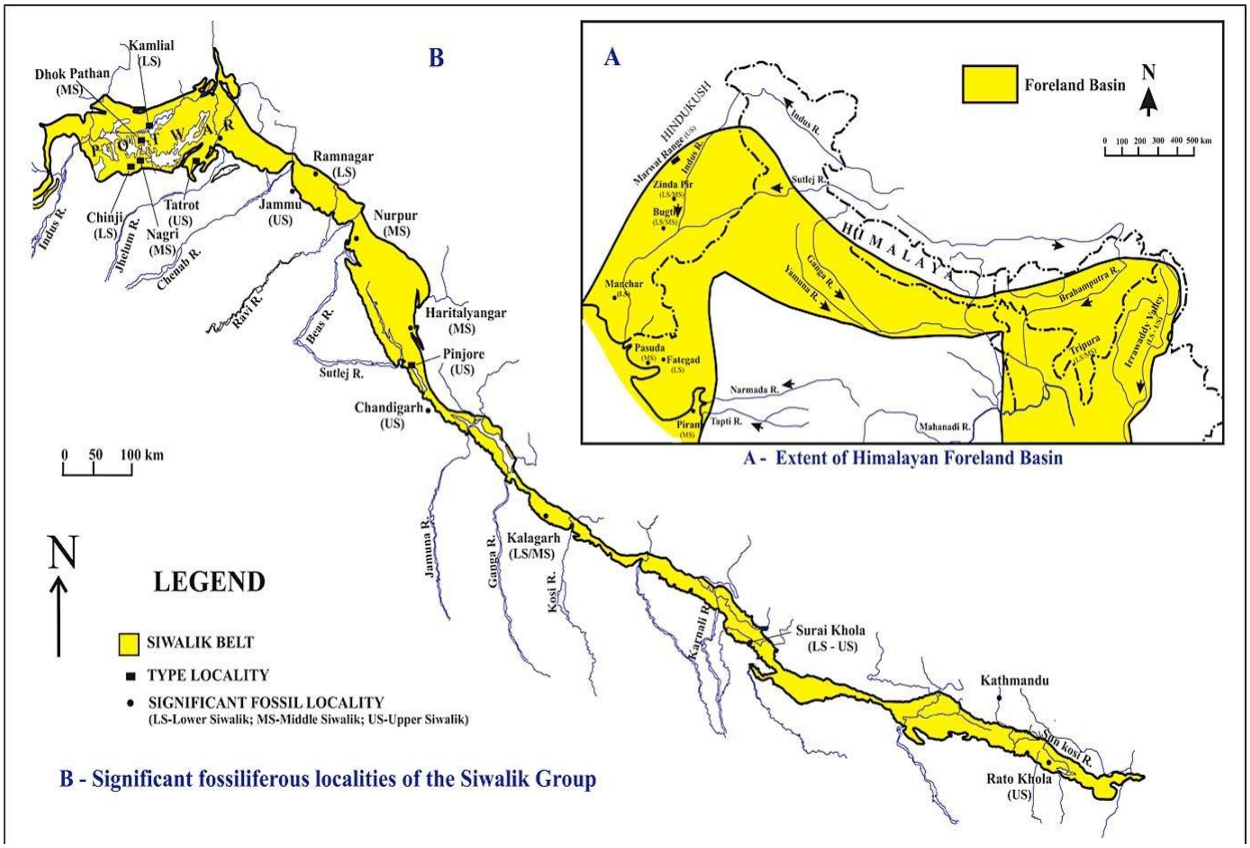

Figure 1. Siwalik-Age faunas from the Himalayan foreland basin in the Indian subcontinent, distribution, and the main localities that yielded most of the fossils (Courtesy; Nanda et al., 2018).

Pre-historic reptilian fauna of Pakistan

Dinosaurian distributions in Pakistan

Pieces of evidence of dinosaurs in Pakistan are found in the Indus basin, which is divided into the Upper Indus (Kohat and Potohar), Middle Indus (Sulaiman), and Lower Indus (Kirthar) basins. Titanosaurid/early titanosaur sauropod remains have been found in the Late Jurassic Sambhar Formation, and sauropod tracks have been found in the Middle Jurassic Chiltan Limestone of the Indus River. Several smaller theropods and a larger *Titanosaur Sagittarius*, are reported along with several footprints in the upper (Kohat and Potwar) basins, and a group in the Barochichno-type Middle Jurassic Samanasuk limestone was recorded from the Mianwali, Punjab. The Middle Indus (Sulaiman) Basin provides the latest Cretaceous titanosaur sauropod fossils, including abelisaurids and tetrasaurian theropods, mesocrocodiles, pterosaurs, and titanosaur sauropod bones. Pakistan is relatively rich in footprints/trackways and Late Cretaceous fossils as compared to its neighbor India (Malkani and Sahni, 2015; Malkani, 2015d; Malkani & Ge, 2016). The following important groups of dinosaurs are recorded from Pakistan:

1) Titanosaurian sauropods (Herbivores dinosaurs) from the Jurassic- Cretaceous periods:

a) *Brohisaurus kirthari,* Malkani 2003: A Titanosaur or early titanosaur-like sauropods found in the lowermost part of the Late Jurassic Sambhar Formation of the Sun C haku region of the Kalkh region of the Kirthar Mountains are based on some little-known postcranial elements (Malkani 2003a)—only one bone.
The Lakha Kach Charo Zidi region, is referred here.

b) *Khetranisaurus barkhani*, Malkani 2004: A Pakisaurid titanosaurian sauropod (slightly broad to sub-squarish midcaudals; based on one holotypic vertebra collected from mid-Kinwa (northwest of stream) and one attributed caudal from Sangiali (Malkani, 2006), and three attributed caudal from Bor, Mari Bohri and Grut Gambrak localities (Malkani, 2009).

c) Sulaimanisaurus gingerichi, Malkani 2004: A Pakisaurid titanosaurian sauropod based on seven fragmentary but associated caudal vertebrae (long and squarish mid caudals) collected from Kinwa locality (Malkani, 2006).

d) *Pakisaurus balochistani*, Malkani 2004: A Pakisaurid titanosaurian sauropod based on four associated tall caudal centra (Malkani, 2006) associated with many surface finds of postcranial skeletons. All fossils are collected from the latest Cretaceous Vitakri Formation in different localities in the Vitakri area, Barkhan, Balochistan (Malkani, 2008a, 2010a, 2014a, 2015a).

e) *Marisaurus jeffi*, Malkani 2004: A Balochisaurid titanosaurian sauropod, based on six heavy and slightly tall to squarish midcaudals (Malkani, 2006; Malkani, 2008a, b, 2010c, 2014a, 2015a; Wilson et al., 2005).

f) *Balochisaurus malkani*, Malkani 2004: A Balochisaurid titanosaurian sauropod based on seven associated heavy and broad to squarish caudal vertebrae (Malkani, 2006).

g) *Gspsaurus pakistani* Malkani 2014, A large-sized gspsaurid titanosaurian sauropod found from red muds of the Vitakri Formation of Alam Kali Kakor locality of Vitakri area and based on a mostly complete skull (Malkani, 2014a, 2015a, d)

h) *Saraikimasoom vitakri*, Malkani 2014: A young gspsaurid titanosaurian sauropod based on a mostly complete skull (Malkani, 2014a, 2015a).

i) *Nicksaurus razashahi,* Malkani 2015: It is based on axial and stocky limb elements of young adults of this taxon from Kinwa north locality of Vitakri area including a pair of femora, a pair of stocky distal tibiae, partial humerus parts; proximal radius, five teeth in jaw ramus, teeth, skull fragments, chevron, cervical, dorsal and caudal centra (Malkani, 2014a, 2015a, d).

j) *Maojandino alami,* Malkani 2015: A large-bodied Balochisaurid titanosaurian sauropod (Malkani, 2015a) with a thick, broad and long neck, short tail, heavy and stocky body and it is based on associated holotypic materials including about 6 cervical, 4 dorsal, and 10 caudal vertebrae along with partial left femur, partial left and right tibiae, and partial radius, a pair of partial distal scapulae, partial sternal plate or ilia, some neural arch and laminae covered partially by yellow-brown muds, etc. The holotypic axial and limb elements were collected from Alam Kali, Kakor locality of Vitakri area.

k) Trackways of some sauropods, the trackways of titanosauriform or early titanosaurian sauropod *Malakhelisaurus mianwali,* and a running theropod *Samanadrinda surghari* were discovered from the Middle Jurassic Samanasuk Limestone of Kohat and Potwar basin (Malkani, 2007, 2008a). A footprint of sauropod was also found 1 km southward from the *Malakhelisaurus* site in the same formation. Some new footprints and trackways of titanosaurian sauropod *Pashtosaurus zhobi* (Malkani, 2014) are found on the Sandstone beds of Vitakri Formation of Qila Saifullah, Balochistan. There is a danger that these trackways may be destroyed during future construction materials required for road construction.

2) Theropods (Carnivorous dinosaurs) from the late Cretaceous Vitakri Formation

a) *Vitakridrinda sulaimani,* Malkani 2006, (Fig. 3): It lived in the Cretaceous period and inhabited Baluchistan. It was a large-sized carnivorous a belisaurian theropod dinosaur based on a pair of left and right proximal femora and basioccipital condyle and a partial braincase (Malkani 2006a, 2014b).

b) *Vitakrisaurus Saraiki,* Malkani 2010: A small-sized carnivorous *Vitakrisauridae noasaurian* theropod based on isolated pes collected from the terrestrial overbank red muds of the latest Cretaceous Vitakri Formation in Kali Kakar, Vitakri area (Malkani, 2010b).

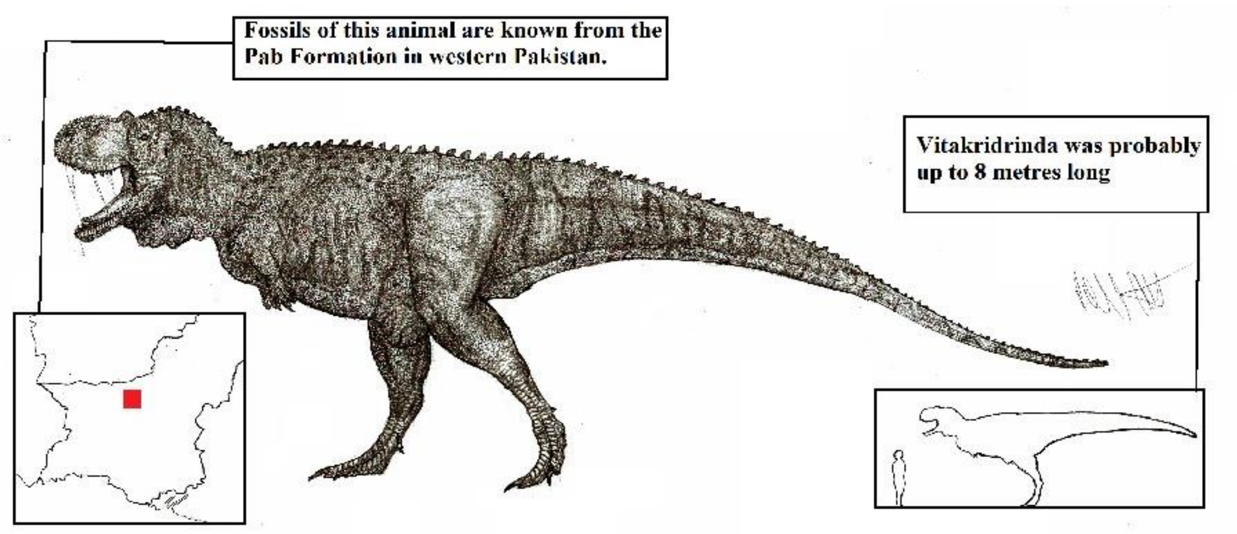

Figure 2. A sketch of *Vitakridrinda sulaimani* Malkani, 2006, (Courtesy: Robinson Kuuz, 2013)

3) Pterosaurs from the Latest Maastrichtian of Pakistan

a) *Saraikisaurus minhui*, Malkani 2013: a pterosaur found in the latest Cretaceous Vitakri Formation of the top Kinwa, Vitakri area (Malkani, 2013, 2014b). The preserved dentary ramus shows a carnivorous-type elongated skull with eight teeth. This ramus shows internal pneumatic texture and structure. The teeth are oval to sub-oval, some overlapped.

b) Trackways of Pterosaurs: *Anmolpakhi alleni* (Pterosaur), Footprints of a Flying reptile were found on level 2 (third bed just below *Pashtosaurus zhobi* titanosaur phenotype bed) of Sor Muzghai locality, Zhob, Balochistan Western most Sulaiman basin. The lithology consists of the Cretaceous Vitakri Formation (overlying the Pab Sandstone). The taxa name *Anmolpakhi* is derived from Urdu and Saraikhi words Anmol, meaning “cannot be purchased”, while Pakhi in Saraiki means flying animals/ birds. The species name A. Allen is after Mr. Nicholas Allen British Journalist who helped a lot with the preparation of 3-D models and preservation of Level 5 ichnotype of *Pashtosaurus zhobi* from this site (Fig. 3).

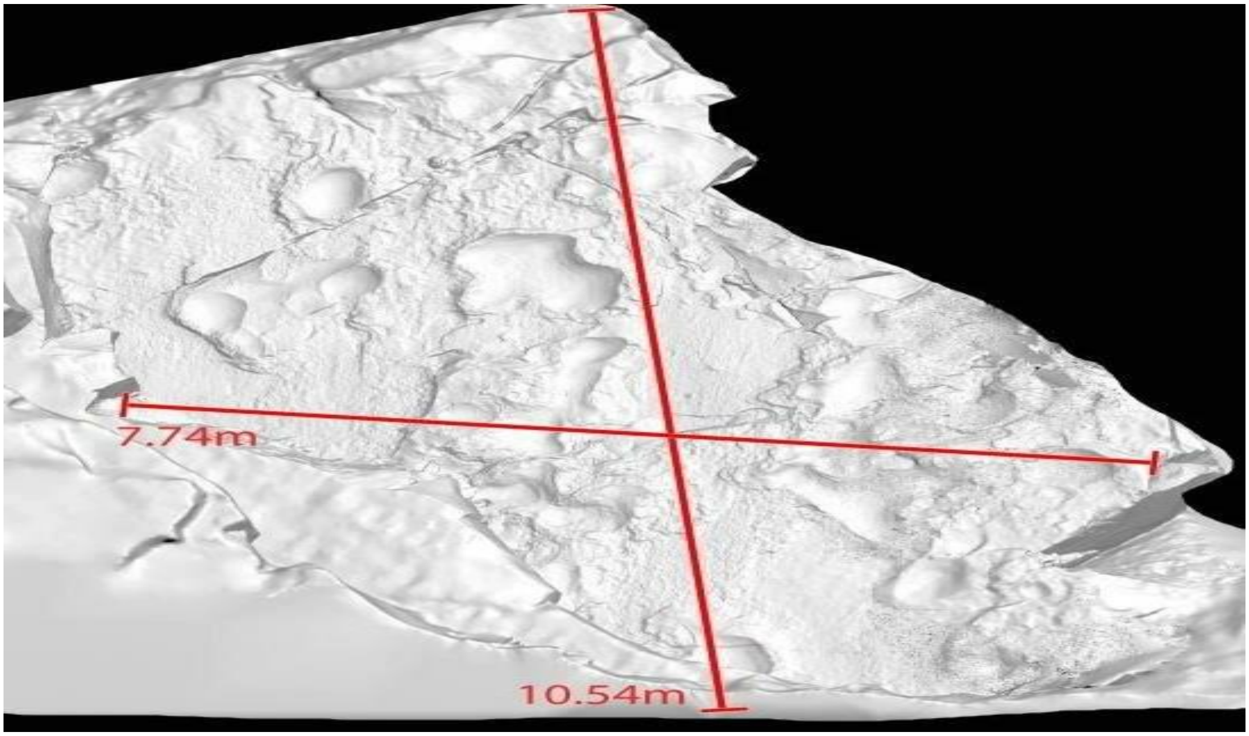

Figure 3. A 3-D model of ichnotype (Footprints and trackway) of *Pashtosaurus zhobi* (on level 5) was prepared by Mr. Nicholas Allen and his team in 2017, according to Malkani (2018).

A marine reptile (Plesiosaur from Khuzdar District, Balochistan) *Zahrisaurus kilmoolai* new species;

Zahrisaurus kilmoolai is a new genus and species of plesiosaur, a marine reptile based on the ribbed body of the MSM-99-K holotype (Fig. 5). This body cross-section is found in the upper part of the Latest Permian-Jurassic Chiltan Limestone of the Sulaiman Group from the Chotok type locality of Kharzan-Moola area, Khuzdar district, Balochistan. The genus Zahrisaurus honored the host Zahri tribe of Balochistan, and Saurus means lizard. The species name *Z. kilmoolai* honors the Kharzan of the Kil region, which owns the Moola River and always flows west to east into the Indus River. The holotype specimen is housed in the Pakistan Geological Survey Museum in Quetta.

Crocodiles

a) *Pabwehshi pakistanensis,* Wilson et al., 2001: This fossil record is based on the rostrum and articulated part of the dentary. *Sulaimanisuchuss kinwai* Malkani 2010, Based on the frontal of the anterior dentary and splenius bone. The diameter of the first and third teeth is small, and the diameter of the fourth tooth is the largest. It shows a marked heterodonty in size and is mainly compressed (Malkani, 2014b, 2015b).

b) *Induszalim bala* Malkani 2014, a terrestrial meso-Eucrocodile Indeterminate taxon based on rostrum found in mid-Alam locality (Malkani, 2014b, 2015d).

Eucrocodiles

***Asifcroco retrai*, Malkani 2015b,** is found in the ferruginous conglomerate deposits of the Oligocene Chitarwata Formation in the Gulki area (Taunsa-Gulki section) in the Dera Ghazi Khan area (eastern Sulaiman Fold Belt). It was a freshwater crocodile of the Paleo-Indus River. The discovered fossil of this taxa has a centrum which is an opisthocoelous type having a ball on the anterior and concave cavity / coel in the posterior. Its ulna has a dorsal groove to set the humerus. Further, the three eggs are collected, one egg may belong to this crocodile while the other eggs may belong to birds/snakes/lizards. This egg-like material may be the osteoderms/coprolite of baluchithere because these are found in association with the *Buzdartherium gulkirao* Malkani, 2015d.

Testudines (Chelonia)

A great number of geoemydid turtle taxa were described from the Siwalik age. Siwalik turtles are closely related to recent taxa (Turtle Extinction Working Group (TEWG) 2015; Turtle Taxonomy Working Group (TTWG) 2017) and thus provide a tool for understanding their Neogene and Quaternary history. The taxonomy of Siwalik geoemydids was recently summarized by TEWG (2015), but as the vast majority of available material has not been evaluated directly in more than 100 years, many conclusions are based on outdated concepts of morphology and taxonomy. At least five Siwalik formations are currently recognized from the Potwar Plateau (Barry *et al.* 2013; Nanda *et al.* 2018): The Kamlial formation, Lower Siwalik (18 to 14 Ma); the Chinji formation, Lower Siwalik (14 to 11.4 Ma); the Nagri formation, Middle Siwalik (11.5 to 9 Ma); the Dhok Pathan formation, Middle Siwalik (9.8 to 3.5 Ma); and the Tatrot formation, Upper Siwalik (3.5 to 3.3 Ma). The material collected by Falconer and Cautley from the Potwar Plateau can, therefore, only be identified as Middle Miocene to mid-Pleistocene in age.

***a)Pangshura tatrotia*,** (Fig. 4).

A Geoemydid pond turtle from the Siwalik period of the Pliocene Epoch. The holotype of this fossil species was found in 1932 in the Tatrot Formation, about two kilometers north of Padri village in the Jhelum District of Pakistan. This specimen is one of the best preserved and oldest representatives of *Pangshura* and also one of few testudinoids from the Indian sub-continent with well-detailed locality data (Safi et al., 2020). Walter and Tyler (2010) first described this specimen as a new species of *Pangshura*. In 1932 a specimen of *Pangshura* was collected by one of the Yale North India expeditions in what is now Pakistan, but the specimen was never formally described. This specimen is arguably the oldest and best-preserved representative of *Pangshura* and also one among few testudinoids from the Indian subcontinent with detailed locality data. Most modern turtle clade origins can be traced back to the Middle Jurassic. Despite this, the interrelationships of these clades are not fully understood (Karl et al., 2021).

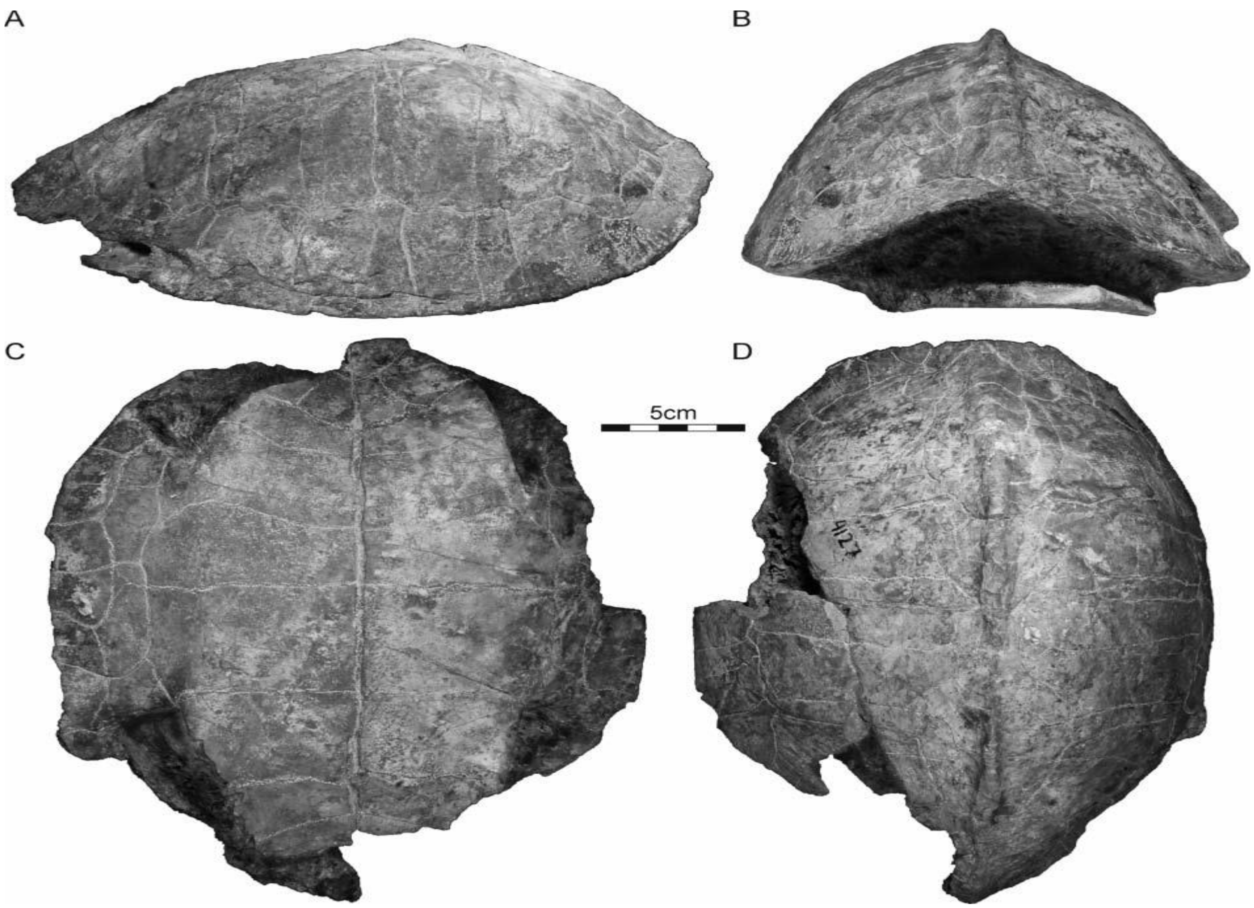

Figure 4. Photographs of YPM 4127, holotype of *Pangshura tatrotia* sp. nov, from the early Pliocene Tatrot Formation of Pakistan. A lateral view of the shell; B, an anterior view of the shell; C, a ventral view of the shell; D, a dorsal view of the shell (Courtesy by: Joyce and Lyson, 2010)

b) *Hardella thurjii,* IM E.94 (Fig. 5): This Miocene to Pliocene specimen from Hassnot, Punjab, Pakistan (Lydekker 1885a) has the center of the shell with all sutures and some grooves closed. It was first drawn by Lydekker in 1885, about *Batagur falconeri* Lydekker (1885a: pl. 25.1). Nerves I to IV are present and present the anterior short side. Nerve IV has a slight median tubercle. Traces of growth are visible on the right side of the rib and ribs I, II, and IV. The region around the Potwar Plateau of Pakistan, the most western part of the Siwaliks, is today inhabited by four species of geoemydid turtles, in particular *Geoclemys hamiltonii, Hardella thurjii, Pangshura tecta* and *Pangshura smithii* (TTWG 2017). The available sample of fossil turtles can only confirm the former presence of the *Pangshura* lineage in this region in the form of *Pangshura tatrotia*. Most fossils from the Potwar Plateau record documented a single species, *Melanochelys sivalensis*, with unclear relationships with the two extant species of Melanochelys. Its occurrence nevertheless documents the former presence of the *Melanochelys* lineages in this region. The southern Indus River valley and its delta in Pakistan are inhabited today by *Geoclemys hamiltonii, Hardella thurjii, Pangshura tecta, and Pangshura smithii* (TTWG 2017), with dubious records registered from the Sind region for *Melanochelys trijuga* (TTWG 2017), *Batagur dhongoka* (Murray, 1884b), *Batagur baska* (Praschag et al. 2008) and *Pangshura tentoria* (Murray 1884b), although the author here was probably referring to *Pangshura tecta* here. Since none of the fossils identified during this study come from southern Pakistan, we cannot be sure whether such geoemydid existed in the Sindh region during the Siwalik age. Geoemydid taxa now inhabit the plains of the Indus, Ganges, and Brahmaputra River basins (Safi et al., 2021).

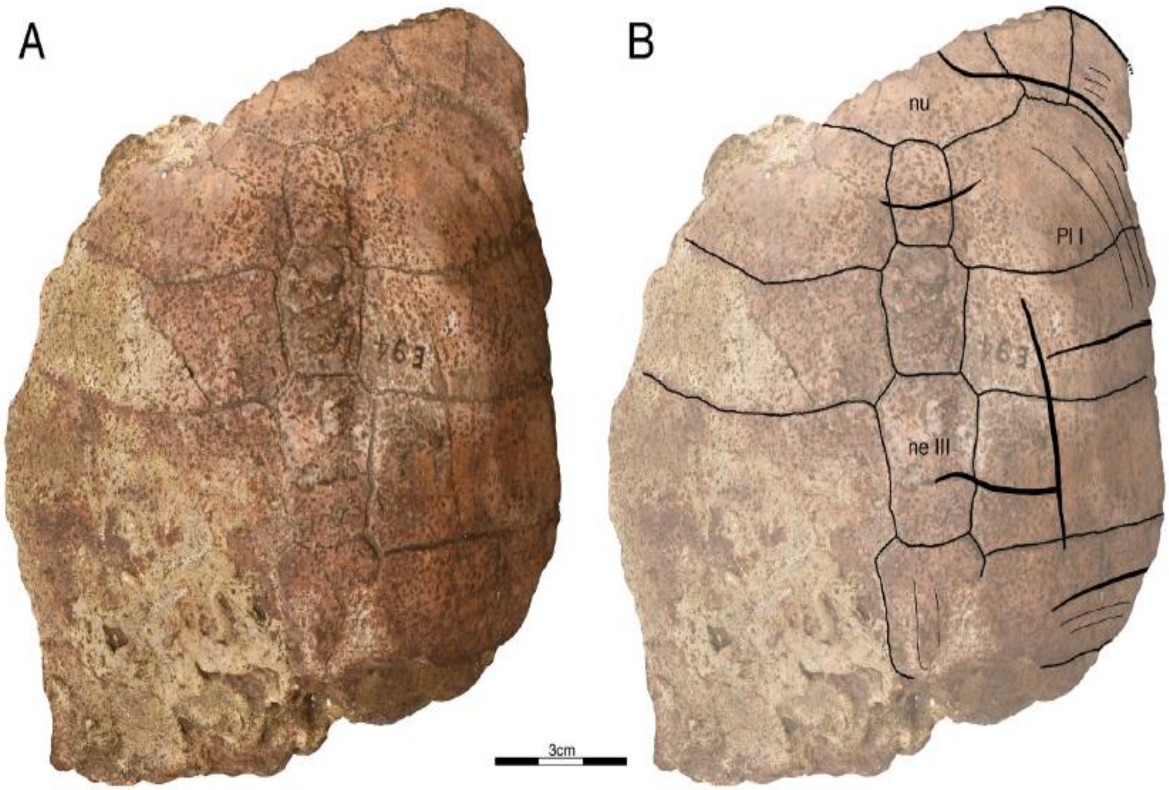

Figure 5. IM E.94, referred to *Batagur falconeri* Lydekker, 1885, here identified as Palatochelydia indet. A. Photograph of carapace. B. Illustration of carapace. Scale bar: 3 cm. (Courtesy by: Garbin et al., 2020).

c)Melanochelys sivalensis **(Theobald, 1877) comb. nov.**

Garbin et al. (2020) proposed that all specimens of '*Clemmys*' from the Siwaliks of Punjab, Pakistan, should be identified as *Melanochelys sivalensis* comb. nov. The region around the Potwar Plateau of Pakistan, the most western part of the Siwaliks, is today inhabited by four species of geoemydid turtles, in particular *Geoclemys hamiltonii*, *Hardella thurjii*, *Pangshura tecta* and *Pangshura smithii* (TTWG 2017). The available sample of fossil turtles can only confirm the former presence of the *Pangshura* lineage in this region in the form of *Pangshura tatrotia*. Most fossils from the Potwar Plateau document a single species, *Melanochelys sivalensis*, with unclear relationships with the two extant species of *Melanochelys* of the Indian sub-continent. Its occurrence nevertheless documents the former presence of the *Melanochelys* lineages from Pakistan. 5 specimens of Miocene/Pliocene, Middle to Upper Siwaliks of Potwar Plateau, were recorded from Punjab (Attock, Jehlum and Chakwal districts), Pakistan. As none of the fossil material analyzed in this study has come from southern Pakistan, we cannot confirm the presence of geoemydid species in the Sind region during the Siwalik age.

d) Drazinderetes (Soft-shell Marine Turtles)

Trionychid turtle remains from the Eocene marine Drazinda Formation, Drazanda is a main village in Dera Ismail Khan District of Pakistan's Khyber Pakhtunkhwa province located at Sulaiman Range, includes much of the bony carapace of a large trionychid described as *Drazinderetes tethyensis gen. et sp. nov*. Drazinderetes is a large trionychin Drazinderetes is a large genus of turtles from the Middle Eocene Drazinda Formation of Pakistan, its presence in shallow marine sediments of the Drazinde Formation suggests that Drazinderetes may have been partially or entirely marine. Unidentified turtle remains from the same structure, with an endogastric shell indicating a length of 1.5 to 2.1 meters, suggesting that Drazinderetes would have been one of the largest turtles. Drazinderetes currently has only one species: *Drazinderetes tethyensis*. The first studies of the Drazinda Formation were carried out by the Pakistan Geological Survey and the University of Michigan in 1993 and 1996. The holotype (GSP-UM 3 195) of Drazinderetes, a nearly complete carapace, was found during the 1996 exploration of the area west of Satta Post in sediments of Bartonian age (39 - 38 Ma) that also yielded archaeocetes, including Basiloterus, and primitive sea cows. (Head et al., 1999). Unlike in many other turtles, the shell of trionychid turtles is composed only partly of the bony carapace, with cartilage making up 20% (Apalone) to 45% (Malayan softshell turtle) of the entire carapace length depending on the species. The exact relationship between Drazinderetes (and GSP-UM 3019) and other softshell turtles is largely unknown to calculate modern taxa's minimum and maximum cartilage size. Quite early the turtle populations had been influenced by the consumption of early hominins and the cheloniophagy is already proven with early hominids and is extended by the described materials (Blasco, 2008; Karl et al., 2012; Karl et al., 2020) (Fig. 6 &7).

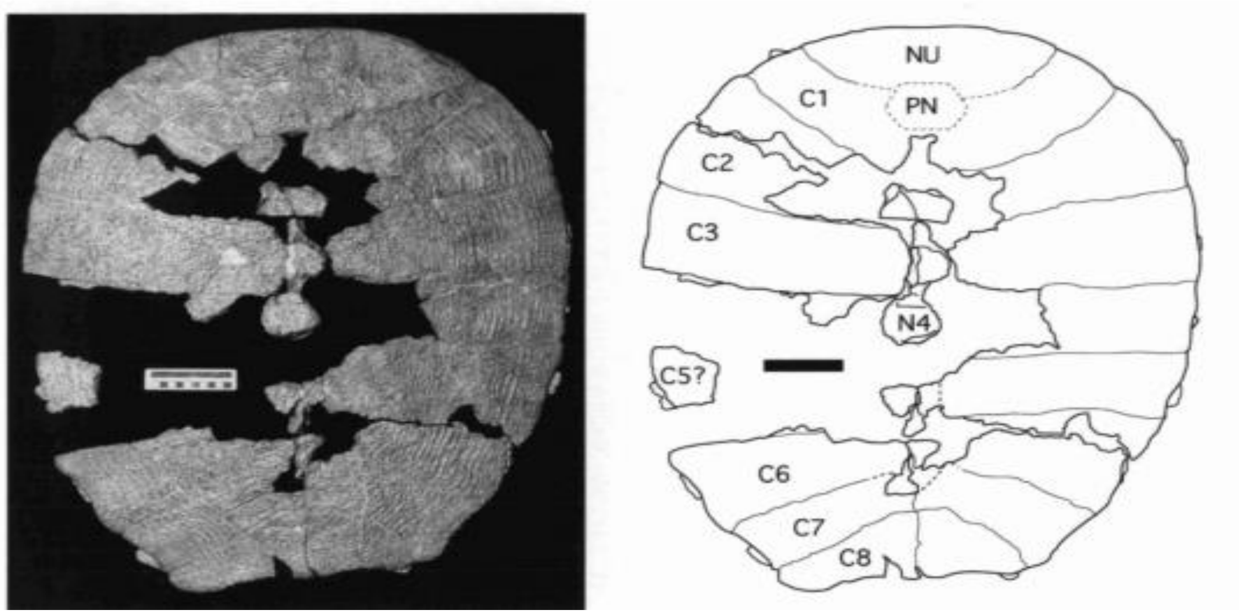

Figure 6. Carapace of *Drazinderetes tethyensis,* gen. et sp. nov., in dorsal view (GSP-UM 3195, holotype, photograph of cast). The exterior is at the top. Scale is in cm. Abbreviations in interpretive drawing at right follow Meylan et al. (1990): C, costal element; N, neural element; NU, nuchal; PN, preneural (Courtesy: Head et al., 1999).

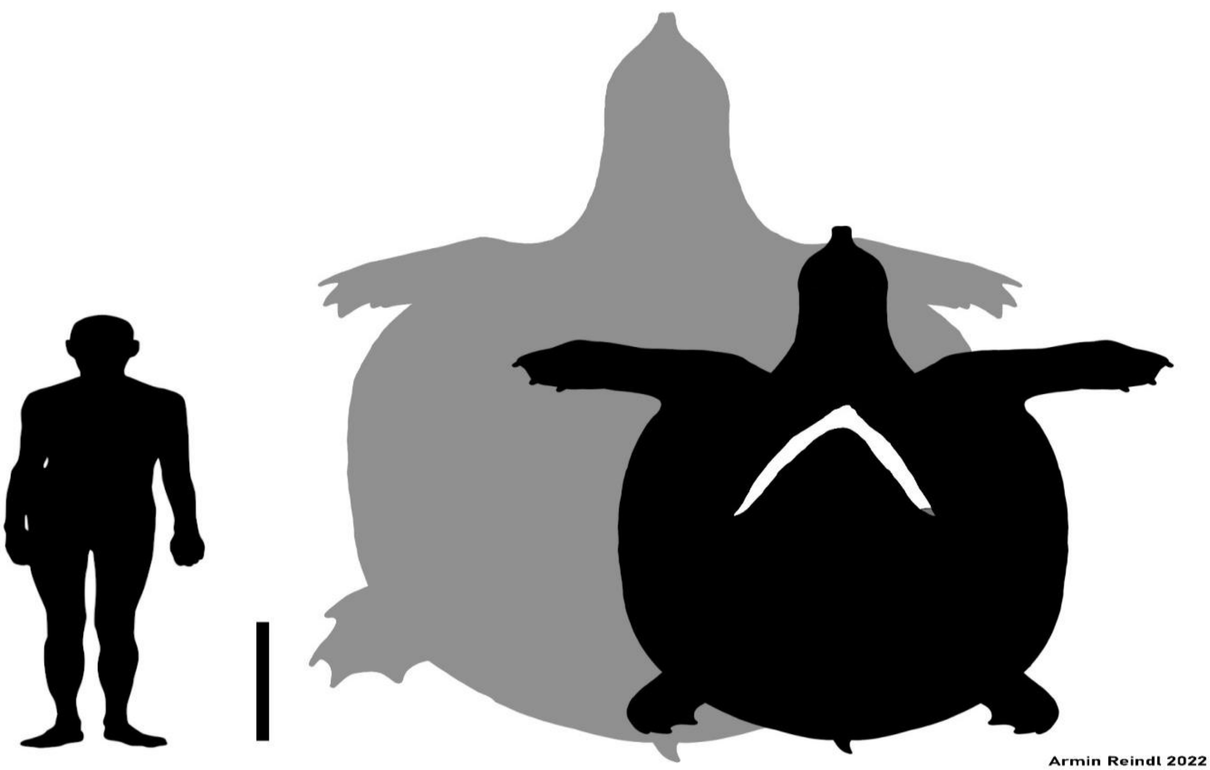

Figure 7. Upper and lower estimates of a large, undetermined trionychid from the Drazinda Formation (Courtesy by: Armin Reindi, 2022).

Snakes

Siwalik snake fauna data contains approximately 1,500 vertebrae collected from surface-collection and screen-washing of the bulk matrix. The data represent 12 taxa and morphotypes, including Python sp., *Erycinae infinite, Acrochordus dehmi, Gansophis potwarensis gen. & sp. nov*., the first fossil record of the *bungarus snake, Natricinae indeterminate, Chotaophis padhriensis gen. & sp. nov*., and Boidae and indeterminate and indeterminate Elapidae and two recognizable but unnamed morphotypes. *Acrochordus* dominates the data in terms of frequency. However, there is a major taxonomic/morphological divergence between 10.0 and 9.0 Mya, coinciding with the development of the Asian monsoon system and the deposition of the Dhok Pathan Formation. These two factors resulting from the uplift of the Tibetan Plateau may have resulted in more habitat for a variety of taxa. The Siwalik Group snake fauna is highly diverse, and the unique presence of *Acrochordus, Bungarus*, and new taxa in the Siwalik sequence described here suggests that the split between the European and South Asian biogeographic regions occurred before the mid-Miocene. The snake fauna of the Siwalik Group is quite different from the snake fauna of the Potwar Plateau, both of these, contain only kraits. These differences occur where the young Siwalik snake is found; this indicates that the main change occurred 6.35 million years later, probably during the Quaternary, with the flow of the Siwalik River from the plateau. Taxonomic differences between the Siwalik Group and coeval European faunas indicate that South Asia was a distinct biogeographic theater from Europe by the middle Miocene. Differences between the Siwalik Group and extant snake faunas indicate significant environmental changes on the Plateau after the last fossil snake occurrences in the Siwalik section (Head, 2005). Rage et al. (2014) reported the discovery of madtsoiid snake remains from the early Paleocene (Khadro Formation) from Ranikot Group, Sindh, Pakistan. These specimens consist of vertebrae and are referred to as *Gigantophis*. This is the first report of *Gigantophis* from outside of Africa. The problem of the generic distinction between *Gigantophis* and Madtsoia is stressed. The specimens from Pakistan slightly differ from the single species (*G. garstini*) referred to the genus *Gigantophis*, but unfortunately, the available material does not allow further considerations and the fossil is referred to as *Gigantophis sp*. However, *Gigantophis sp.* from the Khadro Formation is more closely related to *G. garstini*, from northern Africa, that, is known only from the middle and late Eocene.

Varanids

Varanus sp. (Merrem, 1820) was described in 2010 (SNSB-BSPG 1956 II). The discovered fossil is a large, long vertebra with an inner body. It is well preserved, but its front part and much of the upper left side are covered by a hard sandstone matrix, which has not been removed to avoid damaging the bones. In the ventral view), the area is triangular, converging posteriorly and with smooth lateral edges. The ventral surface is flat and has no spine. Despite the stromal valve, the ventral edge of the procotyledon is posterior to the dorsal edge. In posterior view, the disc is compressed dorsoventrally (Fig. 8).

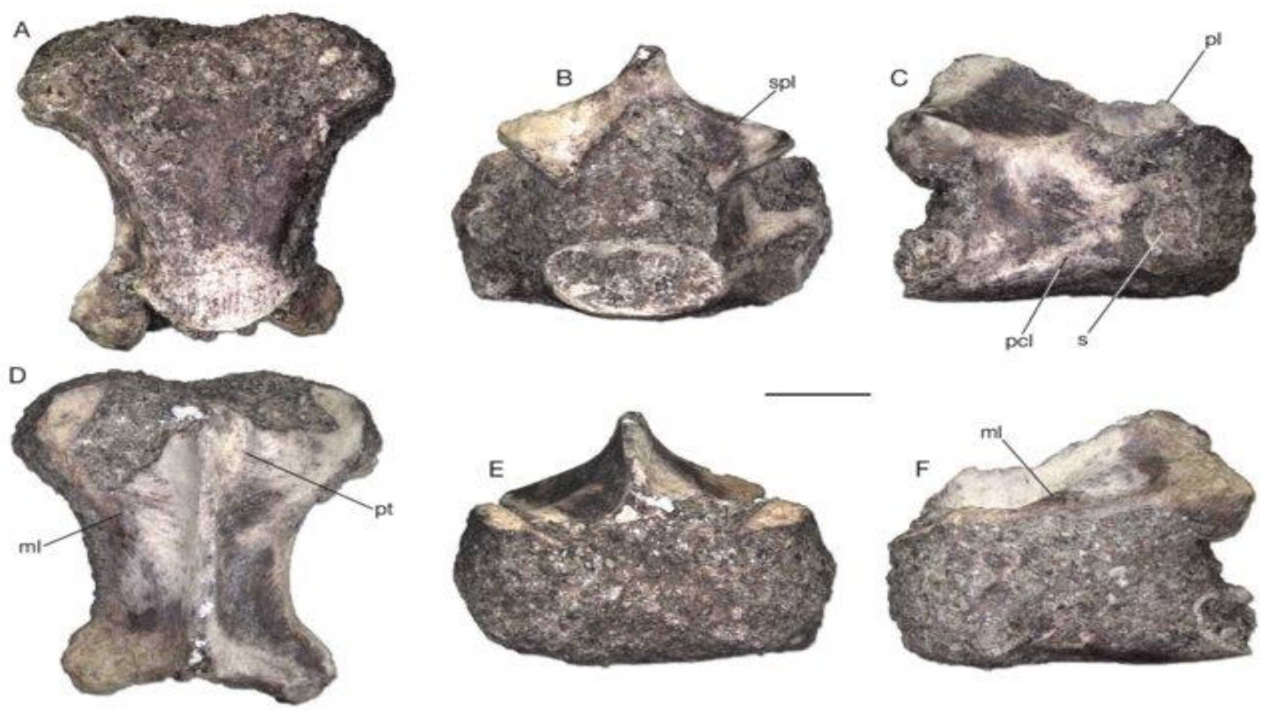

Figure 8. Varanus sp. from the Miocene of Pakistan: trunk vertebra (SNSB-BSPG 1956 II 2010) in ventral (A), posterior (B), right lateral (C), dorsal (D), anterior (E), and left lateral (F) views. Abbreviations: ml, mediospinal lamina; pcl, posterior centrosynapophyseal lamina; pl, prespinal lamina; pt, pars tectiformis; s, synapophysis; spl, spinopostzygapophyseal lamina. Scale bar: 5 mm.

Paleo-biogeographic evolution of the Indo-Pak Peninsula

Indo-Pakistan is a peninsula, but in the past, it was part of Gondwana and was an island once during the northward journey. During the Late Triassic period (about 220 million years ago), landmasses were consolidated into Pangea. Indo-Pakistan separated from Madagascar in the late Jurassic and began advancing northward in the early Cretaceous (135 mya). It is a journey mostly Cretaceous, and about 68-70 million years ago the rapidly moving islands traveled more than 6000 kilometers to the northwest, first meeting Tethys and the Afghan block of Asia. This first collision (67 Ma) created the land bridge (between Indo-Pakistan Shield and Asia) from Afghanistan /Hindu Kush-Kurram-Waziristan-Zhob (Western Indus Suture and adjoining Afghan land) -Ziarat-Fort Munro (D.G. Khan) areas, allowed the migration of the latest Cretaceous fauna from Asia to Indo-Pakistan and vice versa (Malkani & Ge, 2016). Therefore, the West Indus suture area near Zhob-Waziristan-Kurram and the adjacent western part of the Afghan block uplifted more, which provided the lands for the migration of the Eocene vertebrates like baluchithere, the largest rhinoceros from Asia to the Indo-Pakistan subcontinent.

This rising ended the Paleo Vitakri River systems of the Sulaiman Belt (Indo-Pak Shield to Neo-Tethys) and initiated the birth of Paleo Indus River systems flowing from northwest to southeast and north to south. It deposited the deltaic and terrestrial molasses Late Paleocene-Early Eocene Chamalang (Ghazij) Group in the Sulaiman basin Shagala Group of Balochistan. This molasses marks the beginning of the closure of the Neo-Tethys Sea from the northwest of the Indo-Pakistani subcontinent. The Middle Eocene was represented by a major westward and eastward transgression of the sea. Therefore, the transition period of this transgression is represented by the deposition of the Upper Gazi Group, and the major transgression is represented by the release of the Kahan Group (Habib Rahi limestone Domanda shale， Pirkoh limestone, and Drazinda shale) in the Sulaiman basin of Pakistan while the northern Balochistan /Kakar Khorasan basin was under erosion. At the latest Eocene (40--35 Ma) the northern part of Indo-Pakistan collided with Karakoram and Tibetan parts of Asia. This collision resulted in the uplift, folding, and faulting (mainly south verging thrusts) in the northwestern Foreland (Hindukush- Karakoram belt and Kohistan-Ladakh magmatic arc) and its adjoining northern part of the Hinterland now called Himalaya. Consequently, the Tethys Sea was permanently closed by the end Eocene tectonic episode which is responsible for the birth of the Himalayas. This collision started the terrestrial/continental fluvial faces and Neotethys permanently closed from Hindukush-Karakoram belt, Kohistan magmatic arc, Khyber Pakhtunkhwa (uppermost Indus), Kohat and Potwar (northern/upper Indus) and Sulaiman (Middle Indus) basins while the Kirthar (southern / lower Indus) basin remained undersea as the Oligocene marine Nari and Gaj formations were deposited in Kirthar basin. The limestone Domanda Shale (Pirkoh Limestone and Drazinda Shale) in the Sulaiman Basin of Pakistan is being eroded, while the northern Balochistan/Kakkar Khorasan Basin is being eroded. 40-35 Ma) Collision of northern India and Pakistan with the Karakoram

Mountains This collision resulted in uplift, folds, and faulting of the northwest (Hindu Kush-Karakoram belt and Kohistan-Ladakh magmatic arc) and northern hinterland (now known as the Himalayas). (southern thrust faults only). As a result, at the end of the Eocene tectonic period, the Tethys Sea closed permanently, leading to the formation of the Himalayas. The Kohistan magma arc is permanently closed. Since the Oligocene marine Nari and Gaj formations were deposited in the Kirthar basin, the lower basin remains on the coast. It was born in the Ganges River system. The major geological events during the time that led to further invasion of seawater from the Kirtal (lower/southern Indus) basin were: the deposition of the continental Vihowa/Manchar Group, the last major event ever, the end of the Pleistocene, leading to further intrusion of the southern seas and folds. And caused the emergence of faults (Malkani and Mahmood, 2016). The northward movement of the India-Pakistan Plate continues to this day.

The Neo-Tethys still extends east-west, mostly to the west of the Indo-Pak subcontinent, but is now called the Indian Ocean. It is called South Asia because of the contact and collision between the Indo-Pak subcontinent and East Asia. Cenozoic vertebrates show affinity with Eurasia, having migrated from the Indo-Pak subcontinent to Eurasia and vice versa after the initial collision between the Indo-Pak subcontinent and Asia at the end of the Cretaceous. Show Indo-Pak history (Sun, 1993; Sun et al., 2014; Martin et al., 2010; Malkani, 2015d; Malkani & Ge, 2016).

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