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Theropods, Ornithischians and Pterosaurs from South Asia-Review with New Taxa: A Look at Paleontology, Stratigraphy and Mineral Potential of Pakistan

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Abstract

Dinosaur discoveries from India have been known since 1844, while dinosaur discoveries from Pakistan have appeared recently since 2000. 3 large and 2 small theropod dinosaurs are known from Pakistan, while 11 large and 4 small theropods are known from India. Pakistani land uncovered many footprints and trackways of Jurassic small and large theropods, Jurassic ankylosaur and Cretaceous hadrosaur ornithischian dinosaurs, while Indian land uncovered a footprint of small and a footprint of large theropod and 1 footprint of stegosaur. Pakistan uncovered a Jurassic bone taxon of ankylosaur ornithischian based on heavily armored synapomorphies. Recently, Pakistan yielded 1 bone taxon and 1 ichno taxon of pterosaurs, while Indian land yielded 1 bone taxon of pterosaur. Pakistani land uncovered 14 bone taxa (and 2 ichno taxa) of herbivorous sauropod dinosaurs, 5 bone taxa (and 2 ichnotaxa) of carnivorous theropod dinosaurs, 1 bone taxon of ankylosaur and 2 (ichnotaxa) of ornithischian (ankylosaur and hadrosaurs) dinosaurs, 1 bone taxon (and 1 ichno taxon) of pterosaurs, 1 plesiosaur, 7 crocodiles, 1 snake, 1 bird, 11 mammals, 3 fishes, 7 invertebrates and 1 plant. This study fills a significant gap in the literature by bringing together paleontological records from an understudied geographical location, enhancing the global understanding of dinosaur paleobiogeography. Pakistan hosts Precambrian to recent sediments igneous and metamorphic rocks. Pakistan is rich in mineral resources/rocks, but it needs more attention for its development to fulfill local requirements and earn foreign exchange.

Keywords

Theropods, Ankylosaurs, Hadrosaurs, Stegosaurs, Ornithischia, Pterosaurs, Indo-Pakistan Subcontinent, Paleontology, Stratigraphy, Mineral Potential, Pakistan

1. Introduction

Invertebrate paleontology was mostly used for aging the strata and stratigraphic formations in western Pakistan [1], including the Balochistan basins, western Indus Suture, and part of the Kirthar and Sulaiman basins. Numerous scientists use invertebrates for aging the rocks in Pakistan and their results are summarized for Precambrian [2], Paleozoic [3], Mesozoic [4] and Cenozoic [5] stratigraphy providing basic data. Later, these results and updated information were used in stratigraphy of Pakistan [6]-[9]. While vertebrate paleontology was used for aging of terrestrial late Tertiary and Quaternary strata [5]-[9]. Recently since 2000, diverse dinosaurs were discovered and described by M. Sadiq Malkani in various papers [10]-[42], while from neighboring India, research on dinosaurs began about two centuries ago [43]-[45]. Previously, no single combined report was available to get information on theropods, ornithischians and pterosaurs from Indo-Pakistan, while the present report provides this facility. A few new fauna are being added. This study highlights an interdisciplinary approach by linking paleontological data with stratigraphy and mineralogy, which could appeal to broader scientific disciplines.

Institutional Abbreviations: GSP, Geological Survey of Pakistan, Quetta, Pakistan. UM, Museum of Paleontology, University of Michigan, USA. GSI, Geological Survey of India. AMNH, American Museum of Natural History, USA.

2. Materials and Methods

Materials were collected during numerous field visits in many seasons in Pakistan, and previously published records were also collected from Pakistan and India. Methods applied here are disciplines of geological and paleontological diagnosis, comparison and description.

3. Results and Discussion

Results and discussion are presented in 2 major steps. 1st step includes the theropods, ornithischian and pterosaurs from South Asia (Indo-Pakistan). 2nd step is represented by a look at paleontology, stratigraphy and mineral potential of Pakistan.

3.1. Theropod Dinosaurs from Indo-Pakistan Subcontinent (South Asia)

Small to large theropods were reported from Pakistan (**Figures 1-7**; **Table 1**), and India.

3.1.1. Small Bodied Theropod Dinosaurs Discovered in Pakistan

Revised Systematic paleontology and diagnosis of *Saraikisaurus minhui* [37]

Systematic paleontology

Dinosauria

Saurischia

Theropoda

Ceratosauria

Abelisauroidea

Noasauridae

Saraikisaurus minhui [37] (Revised and diagnosed as a new genus and new species of small theropod, see below) (**Figure 2**).

Comments: *Saraikisaurus minhui* [37] has been revised now as a new genus and new species of noasaurid theropod, while previously described informally [27] [30] [32] and described formally by [37] as a toothed pterosaur.

Holotype: Partial dentary ramus GSP/MSM-157-16 with partially articulated teeth (**Figure 2**) belongs to a single individual. Fossil is housed in the museum of Geological Survey of Pakistan, Quetta, Pakistan.

Type locality, horizon and age: Holotype was found in the east Top Kinwa (**Figure 1**) type locality (Pakistan dinosaur locality 16) found at latitude 29.68809 N and longitude 69.4002 E (N 29˚41'17.60"; E 69˚24'0.72"), Barkhan District, Balochistan Province, Pakistan. Holotype was found a few meters west of dividing line between the Kinwa stream and Alam stream. Top Kinwa or east Kinwa area yielded 3 main sites named as west Top Kinwa, east Top Kinwa and mid Top Kinwa (**Figure 1**). Holotype was found as surface find in the upper shale unit (caped by upper sandstone unit) of Vitakri Formation (Table 1 of [39]) of Fort Munro Group ([8] [9] [21]). According to stratigraphic position and previously well dated Maastrichtian Pab Formation (lower formation) and well dated Paleocene formations (upper formations), the age of Vitakri Formation is considered Late Cretaceous (more specifically latest Maastrichtian 67-66 Ma/Million year ago ([8] [9] [21]-[23], pages 416-418 of [35], pages 903-906 of [40]). This type locality also yielded holotypes of titanosaur *Imrankhanshaheen masoombushrai* [42] and crocodile *Pabwehshi pakistanensis* [46].

Etymology: *Saraiki*, in honor of Saraiki people and language, *saurus*, Greek for lizard. Species name *minhui* honors the Prof. Dr. Min Huh of Korea Dinosaur Research Centre and Chonnam National University, Gwanju, South Korea for his kind support for the visit to the 11th Symposium of Mesozoic Terrestrial Ecosystems in 2012.

Revised Diagnosis and Comparison: Noasauridae (Abelisauroidea) theropod with prominent heterodont, transversely compressed and small sized teeth, pneumatic and narrow and small dentary ramus. *Saraikisaurus minhui* teeth are heterodont and all transversely compressed while the teeth of *Shansaraiki* are heterodont but one tooth is transversely compressed and two teeth are circular to subcircular. *Saraikisaurus* dentary length and width (**Figure 2**) are slightly less than the dentary ramus of Noasaurid indeterminate species RTMNU/DG/VERT/1/55P/2020 from Pisdura India (Figure 7 of [47]) and slightly more than the dentary ramus of *Masiakasaurus* [48] from Madagascar (Figure 2 of [48]; Figure 3 of [49]). *Saraikisaurus* teeth transversely more compressed (**Figure 2**) than teeth of Noasaurid indet species from India (Figure 7 of [47]). 4th and 6th dentary teeth are the largest teeth (in anteroposterior length), while 6th dentary tooth has maximum transverse width. *Saraikisaurus* teeth compression is the same as *Masiakasaurus* [48].

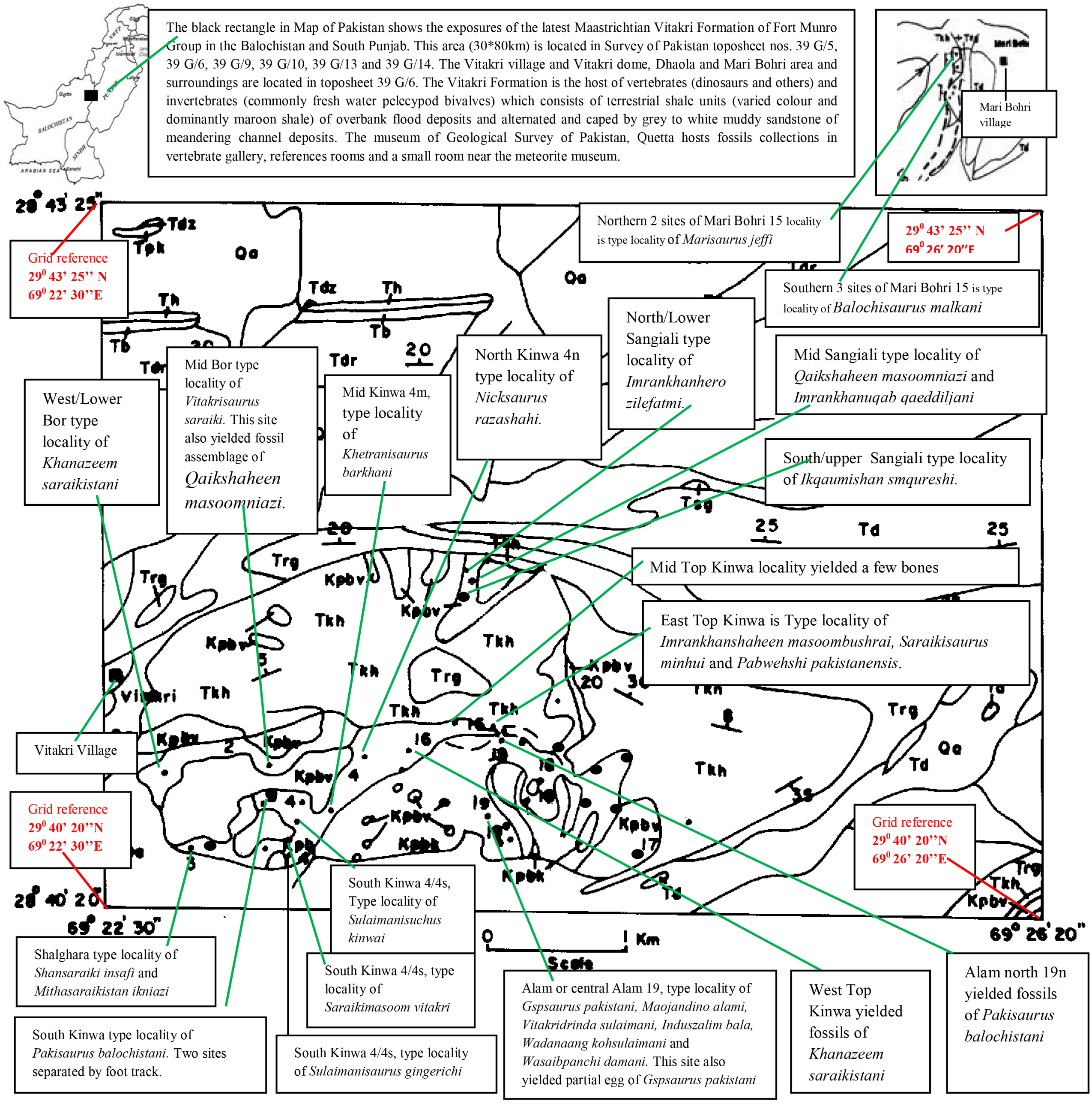

Figure 1. **Upper right map**, Black rectangle in Map of Pakistan shows the exposures of latest Maastrichtian Vitakri Formation in Vitakri and surrounding areas which host 25 localities (represented as small black circle) of fossils in eastern Sulaiman fold and thrust belt, eastern Balochistan and western South Punjab (Saraikistan). **Upper left map**, Geological map of Mari Bohri (Kachi Bohri/Mari Kachi) locality in Barkhan District shows fossil assemblage sites [21]. **Lower map**, Geological map of Vitakri dome area (Barkhan District, Balochistan Province, Pakistan) showing fossil localities. Numerical number represents localities number (except the dip number perpendicular to strike). 1, Sangiali locality divided into north Sangiali/lower Sangiali, mid Sangiali, and south Sangiali/upper Sangiali. 2, Bor locality divided into west Bor/lower Bor, mid Bor, and east Bor/top Bor. 3, Shalghara. 4, Kinwa stream divided into 4/4s, south Kinwa; 4m, mid Kinwa; 4n, north Kinwa, and 16, east Kinwa/Top Kinwa which divided into east Top Kinwa, mid Top Kinwa and west Top Kinwa. 17, Dada Pahi. 18, east Alam. 19, Alam (includes the central Alam and south Alam localities). 20, Rosmani. Abbreviations: Fm, Formation. Qa, Alluvium. Tdz, Drazinda Fm. Tpk, Pirkoh Fm. Tdm, Domanda Fm. Thr, Habib Rahi Fm. Tb, Baska Fm. Tdr, Drug Fm. Tsg, Shaheed Ghat Fm. Td, Dungan Fm. Trg, Rakhi Gaj Fm. Tkh, Sangiali Fm. Kpbv, Vitakri Fm. Kpbk and Kpbd represent Dhaola Member of Pab Fm. This figure is updated after [21] [37]. Scale bar equal to 1 kilometer.

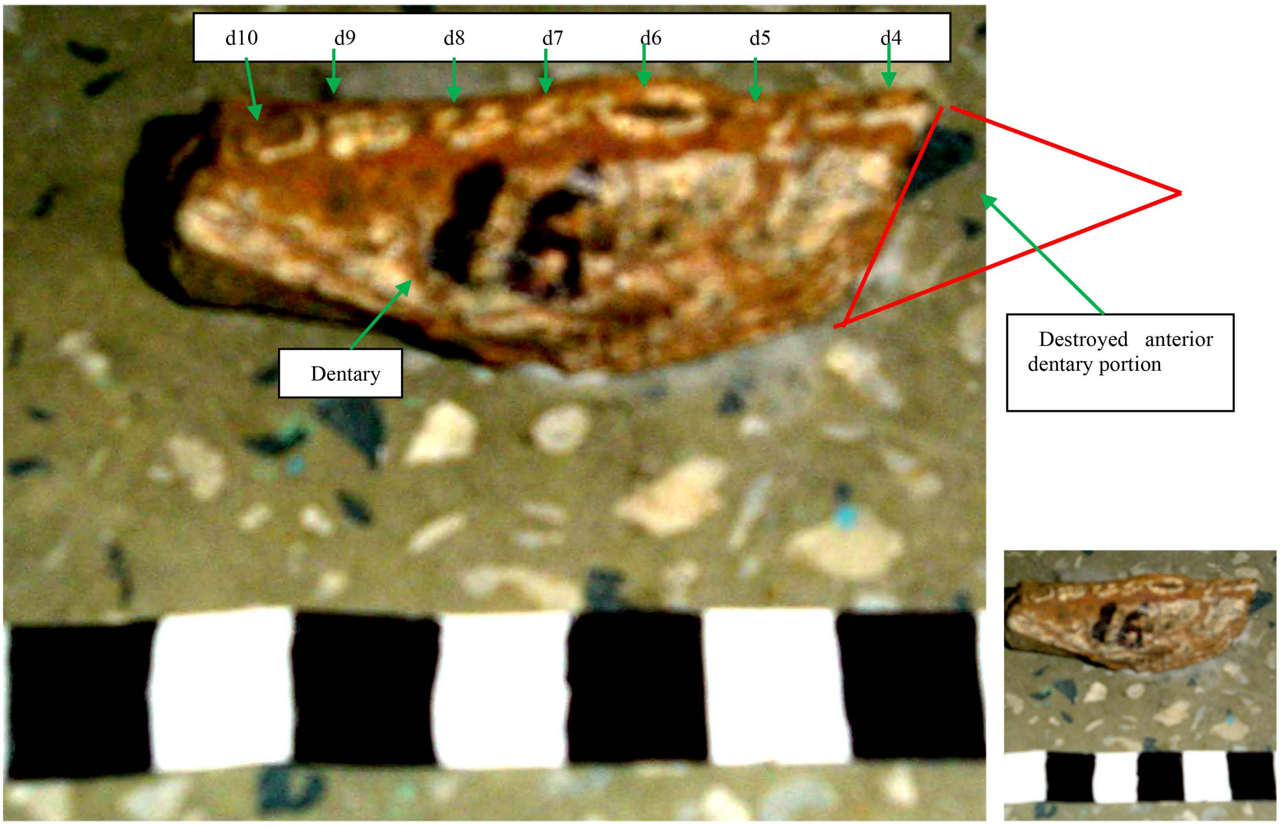

Figure 2. *Saraikisaurus minhui* [37] (revised as new genus and new species of small theropod) holotypic partial left dentary ramus articulated with partial teeth (GSP/MSM-157-16) in medial view, found from the latest Maastrichtian Vitakri Formation of east Kinwa (east Top Kinwa; **Figure 1**) locality, Barkhan District, Balochistan, Pakistan. Scale, each black or white digit is 1 cm (centimeter). Abbreviation: d for dentray, Arabic number after d represents dentary tooth position.

Saraikisaurus 4th dentary tooth anteroposterior (long axis) length is almost the same as 4th dentary tooth of Noasaurid indeterminate species from India [47]. While *Saraikisaurus* 4th dentary tooth transverse width is significantly less than the 4th dentary tooth of Noasaurid indeterminate species from India [47]. *Saraikisaurus* 5th dentary tooth is significantly smaller than the 5th dentary tooth of Noasaurid indeterminate species from India [47]. *Saraikisaurus* teeth (**Figure 2**) are larger (in transverse width and anteroposterior/long axis length) than teeth of *Masiakasaurus* [48] and slightly smaller than the teeth of Noasaurid indeterminate species [47]. Closely contacted teeth are found in Noasaurid indeterminate species from Pisdura India [47], moderately spaced teeth are found in *Saraikisaurus* from Pakistan and widely spaced teeth are found in *Masiakasaurus* from Madagascar [48] [49]. 7th dentary tooth of *Saraikisaurus* is oriented obliquely in anterolateral and posteromedial direction, while a few teeth of *Masiakasaurus* [48] and Noasaurid indeterminate species [47] are oriented obliquely. *Saraikisaurus* has the intermediate body size between the *Masiakasaurus* [48] from Madagascar (small body sized) and Noasaurid indeterminate species [47] from India (large body sized) but all these are noasaurid small bodied theropods. The dentary of *Saraikisaurus* noasaurid has irregular groove on surface of dentary ramus (**Figure 2**), while dentary ramus of medium to large bodied abelisaurid theropod *Shansaraiki* has mostly anteroposteriorly elongated grooves. The dentary ramus of medium to large bodied abelisaurid theropod *Shansaraiki* is distinguished from the *Saraikisaurus* noasaurid dentary by their much larger size, more transversely thick, deeper, laterally more convex and heavily ornamented surface. The dentary ramus of medium to large bodied abelisaurid theropod *Shansaraiki* from Pakistan and *Indosuchus* from India are distinguished from the *Saraikisaurus* noasaurid dentary by their much larger size, more transversely thick, deeper, laterally more convex and heavily ornamented surface. Other diagnostic features are shown below in description.

Description: *Saraikisaurus minhui* is being revised as small theropod because the Late Cretaceous pterosaurs lack teeth and further its dentary ramus and articulated teeth resemble *Masiakasaurus* from Madagascar [48] [49] and indeterminate theropod from India [47]. The dentary ramus is thin and shallow. The slender partial dentary ramus length is 5.8 cm, height is about 2 cm and width is about 1 cm. This preserved dentary ramus hosts the articulated 7 partial teeth with partial crowns (probably from dentary 4th dentary to 10th dentary teeth) positioned in the relevant alveoli (**Figure 2**). Some anterior, posterior and ventral portions of dentary ramus are damaged. All these crowns are broken just above the level of upper margin of jaw. The position of dentary teeth is interpreted from *Masiakasaurus* from Madagascar [48] [49] and Noasaurid indeterminate species from India [47]. Dentary ramus has irregular elongated grooves generally presenting mosaic texture. Teeth are transversely compressed. Teeth are anteroposteriorly long and transversely compressed, oval to suboval, heterodont, close to each other. The 4th dentary tooth (here preserved is first) is about 9 mm anteroposteriorly long and about 5 mm transversely wide. 5th dentary tooth is small and distorted/disturbed and may be about 4 - 5 mm anteroposteriorly long and about 3 - 4 mm transversely wide. 6th dentary tooth is 8 mm anteroposteriorly and 5 mm transversely wide. 7th dentary tooth is 7 mm anteroposteriorly and 4 mm transversely wide. 8th dentary tooth is 6mm anteroposteriorly and 4 mm transversely wide. 9th dentary tooth is 8 mm anteroposteriorly and 4 mm transversely wide. 10th dentary tooth is 6 mm anteroposteriorly and 4 mm transversely wide. These measurements reveal that the transverse widths are mostly constant and also half of anteroposteriorly length. All the teeth crowns are eroded. Closeness of the sockets is found. These measurements reveal that the transverse widths are mostly constant and also half of anteroposteriorly length. All the teeth crowns are eroded. The teeth are heterodont in size. The teeth central cavity and peripheral bone are dominantly exposed as cross section. Most of the teeth are obliquely set having direction from anterolaterally to medioposteriorly and show overlapping with each others. Dentary (**Figure 2**) of *Saraikisaurus* noasaurid have irregular groove on surface of dentary ramus while dentary ramus of medium to large bodied abelisaurid theropod *Shansaraiki* have mostly anteroposteriorly elongated grooves (**Figure 7**). *Saraikisaurus* dentary ramus (**Figure 2**) is distinguished by its much smaller size, relatively less transverse, shallower, laterally less convex and relatively less ornamented surface than the dentary ramus (Figure 7) of *Shansaraiki* and *Indosuchus* from India. Teeth of *Saraikisaurus* are heterodont but all are transversely compressed. Small theropods are rare in southern landmasses [47]-[49]. *Saraikisaurus* is an addition to the noasaurid of southern landmasses (Gondwanan landmasses). This is the first small bodied theropod dinosaur discovered from Pakistan. Discovery of *Saraikisaurus* small bodied theropod from Pakistan, increases the distribution of noasaurid in Gondwanan landmasses. *Saraikisaurus* noasaurid habitat is terrestrial on land.

New indeterminate species of small bodied theropod dinosaurs from Pakistan

Systematic paleontology

Dinosauria; Saurischia; Theropoda; Ceratosauria; Abelisauroidea; Noasauridae; Indeterminate species (Figure 3)

Referred Specimen: A partial dorsal vertebra (GSP/MSM-64-15) (Figure 3), which is housed in museum of Geological Survey of Pakistan, Quetta, Pakistan.

Locality, Horizon and Age: A partial dorsal vertebra (GSP/MSM-64-15) was found in 2001 from the overbank terrestrial maroon, grey, greyish green and mottled clays of Vitakri Formation of Mari Bohri (latitude 29˚42'08"N; longitude 69˚15'08"E) locality (Figure 1), Barkhan District, Balochistan Province, Pakistan. Age is Late Cretaceous (latest Maastrichtian; 67-66 Million years ago/Mya) (see above).

Comments: This dorsal vertebra was found isolated. It has no anatomical overlap with *Saraikisaurus minhui*, while it has overlap with Indian small theropods but it is distinct. Previously this vertebra was tentatively referred to *Induszalim* crocodile. No any fossil of crocodiles were found in Mari Bohri Locality.

Description: Dorsal vertebra (GSP/MSM-64-15; Figure 3) is small, amphicoelous and tall. While recognized due to lacking parapophysis and chevron facets and comparison from vertebrae reported from India [47] [50] and from Madagascar [48] [49].

Figure 3. Vertebra GSP/MSM-64-15 in 3 views of Indeterminate new species of Noasauridae. Scale, each black/white digit is 1 cm.

The dorsal centrum height of Indeterminate species of noasaurid is significantly tall like those of vertebra GSI/K27/604 (Figure 3 of plate 21 of [50]) of *Ornithomimoides ? barasimlensis* [50], while in contrast, *Masiakasaurus knopfleri* vertebral centra from Madagascar [48] [49] and *Ornithomimoides ? barasimlensis* vertebra GSI/K27/531 (Figure 2 of plate 21 of [50]) have almost the same width and height (no tall). Its dorsal centrum is taller than the broad centrum of vertebra GSI K27/578 of *Compsosuchus solus* (Figure 1 of plate 20 of [50]) and centrum of dorsal vertebra GSI/K27/614 of *Jubbulpuria tenuis* (Figure 7 of plate 20 of [50]) or caudal vertebra (Figure 5 of [47]) of *Laevisuchus indicus* from India. Tallness of dorsal centrum of Indeterminate species resembles to tall centrum of dorsal vertebra GSI K20/612 of *Jubbulpuria tenuis* (Figure 6 of plate 20 of [50]), while [47] identified it as caudal vertebra (Figure 6 of [47]) of *Laevisuchus indicus* from India. Dorsal centrum of Indeterminate species from Pakistan has relatively less prominent ventral arc, while *Laevisuchus indicus* dorsal vertebra GSI K27/588 from India (Figure 5 of plate 20 of [50]; Figure 4 of [47]) have more prominent ventral arc. Further, the dorsal centrum of Indeterminate species is taller than *Laevisuchus indicus* dorsal vertebra GSI K27/588 tallness (Figure 5 of plate 20 of [50]; Figure 4 of [47]) from India.

Trackways of a couple of *Himalayadrindoperus* [38], a small Theropaonia [38]

Trackways of a couple of small theropods were described [32] [38] from Pakistan.

Revised Hierarchy of *Himalayadrindoperus potwari* [38] (Ichnospecies)

Systematic paleontology

Dinosauria; Theropoda; Theropaonia [38]; Allosauria; *Himalayadrindoperus* [38] (Genus); *Himalayadrindoperus potwari* [38] (Species) (Figure 14 of [38]).

Revised Diagnosis: Middle Jurassic *Himalayadrindoperus* is a small, bipedal, narrow gauge, digitigrades and functionally tridactyl. In its track, the digit I impression is missing and digit III projects slightly farther anteriorly. Its track is strongly broader than *Grallator* and *Anchisauripes*, with length/width ratio slightly more than 1. Its pes track has high divarication angle II-IV = *c.* 70˚ - 90˚ [32], while middle Jurassic *Samanadrindoperus* from Pakistan has divarication angle II-IV = *c.* 50˚ [32], Early Jurassic *Grallator tenuis* small and *Eubrontes* cf *giganteus* large theropods from India has divarication angle of II-IV = *c.* 50˚ and 40˚ [51] respectively. Track of *Himalayadrindoperus* from Pakistan is small (about 15 cm long and 12 cm wide) [32], while *Grallator* from India is very small (5.5 cm long and about 3 cm wide) [51]. *Himalayadrindoperus* track size and shape are almost similar to *Hopiichnus*, but *Himalayadrindoperus* track has anterolaterally directed II digit claw, while *Hopiichnus* has straight aligned claw and *Anomoepus* has laterally directed claws of all three digits. *Himalayadrindoperus* track has slender digits while *Anomoepus* has robust digits. *Himalayadrindoperus* track is strongly broader than *Grallator.* Sub-symmetric slender tritoed small pes with relatively narrow and long claws of trackmaker *Himalayadrindoperus* show a link with Allosauria, Theropaonia [38], Theropoda. Its higher classification is being reported here which was not mentioned previously [38].

3.1.2. Review of Medium to Large Sized Theropod Dinosaurs from Pakistan

Vitakridrinda sulaimani

It was informally described during 2004 to 2021 [14] [15] [17] [21] [25] [30] [32] [36] and formally described in 2021 [37]. Its holotype is 8 teeth, 1 cervical spine, 1 dorsal spine, 1 neural arch laminae, 2 dorsal vertebrae, left and right femora, manus bones, 2 pedal unguals, 1 scapula, 1 ulna, 1 fibula, and 1 scute (**Figure 4**, **Figure 5**; **Table 1**) from central Alam type locality (**Figure 1**). However, the assignment of scapula, ulna, fibula and scute (GSP/MSM-1101-19; **Figure 4**; **Table 1**) to *Vitakridrinda* theropod or *Induszalim* crocodile is problematic due to coexistence of their holotypes found at one site. Its proximal femora was found away (50 - 100 m) from other holotypic materials. Its holotypic materials are found on the surface of Vitakri Formation, and their size agreement shows a single individual. Referred materials include two dorsal vertebrae, a single distal tail vertebra and meta tarsal (**Figure 5**) from Top Kinwa (**Figure 1**), one anterior caudal and one middle caudal vertebrae (**Figure 5**) from Mari Bohri (**Figure 1**), one dorsal vertebra (**Figure 5**) from Sangiali (**Figure 1**) and a metatarsal and a scute (**Figure 4**, **Figure 5**; **Table 1**) from south Kinwa (**Figure 1**).

Revised diagnosis, comparison and description

Vitakridrinda sulaimani is a medium sized abelisauroid theropod having transversely expanded neural canal in dorsal vertebra which is the synapomorphy of abelisauroids. Please see below for diagnostic features, comparisons and descriptions.

Teeth: Holotypic 8 partial teeth GSP/MSM-1085-19, GSP/MSM-1089-19, GSP/MSM-1090-19, GSP/MSM-1091-19, GSP/MSM-1092-19 and GSP/MSM-1093-19, GSP/MSM-1097-19 and GSP/MSM-1098-19 were collected (**Figure 4**). Teeth are asymmetric D-shaped, subcircular, strongly transversely compressed, slightly recurved, heterodont, and taper gradually. Strong transversely compressed tooth with oval shape has slightly convex outward on both lingual and labial sides and also on anterior and posterior edges. Teeth show dorsoventrally elongated irregular fibrous structures. Teeth cavity follows the outer profile of teeth. The estimated ratio of the teeth height to its base antero-posterior width is about 3 to 4 (unlike *Indosuchus* which has short teeth) like this ratio in other carnosaurs varies from 3 to 4 [52]. *Rajasaurus narmadensis* has no preserved teeth or cranial elements [53]. Tear drop texture especially on subrounded tooth is created by fibrous structures. *Vitakridrinda sulaimani* has heterodont teeth such as asymmetric D-shaped, subcircular and strong transversely compressed teeth, while *Shansaraiki insafi* has asymmetric D-shaped and subcircular teeth with tear drop, *Rahiolisaurus gujaratensis* [54] has transversely compressed teeth with tear drop.

Cervical Neural spine: Its cervical neural spine? (Part of GSP/MSM-1101-19; **Figure 4**) is relatively broad and triangular shaped on anterior or posterior views.

Dorsal vertebrae: 2 anterior dorsal vertebrae GSP/MSM-706-19 and GSP/MSM-

765-19, and 3 mid to posterior dorsal vertebrae GSP/MSM-56-1, GSP/MSM-1040-16 and GSP/MSM-1048-16 (**Figure 5**) and a dorsal neural spine (part of GSP/MSM-1101-19; **Figure 4**) were found. Anterior dorsal vertebra has transversely broad neural canal and ventral smooth plain. Its dorsal neural spine is relatively small (than cervical neural spine) and subrounded in shape. Its neural arch lower contact covers mostly the dorsal view of anterior dorsal centrum. Its postzygapophysis of mid-posterior dorsal vertebra is a long strip trending anterolaterally, creating a coel between its fellows. The mid-posterior dorsal centrum GSP/MSM-56-1 is 3.5 cm wide and 5.7 cm high, while its neural arch provides the best information, especially in terms of differentiation from *Rajasaurus* [53]. Dorsal centra are amphicoelous, waisted, ventrally expanded and dorsally reduced. The anterior dorsal centra are slightly tall, cylindrical, and subcircular, while the mid-posterior dorsal centra are tall. Neural arch covers most of the dorsal surface of anterior dorsal centrum like *Rajasaurus* [53]. *Vitakridrinda* has ventrally expanded sub cylindrical dorsal vertebrae, while *Shansaraiki* [39] have elongated cylindrical dorsal vertebrae and *Rajasaurus narmadensis* [53] have short and tall dorsal vertebrae. *Vitakridrinda* centrum is devoid of double pleurocoels unlike other abelisauroids (e.g. *Carnotaurus*, *Majungasaurus*, *Laevisuchus*). *Vitakridrinda* like those of *Vitakrisaurus* lack ventral keel, while *Rajasaurus* [53] and *Rahiolisaurus* [54] have ventral keel on centra. *Vitakridrinda* has anteroposteriorly elongated groove bounded by lateral ridge in ventral view of dorsal, while *Vitakrisaurus* has the very feeble impression of groove and bounded lateral ridge, unlike those of *Rajasaurus* [53] and *Rahiolisaurus* [54] which have no ventral groove. The anterior and posterior articular surfaces of the centra of *Vitakridrinda* have well developed amphicoelous concavity, while *Rajasaurus* and *Rahiolisaurus* have only slight concavity or mostly flat or feeble or gentle amphicoelous natures. *Vitakridrinda* neural canal is dorsoventrally compressed like those of *Vitakrisaurus*, and unlike those of *Rajasaurus* which has transversely compressed neural canal. Its dorsal neural spine is subtriangular shaped with rounded dorsal peak. Two lateral fossa were observed on the highly pneumatic neural arch of mid-posterior dorsal vertebra GSP/MSM-56-1. Lower fossa extended from dorsal margin of centrum to neural arch. Neurocentral opening suture is found close to the dorsal margin of fossa. *Vitakridrinda* has anteroposteriorly elongate lense shaped lower fossa like *Carnotaurus*, and unlike *Rajasaurus* which has subtriangular shaped fossa [53]. Upper fossa is found just above lower fossa on lateral view and bounded by dorsal and ventral laminae which trend anteroposteriorly. Upper fossa started just anterior of postzygapophysis. There are a number of small pneumatic diverticulae and several laminae that separate larger pneumatic fossae. On lateral view, two postzygapophyseal laminae (postzygodiapophyseal lamina) started from postzygapophysis toward anteriorly and their divergence forms the dorsal fossa. In posterior view, paired laminae (spinoprezygapophyseal, spinopostzygapophyseal) enclose a narrow median fossa as they extend dorsally from the postzygapophyses to the neural spine.

Figure 4. *Vitakridrinda sulaimani* [37] holotypic bones (Rows 1-3) found from Alam locality (except the referred possible armor spine GSP/MSM-1202-4 from south Kinwa). **Row 1**, tooth GSP/MSM-1085-19; tooth cross section GSP/MSM-1093-19; tooth cross section GSP/MSM-1090-19 in 2 views and tooth GSP/MSM-1089-19 in 2 views. **Row 2**, teeth GSP/MSM-1091-19 and GSP/MSM-1092-19 in 2 views, two teeth GSP/MSM-1097-19 and GSP/MSM-1098-19 as labeled. **Row 3**, plate1/p1, pedal unguals GSP/MSM-1099-19 and GSP/MSM-1100-19; cervical spine, dorsal spine, neural arch laminas, distal scapula, ulna, fibula and armor bony plate/scute GSP/MSM-1101-19; manus articulated unguals GSP/MSM-1101-19; scute GSP/MSM-1202-4; all shown as labeled: p2, manus including articulated 3 digits bones shown as labelled. Scale, each black or white digit is 1 cm.

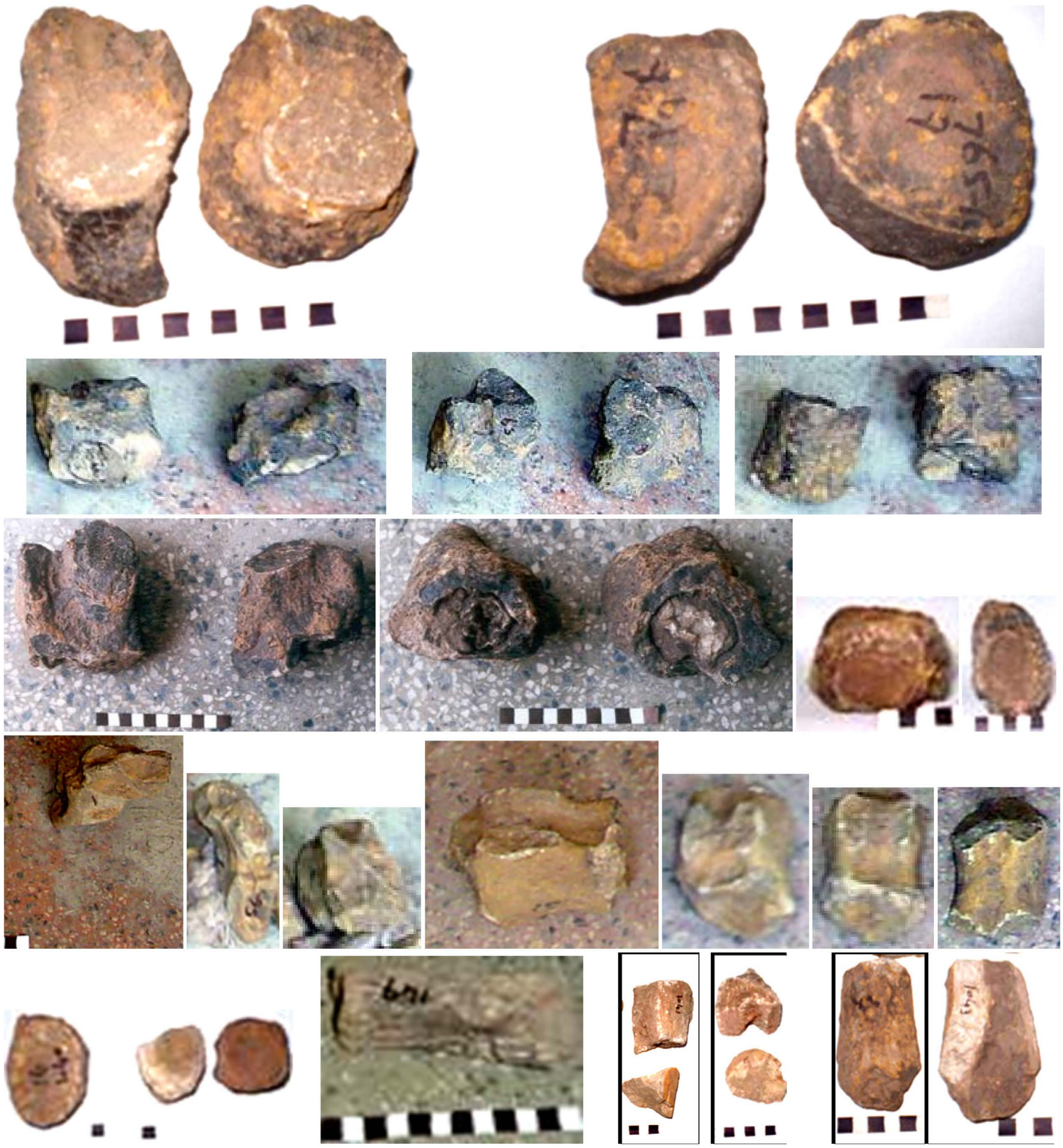

Figure 5. *Vitakridrinda sulaimani* [37] holotypic (Rows 1 - 3) and referred (Rows 4 - 5) bones. **Row 1**, anterior dorsal vertebrae GSP/MSM-706-19 and GSP/MSM-765-19 in 2 views. **Rows 2**, left and right femora GSP/MSM-59-19 and GSP/MSM-60-19 in 3 views. **Row 3**, left and right femora GSP/MSM-59-19 and GSP/MSM-60-19 in 2 views; distal femur cross section GSP/MSM-1039-19 in 2 views. **Row 4**, mid-posterior dorsal vertebra GSP/MSM-56-1 in 3 views, anterior caudal vertebra GSP/MSM-58-15 in 4 views. **Row 5**, tall mid-posterior dorsal vertebra GSP/MSM-1040-16 and GSP/MSM-1048-16; squarish mid caudal centrum GSP/MSM-282-15; long distal caudal vertebra GSP/MSM-149-16, metatarsals II (GSP/MSM-1041-16 upper; GSP/MSM-1042-16 lower) in 2 views; metatarsal III (GSP/MSM-1043-4) in 2 views. Scale, each black or white digit is 1 cm.

Postzygapophyses are longer anteroposteriorly than broad transversely and have inclined orientation in *Vitakridrinda* while orientation is horizontal in *Rajasaurus*. Short and vertical intrapostzygapophyseal laminae join each postzygapophysis.

Anterior caudal vertebrae: 2 anterior caudals GSP/MSM-58-15 and GSP/MSM-282-15. Its anterior caudal centrum has a rectangular yard on posterior part of dorsal view, while anterior and mid part is covered by neural arch. Anterior caudal centrum GSP/MSM-58-15 (**Figure 5**) is 7.9 cm long, 5.6 cm wide and 6.2 cm high. Anterior caudal vertebrae are relatively short, slightly tall with subcircular articular rings, amphicoelous, slightly waisted and lack pleurocoel (**Figure 5**). *Vitakridrinda* has elongated and square shaped cylindrical caudal vertebrae while *Vitakrisaurus* have elongated and tall caudal vertebrae. In *Vitakridrinda* the neural arches are inserted anteriorly on dorsal surface of anterior caudal centra while in *Rajasaurus* [53], the neural arch covers most of the dorsal surface of centrum. *Vitakridrinda* and *Vitakrisaurus* lack ventral keel on the centra and in this regards differ from *Rajasaurus* and *Rahiolisaurus* which have longitudinal keel present on ventral surface of centrum. *Vitakridrinda* (and also *Vitakrisaurus*) have groove bounded by lateral ridge in ventral view of anterior caudal vertebra, while *Rajasaurus* [53] and *Rahiolisaurus* [54] have no groove and no lateral bonded ridges in ventral views of caudal vertebrae. The cranial rim of the centrum is slightly more than the caudal articular surface. The centrum is in the shape of a subrectangular and does not show parallelogram in side view, however, the anterior articular ring on the dorsal part is forwardly extended or offset. The transverse process is dorsoventrally oval shaped and oriented on upper half of articular rim. The transverse process is found only on centrum and not connected with neural arch in *Vitakridrinda*, while it is partly on centrum and partly on neural arch in *Rajasaurus*. *Vitakridrinda* has asymmetric oval shaped transverse processes, while *Rahiolisaurus* has triangular (cross-section) transverse process. *Vitakridrinda* has transverse process with dorsoventrally oval shaped while the thickness is increasing in the mid and dorsal portions. Well developed chevron facets are observed in anterior and middle caudal centrum of *Vitakridrinda*, while *Rajasaurus* have no obvious chevron facets, although the ventral margins of the centrum are weathered [53]. *Vitakridrinda* has deeply concave amphicoelous caudal vertebrae, while *Rajasaurus* and *Rahiolisaurus* have almost flat or amphiplatyan/gently or feebly developed amphicoelous surfaces.

Distal caudal vertebra: One distal caudal centrum GSP/MSM-149-16 (**Figure 5**) found from Topkinwa. Its distal caudal vertebra is elongated, showing whiplash type tail. This vertebra is 11 cm long and 3 - 4 cm wide. This vertebra is amphicoelous (biconcave, having concave both ends), sub cylindrical long, slender and lacks pleurocoel and also lacks articular surface for neural arch revealing position in distal tail. There are no chevron facets. It has parallel longitudinal ridges /fibrous/laminar structures alternated by long grooves trending anteroposteriorly located on all sides except the anterior and posterior concave articular surfaces. This distal centrum has no apparent neural arch connection.

Scapula: Its distal scapula has expanded fan shaped. Its distal-most extremity has expanded rugosities.

Ulna: Its proximal ulnar shaft is anticline type.

Manus: Its manus shows 3 digits. The central digit bone is slightly broad transversely, while the lateral/medial digit bone is subcircular.

Femur: Holotypic proximal left and right femora GSP/MSM-59-19 and GSP/MSM-60-19 and a distal femoral shaft GSP/MSM-1039-19 (**Figure 5**) were collected. The preserved portions are the proximal shaft, lateral trochanter and subcircular head joint with shaft while the portion of greater trochanter and interned head is broken. Proximal femora show hollow in the core and thick walled bone on the periphery. It shows evidence of inturned head with a distinct neck. Anterior trochanter is well developed and slightly blunted. Anteroposterior and transverse diameter of the central hollow cavity is about 5 and 5.5 cm. Thickness of peripheral bone is 1 cm on the ventral side and 2.5 cm just below the inturned head. The femoral cross section just below the inturned head is slightly oval having the anteroposterior and transverse maximum width of 7.5 and 9.5 cm respectively. Distal femoral shaft is transversely wider than anteroposterior wide of proximal femur. The distal femur has core hollow cavity same as proximal part. This core cavity is enveloped by thick peripheral bone dorsal side but on ventral side fibrous bone network replaced the hollow, revealing close approach to fibular and tibial condyles. The femur shaft is compressed anteroposteriorly and longer transversely than anteroposteriorly. Huene distinguished two types of femur and tibia like stouter to *Indosaurus* and slender to *Indosuchus*. This division is also found in Pakistan like *Vitakridrinda* has stouter limb bones with thick bone envelopes on hollow cavity and *Vitakrisaurus* has slender limb bones with thin bone envelopes on hollow cavity. A low but slightly blunted lateral trochanter on femora share with the femora of *Carnotaurus*, *Ekrixinatosaurus*, and *Xenotarsosaurus.*

Fibula: The proximal fibular scar is prominent, anterior end profile of proximal fibula is thin at the upper curve and expanded in the mid and again becomes thin downward, while *Rahiolisaurus* fibula has no suck expansion.

Metatarsals: Referred partial metatarsal II (GSP/MSM-41-16 and GSP/MSM-42-16) and metatarsal III (GSP/MSM-1043-4) from Top Kinwa (**Figure 5**) were collected with the distal whiplash caudal vertebra MSM-149-16. Metatarsal II (GSP/MSM-41-16 and GSP/MSM-42-16) is relatively thicker than metatarsal III. These have central hollow cavity which is surrounded by thick peripheral bones. Its end is slightly inflated or expanded. Metatarsal II is a robust metapodial similar to that in *Ceratosaurus* and basal tetanurans such as *Allosaurus* and *Sinraptor*. The proximal shaft is broader than that of noasaurids. The lateral view of proximal metatarsal II is convex and medial side is concave. Metatarsal III (GSP/MSM-1043-4) is relatively less thick than metatarsal II. This has central hollow cavity which is surrounded by thick peripheral bones. This is the reason for referring to *Vitakridrinda* because *Vitakridrinda* have thick peripheral bone and *Vitakrisaurus* have relatively thin peripheral bones. Its end is slightly inflated or expanded. This end also has some rugosity. Metatarsal III is a relatively slender metapodial. End of metatarsal III is convex, asymmetric and rugose.

Pedal phalange: Its pedal phalange is constricted in the anterior view and is tapered to distal end. Its distal end is also constricted.

Pedal unguals: Its pedal ungual is transversely compressed, significantly thick on posteriorly and tapered toward end. Its pedal ungual end is recurved downward.

Vitakrisaurus saraiki

Vitakrisaurus saraiki was named and informally described in 2010 [23] and later formally described in 2021 [37]. Its holotype consists of 4 partial vertebrae, 1 neural spine, 1 humerus section, 1 ulnar section (just above the mid shaft), 1 partial ulnar section, right manus (including articulated elements) (**Figure 6**; **Table 1**) from mid Bor locality (**Figure 1**). Its referred bones (**Figure 6**; **Table 1**) are limb elements from Karkh, Pakistan, and a tall vertebra with articulated neural arch, and isolated 2 chevrons from Bara Simla, India (**Figure 6**; **Table 1**). Brief description is as below, while the diagnosis, comparison and description of these holotypic and referred bones were well described in pages 520-528 of [36] and further well illustrated in Figure 4, Figure 5 and Row 2 of Figure 6 of [36]. It is necessary to mention that it's referred vertebra GSP/MSM-57-3 (Row 1 of Figure 6 of [36]) from Shalghara was later established as the holotype (along with cranial bones) of *Shansaraiki insafi* [39].

Anterior caudal vertebra: Anterior caudal centrum GSP/MSM-53-2 (**Figure 6**) is 6.4 cm wide and 7.5 cm high. It is relatively short, slightly tall to squarish, amphicoelous, slightly waisted and has chevron facets, lacks ventral keel and pleurocoel. Its neural arch is inserted relatively forward on dorsal aspect of centrum. Its anterior caudal centrum has anteroposteriorly elongated ventral groove which is bordered by medial and lateral sides by parallel lateral and medial ridges. Anterior and posterior portion of grooves is contacted by medial and lateral chevron facets. *Vitakrisaurus* lacks ventral keel on ventral surface of centrum like those of *Vitakridrinda*, and differ from those of *Rajasaurus* and *Rahiolisaurus* which have ventral keel. Anterior articular ring is slightly larger than posterior articular ring. Its centrum has waisted concave profiles of the ventral margin in side view. *Vitakrisaurus* neural canal is transversely expanded and dorsoventrally compressed like those of *Vitakridrinda*, while in *Rajasaurus* the neural canal is circular to slightly tall. Chevron facets are well developed in anterior and posterior end of centrum of *Vitakrisaurus*, while *Rajasaurus* have no obvious chevron facets, although the ventral margins of the centrum are weathered [53]. Its chevron facets are subcircular. Its chevron has a shallow haemal canal. Its prezygapophysis process is oval shaped and elongated in dorsoventral aspects. Its prezygapophysis is broad ventrally and relatively thin dorsally.

Mid-Caudal vertebrae: Holotypic 2 mid-caudals GSP/MSM-54-2 and GSP/MSM-55-2 (**Figure 6**) from mid Bor locality of Pakistan and referred 1 mid-caudal vertebra K20/316 and two chevrons (K20/318) (**Figure 6**) from Bara Simla hill, Jubbulpore, India [50] were reported [35] [36]. The Indian vertebra was referred to *Vitakrisaurus saraiki* due to its similarity with holotypic caudal vertebrae shape and characters from Pakistan and considering India and Pakistan as one land during the latest Cretaceous. Caudal centrum GSP/MSM-54-2 is 8.2 cm high, caudal centrum GSP/MSM-55-2 is 8.7 cm long, 5.5 cm wide and 7.0 cm high. The mid-caudal vertebrae are amphicoelous, slightly waisted, and lacking in pleurocoel and ventral keel. Caudal centra are long and tall. Neural arches cover most of the whole length of dorsal view of anterior dorsal centra of *Vitakridrinda* and *Shansaraiki*, while in caudal centra the neural arch of *Vitakridrinda* and *Vitakrisaurus* is anteriorly forwardly inserted. Mid caudals lateral surface is flat and ventral surface is waisted or concave profiles shown in side view. *Vitakrisaurus* mid caudal centra did not have a reduced longitudinal ridge on its lateral surface and also did not have ventral keel in mid caudal centra, while *Rajasaurus* centrum bears a reduced longitudinal ridge on its lateral surface, and its ventral surface is keeled, and *Rahiolisaurus* have ventral keel. Both cranial and caudal articular surfaces of the centrum are concave, while *Rajasaurus* have amphiplatyan or gentle or feeble amphicoelous concavity. Mid caudals have feeble chevron facets as compared to anterior caudals which have well developed chevron pairs of facets located on anterior and posterior articular rings ventral view. The proximal chevron of mid caudal vertebra shows a very shallow haemal canal forming broad gentle limb of haemal arch. Neural arch on anterior caudal is forwardly inserted, while in *Rajasaurus* the neural arch covers all along the dorsal surface of centrum. *Vitakrisaurus* neural canal is dorsoventrally compressed, transversely elongated subrectangle shaped in anterior and middle caudal vertebrae, while *Vitakridrinda* has dorsoventrally compressed neural canal and *Rajasaurus* neural canal is circular shaped in anterior caudal vertebrae. *Vitakrisaurus* anterior and midcaudal vertebrae have posterior yard on the posterior vacant/uncovered part of dorsal aspect of centrum. This yard is surrounded laterally and posteriorly by a thin boundary wall and it is not found in caudal vertebra of *Rajasaurus.*

Humerus: Holotypic humerus cross sections GSP/MSM-1044-2 (**Figure 6**) found from mid Bor. The humerus cross section shows transversely broad humerus.

Ulna: A proximal right ulna just below the proximal end GSP/MSM-1076-2 and an ulnar cross section GSP/MSM-984-2 (**Figure 6**) were collected. It has central cavity which is subparallel to bone morphology. Outer morphology and central cavity are trirays. Its medial portion is flat while lateral portion has one ray extended lateroanteriorly for radius attachment. Its shaft is transversely broad. Its central cavity is enveloped by relatively thin bone, while *Vitakridrinda* has thick peripheral limb bone.

Hand/Manus: Holotypic right hand/manus specimen GSP/MSM-303-2 is best preserved with its some elements articulated; some have impressions and a few are isolated, all these found in one block (**Figure 6**). Manus is tridactyl. Digit I has carpal, metacarpal I (robust), phalanx I, and hand ungual I/claw I /toe I. Digit II has preserved carpal, metacarpal II, phalange II-1, phalange II-II and possibly ungual II/claw II /toe II). Ungual/claw II is found in the matrix. Digit III has bones and impressions of bones like carpal, metacarpal III, phalange III-I, phalange III-II, phalange III-III, and ungual III or claw III or toe III. Only one phalange is preserved in the relevant digit III row while other phalanges, toes and carpal found in the matrix just below the digit 1 and also may be in the matrix. Carpal I is

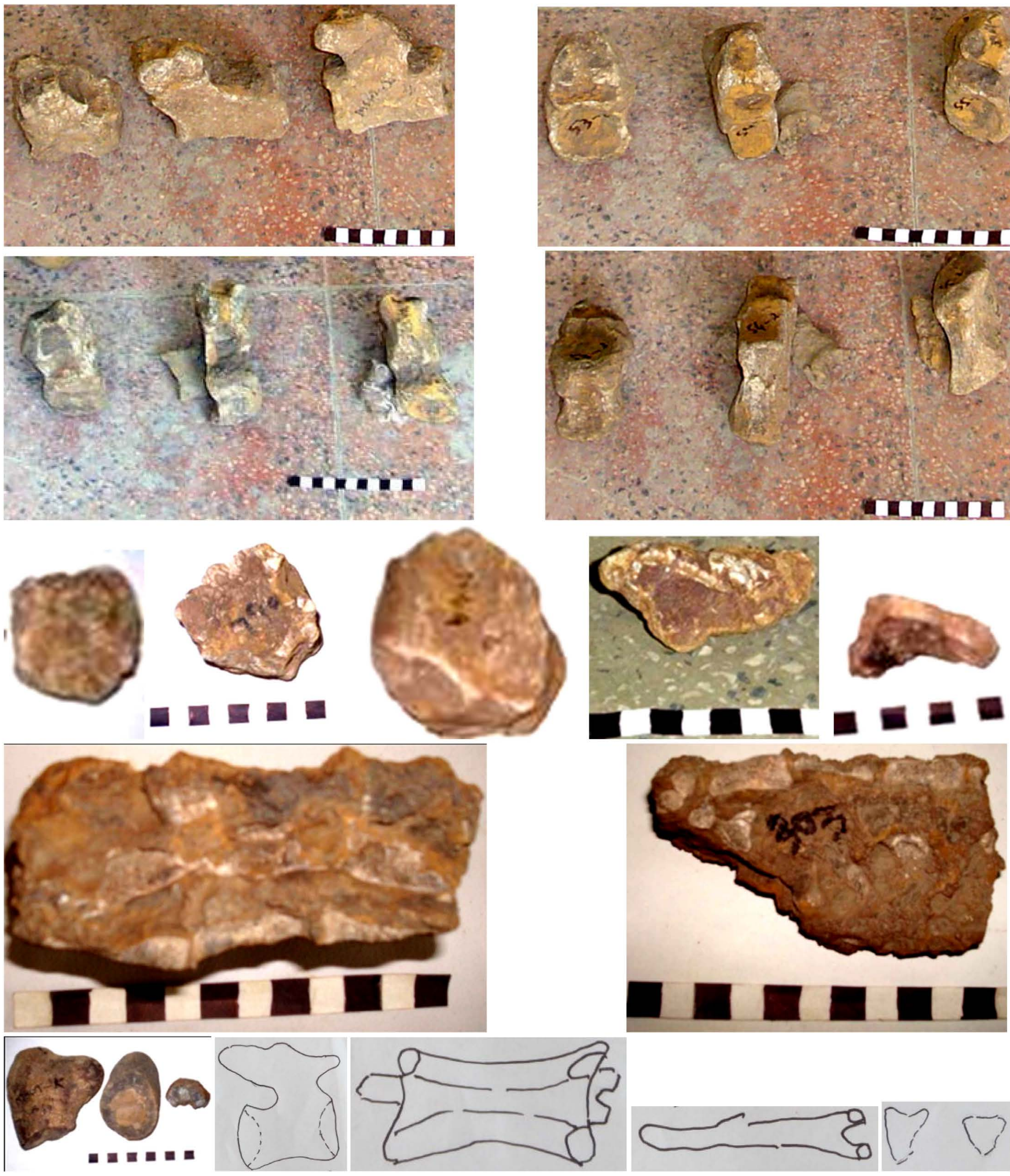

Figure 6. *Vitakrisaurus saraiki* [37] holotype (rows 1 - 4) and referred fossils (row 5**). Rows 1, 2**, anterior caudal GSP/MSM-53-2 and mid-caudal vertebrae GSP/MSM-54-2, GSP/MSM-55-2 in lateral and anterior views (row 1) and posterior and ventral views (row 2). **Row 3**, partial vertebra GSP/MSM-984-2, neural spine GSP/MSM-780-2, humerus cross section GSP/MSM-1044-2, ulnar sections GSP/MSM-1076-2, GSP/MSM-1027-2. **Row 4**, right hand/manus GSP/MSM-303-2 in dorsal and medial views. **Row 5**, p1, proximal femur GSP/MSM-1049-K, mid femur section GSP/MSM-1055-K and leg bone with hollow cavity GSP/MSM-1059-K from Karkh locality of Khuzdar District, Balochistan Province, Pakistan, p2, 3, Line drawings of tall amphicoelous caudal vertebra K 20/316 in right lateral and ventral views from Bara Simla, India; p4, its neural arch including prezygapophysis and postzygapophysis in dorsal view, and p5, two small chevrons K 20/318 from Bara Simla, India [36]. Scale, each black or white digit is 1 cm.

anteroposteriorly thin plate and has anterior concavity. Metacarpal I is the smallest while metacarpal II is the largest and metacarpal III is relatively intermediate. Metacarpal I is expanded at proximal and distal ends while in the middle, it seems to be constricted. Metacarpal II is the longest and also thickest but middle constriction is not clear. Metacarpal III is intermediate in length and also in thickness than metacarpal I and metacarpal II. Width of metacarpal I is about 7 mm (millimeter) while length is about 21 mm. Phalanges are robust and elongated having expanded articular surfaces/condyles. The width of phalange of digit I is about 7 mm while length is about 21 mm. Manus elements were preserved in articulation with their position in the foot, which provided the possible Phalangeal formula for *Vitakrisaurus saraiki.* Manual phalangeal formula 1-2-3 including manual ungual/claw/toe formula 1-1-1. Central digit II is the longest and broadest while left digit (digit I) is short or reduced and digit III is intermediate [36].

Shansaraiki insafi

Shansaraiki insafi was named and described in 2022 [39]. Its holotype is partial dentary including anterior dentary symphysis and mid dentary ramus articulated with partial teeth and a dorsal vertebra (**Figure 7**) found from Shalghara locality (**Figure 1**). Its basic informations are shown in **Table 1**. *Shansaraiki insafi* is distinct from other theropods especially from Indo-Pakistan subcontinent. Its comparisons with other theropods are shown on pages 1069-1071 of [39] and pages 500-501 [42] and partially shown as above in comparison with other Pakistani theropod dinosaurs.

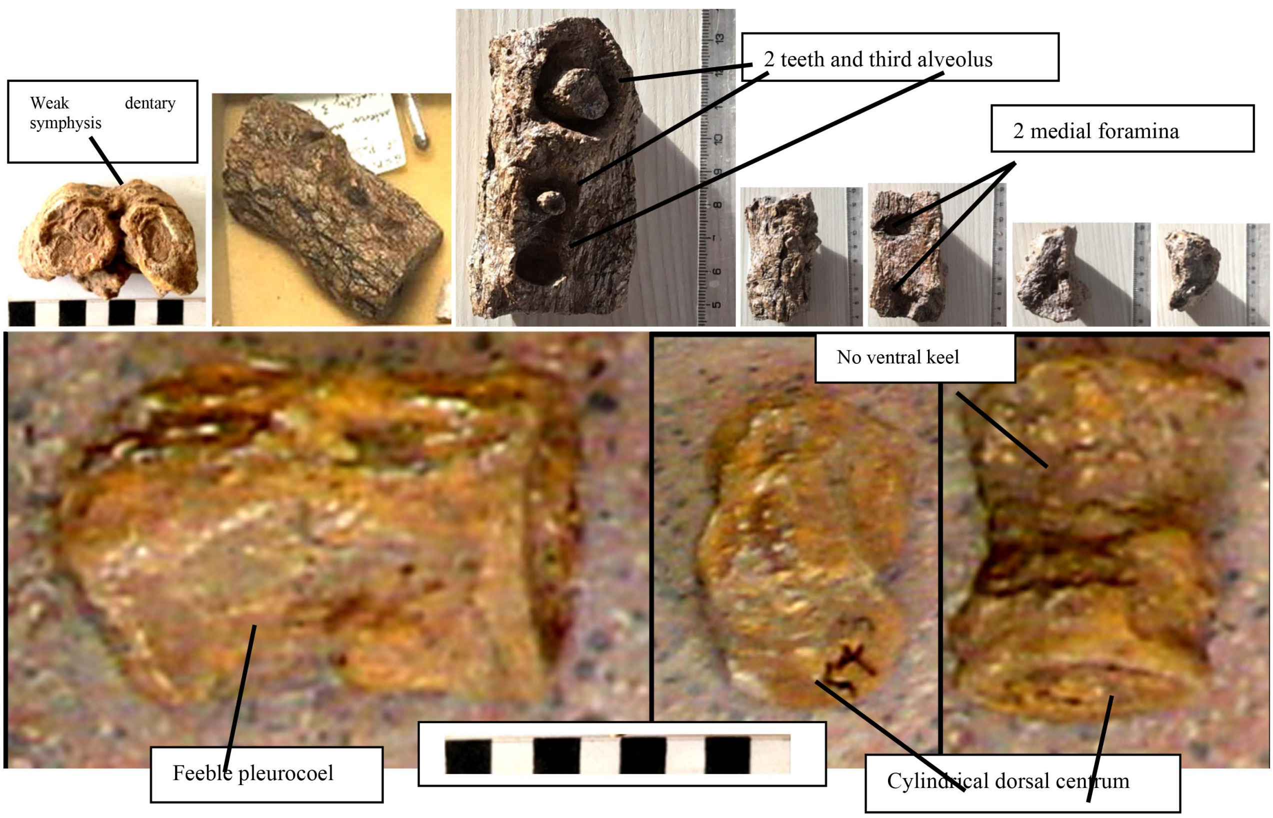

Figure 7. *Shansaraiki insafi* [39] holotype. **Row 1**, Anterior dentary with weak symphysis GSP/MSM-140-3, and dentary ramus with two teeth and third alveolus GSP-UM/MSM-5-3 in different views. **Row 2**, dorsal vertebra GSP/MSM-57-3 in 3 views. Scale, each black and white digit is 1 cm. For scale of photo 2 of row 1 see Figure 5 of [39]. Scale in photos 3-7 of row 1 is in centimeter.

Table 1. Revised data of noasaurid (*Saraikisaurus minhui* and an indeterminate species) and vitakrisaurid (*Vitakridrinda*, *Vitakrisaurus* and *Shansaraiki*) abelisauroid Theropod dinosaurs from Pakistan. Abbreviation; H for holotype and R for referred elements.

Title	Vitakrisauridae (medium to large sized theropods)			Noasauridae (small bodied theropods)	
	Vitakridrinda sulaimani	*Vitakrisaurus saraiki*	*Shansaraiki insafi*	*Saraikisaurus minhui*	*indeterminate species*
Informal Description	[14]	[23]	-	[27]	-
Formal Description	[37]	[37]	[39]	[37]	In present research
Holotype	Partial teeth GSP/MSM-1085-19, GSP/MSM-1089-19, GSP/MSM-1090-19,GSP/MSM-1091-19,GSP/MSM-1092-19, GSP/MSM-1093-19,GSP/MSM-1097-19 and GSP/MSM-1098-19; dorsal vertebrae GSP/MSM-706-19 and GSP/MSM-765-19; Cervical spine, Dorsal spine, Neural arch laminas, Scapula, Ulna, Fibula, Armor bony plate/scute and Manus 3 digits GSP/MSM-1101-19; left and right femora GSP/MSM-59-19 and GSP/MSM-60-19; femur cross section GSP/MSM-1039-19; large and small pedal unguals GSP/MSM-1099-19 and GSP/MSM-1100-19 (Figure 4, Figure 5) found from Alam locality (Figure 1).	Anterior caudal GSP/MSM-53-2; two mid-caudal vertebrae GSP/MSM-54-2 and GSP/MSM-55-2; partial vertebra GSP/MSM-984-2; neural spine GSP/MSM-780-2; humerus cross section GSP/MSM-1044-2; proximal ulna GSP/MSM-1076-2; ulna cross section GSP/MSM-1027-2; and right hand/manus GSP/MSM-303-2 (Figure 6) found from mid Bor locality (Figure 1).	Left and right anterior mandibular rami fused at symphysis GSP/MSM-140-3; partial mid ramus with articulated partial teeth GSP/MSM-5-3; and a dorsal vertebra GSP/MSM-57-3 (Figure 7) found from Shalghara locality (Figure 1).	Partial dentary ramus GSP/MSM-157-16 with partial articulated teeth (Figure 2) found from east Kinwa or Top Kinwa locality (Figure 1).	Dorsal vertebra GSP/MSM-64-15 (Figure 3) found from Mari Bohri/Kachi Bohri locality (Figure 1).
Holotypic elements	24	9	3	1	1
Type locality	Alam/Central Alam. Holotypic left and right proximal femora found at latitude 29˚41'00"N, and longitude 69˚23'58"E; and other holotypic materials were found at latitude 29˚41'01"N, and longitude 69˚23'59"E (Figure 1).	Mid Bor latitude 29˚41'12.8"N, and longitude 69˚23'07"E (Figure 1).	Shalghara Latitude 29.68288 and Longitude 69.38008 (N 29˚40'58"; E 69˚22'48") (Figure 1).	Top Kinwa or east Kinwa locality at latitude 29.68809 N and longitude 69.4002E (N29˚41'17.60"; E69˚24'0.72") (Figure 1).	Mari Bohri/Kachi Bohri locality, most probable from northern sites (latitude 29˚42'08"N; longitude 69˚15'08"E) of Mari Bohri locality (Figure 1).

Continued

Referred material	Mid-posterior dorsal vertebrae GSP/MSM-1040-16 and GSP/MSM-1048-16, distal elongated caudal vertebra GSP/MSM-149-16, metatarsal cross sections II GSP/MSM-1041-16 and GSP/MSM-1042-16 from Top Kinwa; anterior caudal vertebra GSP/MSM-58-15 and mid caudal vertebra GSP/MSM-282-15 from Mari Bohri; metatarsal III (GSP/MSM-1043-4) from south Kinwa, and anterior caudal vertebra GSP/MSM-56-1 from mid Sangiali (Figure 5). Scute GSP/MSM-1202-4 from south Kinwa (Figure 4).	Proximal femur GSP/MSM-1049-K; femur cross section GSP/MSM-1055-K; and part of peripheral bone of leg section GSP/MSM-1059-K from Karkh, Khuzdar, Pakistan. Tall amphicoelous caudal vertebra K 20/316 and two small chevrons K 20/318 from Bara Simla, India (Figure 6).	-	-	-
Referred Elements	10	6	-	-	-
Referred localities	Sangiali, Eastern Kinwa (Top Kinwa), Mari Bohri and South Kinwa (Figure 1).	Karkh (Figure 1 of [38]), Pakistan. Bara Simla, India.	-	-	-
Total H&R elements	24 + 10 = 34	9 + 6 = 15	3	1	1
Total Individuals	5	3	1	1	1
Horizon/Formation	Vitakri Formation	Vitakri Formation Lameta Formation	Vitakri Formation	Vitakri Formation	Vitakri Formation
Age	Latest Maastrichtian	Latest Maastrichtian	Latest Maastrichtian	Latest Maastrichtian	Latest Maastrichtian
Distribution Territory; (Basin) wise	Barkhan District, Balochistan Province; (Sulaiman Range; Sulaiman Basin)	Barkhan, Balochistan (Sulaiman Range). Khuzdar, Balochistan (Kirthar Range). Bara Simla, Jabalpur, India.	Barkhan, Balochistan Province; (Sulaiman Range; Sulaiman Basin)	Barkhan District, Balochistan Province; (Sulaiman Range; Sulaiman Basin)	Barkhan District, Balochistan Province; (Sulaiman Range; Sulaiman Basin)

Trackway of *Samanadrindoperus* large Theropaonia [38], Theropoda

Trackway of large theropods was described [32] [38] from Pakistan.

Hierarchy of *Samanadrindoperus surghari* [38] (Ichnospecies)

Systematic paleontology

Dinosauria; Saurischia; Theropoda; Theropaonia [38]; Megalosauria; *Samanadrindoperus* [38]; *Samanadrindoperus surghari* [38] (Figure 14 of [38])

Revised Diagnosis: Middle Jurassic *Samanadrindoperus* is bipedal, narrow gauge, functionally tridactyl and digitigrade. Its sub-symmetric pes track has relatively narrow and long claws. Its claws are thick anteriorly and become thin distally. Pes track central digit III projected slightly farther than digits II and IV like those of *Himalayadrindoperus* but both are differentiated on strongly variable divarication angles and size. Its pes tracks has moderate divarication of robust digits II-IV = *c.* 50˚ with straight alignment of digit and claws [38], while *Himalayadrindoperus* small theropod has high divarication of slender digits II-IV = *c.* 70˚ - 90˚, a footprint of *Grallator tenuis* small and *Eubrontes* cf *giganteus* large theropod from India has divarication angle of II-IV = *c.* 50˚ and 40˚ [51] respectively. Its central digit III of pes print is projected slightly farther from adjoining digits, while *Megalosauropus* central digit III is projected farther from adjoining digit. *Samanadrindoperus* pes claws are very thick anteriorly and sharply reduce toward terminal end, while *Megalosauropus* claws gradually reduce toward terminal end. *Samanadrindoperus* pes is about 60 cm long and 45 cm wide, while *Megalosauropus* holotypic track is about 53 cm long and 36 cm wide and *Megalosauropus* referred tracks dimension vary from 39 to 72 cm in length and 29 - 65 in width. It was previously reported as a member of Theropaonia [38], while its higher classification is mentioned here. Its close resemblance to *Megalosauropus* provides clues for its higher assignment to Megalosauria. *Samanadrindoperus* (ichnotaxon) discovered from Pakistan is first Megalosaur known from Indo-Pakistan subcontinent.

3.1.3. Small-Bodied Theropod Dinosaurs (Abelisauria: Noasauridae) from the Latest Maastrichtian Lameta Formation of India

Bone taxa *Laevisuchus indicus* [50], *Jubbulpuria tenuis* [50], an indeterminate species [47] (see below) and *Dubeynarainsaurus* new genus and new species (see below) of noasaurid and ichnotaxon *Grallator* [51] of small Theropods are known from India.

Laevisuchus indicus: This is based on cervical vertebrae GSI/K27/613, GSI/K27/696 and GSI/K20/614 (Figure 2, Figure 3, Figure 4 of plate 20 of [50]) and dorsal vertebra GSI/K27/588 (Figure 5 of plate 20 of [50]). Reference [47] suggested the caudal vertebrae GSI/K20/612 and GSI/K27/614 (Figure 6, Figure 7 of plate 20 of [50]) may belong to type series of *Laevisuchus indicus*, which was previously assigned to *Jubbulpuria tenuis* [50].

Jubbulpuria tenuis: *Jubbulpuria tenuis* [50] based on dorsal vertebrae GSI/K20/612 and GSI/K27/614 (Figure 6, Figure 7 of plate 20 of [50]). References [49] [54] considered these vertebrae as caudal vertebrae instead of dorsals. These caudal vertebrae may belong to type series of *Laevisuchus indicus* due to similar morphology, consistent size, lack of duplication and provenance within a fairly restricted area [47].

Indeterminate species of small theropod: A new indeterminate species of small theropod based on partial right dentary articulated with partial teeth RTMNU/DG/VERT/1/55p/2020 reported from Pisdura, central India [47].

New small bodied theropod dinosaur from India

Systematic paleontology

Dinosauria

Saurischia

Theropoda

Ceratosauria

Abelisauroidea

Noasauridae

Dubeynarainsaurus sahni new genus and new species (**Figure 8**)

Holotype: Partial dentary articulated partial teeth (un-numbered, sent to British museum [55]) (**Figure 8**).

Locality, Horizon and Age: Holotype was found by Dubey and Narain in a boulder in January 1944 from Sirolkhal locality (near the village of Sirolkhal and 5 km westward from Shahabad), Shahabad Tehsil, Baran District, Kota Division of Rajasthan state, India [55]. The location is an isolated hill which is 5 km before Shahabad when travelling from Kota to Shahabad (known from 1989 report of Narain). The boulder which hosted this partial dentary occurs in a formation (Lameta Formation) that overlies the Vindhyans and is overlain by the Deccan trap flows. Recently, reference [56] mentioned the late Maastrichtian age. Lameta Formation regarded as Maastrichtian on the basis of microfossils, vertebrates, and the overlying Deccan basaltic flows [45] [56] [57]. Deccan volcanics were radiometrically aged as 65.5 Ma [58].

Etymology: *Dubeynarain*, in honor of collectors V. S. Dubey and Kedar Narain of Department of Geology, Benares Hindu University, India, *saurus*, Greek for lizard. In general, it is a lizard of Dubey and Narain. Species name *D. sahni* honors the Prof. Dr. Ashok Sahni of Panjab University, Chandigarh, India, for his contributions and research in paleontology and geology.

Diagnosis and Comparison: Noasauridae (Abelisauroidea) is theropod with prominent heterodont and transversely compressed teeth, small-sized teeth, and narrow and small dentary ramus. *Dubeynarainsaurus sahni* dentary ramus length and width (**Figure 8**) are slightly more than the dentary ramus of Noasaurid indeterminate species RTMNU/DG/VERT/1/55P/2020 from Pisdura, India (Figure 7 of [47]) and *Saraikisaurus minhui* from Pakistan (**Figure 2**) and *Masiakasaurus knopfleri* from Madagascar (Figure 2 of [48]; Figure 3 of [49]). *Dubeynarainsaurus sahni* teeth are more transversely compressed than the teeth of Noasaurid indeterminate species RTMNU/DG/VERT/1/55P /2020 from India and noasaurid *Saraikisaurus minhui* from Pakistan. *Dubeynarainsaurus sahni* teeth width (minor axis) and length (major axis) are slightly more than the teeth width and length of *Masiakasaurus knopfleri* from Madagascar. *Dubeynarainsaurus sahni* teeth width (minor axis) and length (major axis) are slightly less than the teeth width and length of Noasaurid indeterminate species from India [47] and noasaurid *Saraikisaurus minhui* from Pakistan.

Dubeynarainsaurus sahni teeth transverse compression ratio is almost same as

Noasaurid indeterminate from India and *Saraikisaurus minhui* from Pakistan, and *Masiakasaurus knopfleri* from Madagascar. *Dubeynarainsaurus* teeth are slightly larger (in transverse width and anteroposterior/long axis length) than the teeth of *Masiakasaurus* from Madagascar. *Dubeynarainsaurus sahni* teeth are slightly smaller (in transverse width and anteroposterior/long axis length) than the teeth of Noasaurid indeterminate species from India [47] and noasaurid *Saraikisaurus minhui* from Pakistan. *Dubeynarainsaurus sahni* has crown dorsoventral length 0.6 cm which is the same as *Masiakasaurus knopfleri* from Madagascar (small body sized).

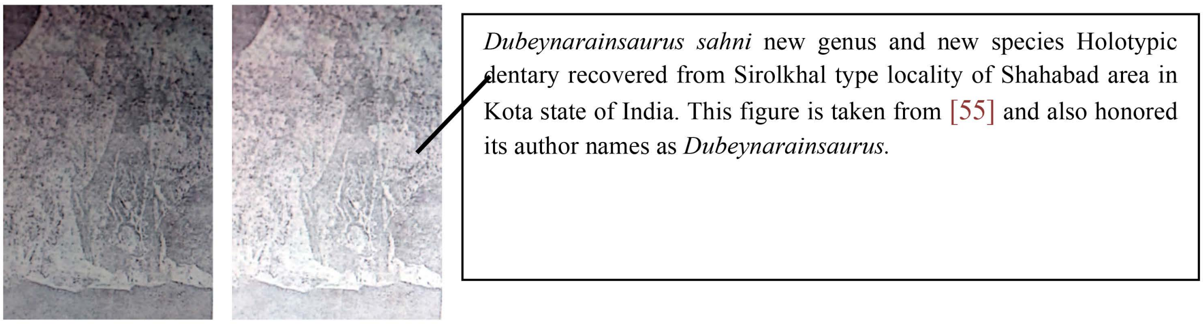

Figure 8. *Dubeynarainsaurus sahni* new genus and new species holotypic dentary.

Description: Preserved jaw length is 7.5 cm and breadth at posterior end is 1.4 cm. Length of the gum at the anterior end after the 2.4 cm is 0.3 cm. After 2.4 cm., there is a notch from where it is projected onward in a beak-like form. Jaw contains five, sockets, three of which contain teeth and two are marked by the impressions. One tooth is fully preserved and the other two are partial. Sockets arc close to each other and the teeth are placed at the margin of the jaw. Teeth are slender, conical and blunted. Breadth of the gum is 1.4 cm. Length of the gum in the specimen containing three teeth is 4 cm. Breadth of the gum at the distal end is 1.6 cm. Height of tooth is 1.6 cm. Measurement of sockets at the base of crown; major axis is 0.5 cm and minor axis is 0.3 cm [55]. *Dubeynarainsaurus* is tentatively named to honor the discoverers.

A footprint of *Grallator* small Theropaonia, Theropoda from India

A footprint of *Grallator tenuis* small theropod was reported from the Early Jurassic Thaiat Member of the Lathi Formation of Thaiat ridge near Jaisalmer in western Rajasthan, India [51]. A footprint of *Grallator tenuis* from India has divarication angle of about 50˚ [51], while *Himalayadrindoperus potwari* from Pakistan has divarication angle 70˚ - 90˚ [32]. *Himalayadrindoperus* from Pakistan and *Grallator* from India belong to Theropaonia [38].

3.1.4. Medium to Large Bodied Theropod Dinosaurs (Abelisauria: Abelisauridae) Discovered from the Latest Maastrichtian Lameta Formation of India

From India, 10 bone genera (including 11 species) and 1 ichnotaxon were reported.

Orthogoniosaurus matleyi: *Orthogoniosaurus matleyi* was named and described by [59] based on a tooth which has a straight posterior part and lacks ceration at tip.

Lametasaurus indicus: *Lametasaurus indicus* is based on sacrum, ilia, tibia and armor bones and was named in 1923 as stegosaur may be due to armor bones [60]. This material was originally thought of in 2021 as theropod [61]. Further, Dr. Barnum Brown collected the material in 1922 from the Gun Carriage Factory at Bara Simla, India (page 69 of [50]) which includes a large osteodermal ellipsoidal plate (AMNH 1959), amphicoelous caudal vertebra (8.8 cm long), several dozen bone fragments, armor scutes and three theropod teeth (page 166 of [62]). This material was observed by Huene in 1930 at American museum of Natural History, New York. Huene and Matley mentioned this material including large plate (large armor plate) collected nearby from the site of *Lametasaurus* bones from Jabalpur. According to [50], these armor bones of *Lametasaurus* are like the *ankylosaurus* from Canada which contain club at the end of tail. Reference [50] interpreted *Lametasaurus indicus* as stegosauridae ornithischian dinosaur. Later [63] suggested the sacrum and ilia of *Lametasaurus indicus* may belong to theropod. Isolated armor bones assignment may be difficult because these belong to diverse taxa of titanosaurs and theropods (Saurischian) and thyreophorans (Ornithischian) dinosaurs and crocodylomorphs [52]. Among the material of Dr. Barnum Brown (AMNH), the amphicoelous caudal vertebra (8.8 cm long) and three theropod teeth may belong to *Lametasaurus indicus* because this material was found from carnosaur bed and a few feet away from both sites. Both sites here represent Matley collection in 1921 site and Dr. Barnum Brown collection in 1922 material site. Conclusively the *Lametasaurus indicus* materials and possibly may or may not belong to a single individual including sacrum, ilia, (tibia?), amphicoelous caudal vertebra and three teeth. The size and especially 8.8 cm length of amphicoelous caudal vertebra show *Lametasaurus indicus* is a medium sized theropod. Reference [64] (page 514) was first from India to mention that these armor scutes belong to titanosaurids. *Lametasaurus indicus* validity as theropod remains in question (page 167 of [62]). The ilia and sacrum of *Lametasaurus indicus* are significant collection [53].

Indosuchus raptorius: *Indosuchus raptorius* was described by [50] based on skull roof K20/350, lower part of another skull K27/685 and frontal K27/690 (Figure 1, Figure 2 of plate 9 of [50]). Reference [53] mentioned the significant collection such as the paired premaxillae, maxilla and dentary collected by Dr. Brown and attributed to *Indosuchus raptorius* [52] and third is the fossil remains of *Indosuchus* [64]. Reference [52] described partial jaws of AMNH specimens of *Indosuchus*. Maxilla (AMNH 1955) collected by Dr. Berman Brown is similar to maxilla of *Indosuchus* [50]. Lacrimal, jugal and posterior part of jaw (ISI R 163) of *Indosuchus* collected by [64] from Bara Simla hill of Jabalpur. They collected a nearly complete skeleton of *Indosuchus* from Rahioli and restored skeleton based on ISI R 401-454 (Figure 13 of [64]).

Indosaurus matleyi: *Indosaurus matleyi* was described by [50] based on partial braincase K27/565, middle part of skull K27/565 and posterior part of skull K27/565 (Figure 3, Figure 4 of plate 9 of [50]; Figure 1 of plate 10 of [50]).

Dryptosauroides grandis: *Dryptosauroides grandis* [50] based on dorsal vertebrae K20/334, K20/609, K27/549 and K27/601 (Figures 1-4 of plate 22 of [50]).

Coeluroides largus: *Coeluroides largus* [50] based on 3 dorsal vertebrae K 27/562 (Figure 6 of plate 21 of [50]), K 27/574 (Figure 4 of plate 21 of [50]) and K 27/595 (Figure 5 of plate 21 of [50]).

Composuchus solus: *Composuchus solus* [50] based on articulated first and second cervical vertebrae (GSI/K27/578; Figure 1 of plate 20 of [50]), while [47] (page 13) marked this specimen as changed number GSI/K27/696, may be mistype. Reference [47] described in detail and considered it belongs to Abelisauridae (and not noasauridae small theropods). The identification of this as abelisaurid is further supported by its general resemblance to abelisaurid *Vitakridrinda sulaimani*. The significant expansion of posterior articular ring of axis GSI/K27/578 of *Composuchus solus* (Figure 1 of plate 20 of [50]) is like those of the expansion of articular ring of vertebra GSP/MSM-706-19 of abelisaurid *Vitakridrinda sulaimani* and also a carnosaur vertebra GSI/K27/598 (Figure 11 of plate 13 of [50]). But articular ring of cervical vertebra GSI/K27/578 of *Composuchus solus* (Figure 1 of plate 20 of [50]) is broad, while in contrast the articular ring of centra of vertebrae GSP/MSM-706-19 and GSP/MSM-765-19 of *Vitakridrinda* is subcircular to tall, and also a carnosaur vertebra GSI/K27/598 (Figure 11 of plate 13 of [50]) is also subcircular. The large carnosaur dorsal vertebra GSI/K27/598 (Figure 11 of plate 13 of [50]) and centra of vertebrae GSP/MSM-706-19 of *Vitakridrinda* is subcircular, and it may be possible the both vertebrae from India and Pakistan may belong to large carnosaur *Vitakridrinda*.

Ornithomimoides mobilis: *Ornithomimoides mobilis* [50] based on vertebrae GSI/K27/600, GSI/K20/610 and GSI/K20/614 598 (Figures 8-10 of plate 20 of [50]) and GSI/K27/595 598 [50] (page 64). These large vertebrae of *Ornithomimoides mobilis* belong to abelisaurid-medium to large theropod [50].

Ornithomimoides ? barasimlensis: *Ornithomimoides ? barasimlensis* [50] based on medium sized (~5 cm long) vertebrae GSI/K27/541, GSI/K20/531 and GSI/K20/604 (Figures 1-3 of plate 21 of [50]) and GSI/K27/682 [50] (page 64). Reference [54] (page 81) identified these as caudal vertebrae having no autapomorphic features. Reference [47] (page 16) considered these four vertebrae as indeterminate abelisauroid species. Observing on size of vertebrae this species is larger than *Laevisuchus* from India, *Saraikisaurus minhui* from Pakistan and *Masiakasaurus* from Madagascar.

Rajasaurus narmadensis: *Rajasaurus narmadensis* [53] based on cranial (braincase), vertebral and appendicular bones hosted by Lameta Formation in Narmada valley. It is a famous theropod and its comparisons with Pakistani theropods are shown above.

Rahiolisaurus gujaratensis: *Rahiolisaurus gujaratensis* [54] based on right ilium, pubis and femur hosted by Lameta Formation in the Rahioli area. Its referred materials are premaxilla with articulated teeth, cervical, dorsal, sacral and caudal vertebrae, and hind and fore appendicular bones. It is significant theropod from India. Its comparisons with Pakistani theropods are mentioned above.

It is necessary to note that [65] reported a carnosaurian dinosaur from Tamil Nadu which was later considered as large titanosaurian sauropod.

A footprint of *Eubrontes*, a large Theropaonia, Theropoda from India

A footprint of *Eubrontes* cf. *giganteus* large theropod was reported from the Early Jurassic Thaiat Member of the Lathi Formation of Thaiat ridge near Jaisalmer in western Rajasthan, India [51]. A footprint of *Eubrontes* cf *giganteus* from India has divarication angle of about 40˚ [51], while *Samanadrindoperus surghari* from Pakistan has divarication angle 50˚ [38]. The footprints of *Samanadrindoperus surghari* from Pakistan [38] are larger than giant theropod footprint from the Early Jurassic of Poland [66] and also larger than Indian theropod footprints [51]. *Samanadrindoperus* from Pakistan and *Eubrontes* from India belong to Theropaonia [38].

3.2. Ornithischian Dinosaurs from Indo-Pakistan Subcontinent: Some Evidences

3.2.1. First Ornithischian Dinosaurs from Pakistan

Ankylosaurian bones and footprints are found in the Jurassic of Pakistan. Further hadrosaur tracks were also found from the Late Cretaceous Pab Formation of Pakistan.

Revised diagnosis of *Brohisaurus kirthari* [12] ankylosaur from Pakistan

Systematic paleontology

Dinosauria; Archosauria; Ornithischia; Thyreophora; Ankylosauria; Ankylosauridae; *Brohisaurus* [12]; *Brohisaurus kirthari* [12] (Figure 2, Figure 3 of [12]) (Figure 5 of [37])

Revised Diagnosis: Late Jurassic-Early Cretaceous *Brohisaurus kirthari* [12] has many pneumatic and spongy strip-shaped armors GSP/MSM-87-K, GSP/MSM-92-K, GSP/MSM-93-K, GSP/MSM-94-K and spine-shaped armors GSP/MSM-95-K, GSP/MSM-96-K and tubule-shaped osteoderm GSP/MSM-98-K (Figure 5 of [37]) which show high level assignment to ankylosaurian Ornithischia (instead of titanosauriform) due to its heavily armored synapomorphy. Its fibular scar and pneumatic and transversely elliptical femur are its autapomorphy. *Brohisaurus* is first confirmed ankylosaur (ornithischian bone fossils) from In-do-Pakistan subcontinent.

Revised diagnosis of *Malakhelisauroperus mianwali* [38] ankylosaur of Pakistan

Systematic paleontology

Dinosauria; Archosauria; Ornithischia; Ornithopaonia [38] (Ichnogroup); Thyreophora; Ankylosauria; *Malakhelisauroperus* [38] (Ichnogenus); *Malakhelisauroperus mianwali* [38] (Ichnospecies) (Figure 14 of [38]).

Revised Diagnosis: Middle Jurassic *Malakhelisauroperus* tracks show plantigrade and quadroped trackmaker. The manus track is considerably smaller than the pes print, wider than the long one, crescent to D-shaped and convex anteriorly, and has no digit impression. Its manus lack claw impression like those of *Deltapodus*, while *Stegopodus* manus has claw impressions. Very large, functionally tridactyl pes prints with blunted thick toe impressions. Pedal digits are very short, broad and moderately divaricated. Pes is asymmetrical, with the broad pad located posterolaterally like those of *Stegopodus*, while centrally in *Pashtosauroperus,* having w-shaped posterior profile and a long pad is centrally located in *Deltapodus*. *Malakhelisauroperus* has blunted thick toes while *Gigantosauropus* has thin slender toe. Central digit directed anteriorly while lateral digit directed anterolaterally and medial digit directed anteromedially. Claw is oval shaped long anteroposteriorly and less broad transversely with sharp anterior and posterior edges. A well-preserved cushion is preserved on the periphery of the claw/ungual. Heteropody Index is about 2. Its subsymmetric pes tracks show webbed digits with broad, thick and robust 3 claws showing its assignment to Ankylosauria, further assisted by finding of richly armored *Brohisaurus* ankylosaur (see above). *Malakhelisauroperus* is first ankylosaur ichnotaxon from Indo-Pakistan subcontinent.

Revised diagnosis of *Pashtosauroperus zhobi* [38] hadrosaur from Pakistan

Systematic paleontology

Dinosauria; Archosauria; Ornithischia; Ornithopaonia [38] (Ichnogroup); Hadrosauria; *Pashtosauroperus* [38] (Ichnogenus); *Pashtosauroperus zhobi* [38] (Ichnospecies) (Figure 14 of [38]).

Revised Diagnosis: Late Cretaceous *Pashtosauroperus* tracks show plantigrade and quadroped trackmaker. Manus track is considerably smaller than pes, wider than long, crescent to D-shaped and anteriorly convex but without claw impression like those of *Deltapodus*, while *Stegopodus* manus has claw impression. Very large, tridactyl pes track has blunted thick toe impressions. Pedal digits are very short, broad and moderately divaricated. Pes is asymmetrical, with the broad pad located centrally having w-shaped posterior profile, while pad is posterolaterally situated in *Stegopodus*, and long pad is centrally located in *Deltapodus*. *Pashtosauroperus* pes tracks has blunt claws, while *Malakhelisauroperus* has large oval shaped claws and *Gigantosauropus* has thin slender toe. *Pashtosauroperus* pes print is 1.27 m long and 1.28 m wide, while *Gigantosauropus* pes print is 1.35 m long and 1.18 m wide. Heteropody Index HI is 4 - 5. Being large sized, thick tridactyl, broad pes with thick claws and Maastrichtian age, the trackmaker is Hadrosaurian ornithischia. *Pashtosauroperus* discovered from Pakistan is first Hadrosaur from Indo-Pakistan subcontinent. *Pashtosauroperus* discovered from Pakistan is first Hadrosaur from Indo-Pakistan subcontinent. *Pashtosauroperus* tracks morphology has close resemblance to largest Hadrosaur *Shantungosaurus* from Late Cretaceous of China, *Hadrosauropodus* tracks from the Late Cretaceous of New Mexico and *Caririchnium* track, while has far resemblance to *Amblydactylus* from lower Cretaceous of Canada and *Igaunodontipus* track.

3.2.2. Ornithischian Dinosaurs from India

A few bones from India were assigned to ornithischian [50] [67]-[70]. The reference [50] interpreted *Lametasaurus indicus* as stegosauridae ornithischian dinosaur, which may be due to armor bones. Later [63] suggested the sacrum and ilia of *Lametasaurus indicus* may belong to theropod. Armor bones may belong to titanosaurs and theropods (Saurischian) and thyreophorans (Ornithischian) dinosaurs and crocodylomorphs [53]. The reference [53] mentioned, "Despite several reports of stegosaur bones from India [50]; *Brachypodosaurus gravis* [67]; *Dravidosaurus blanfordi* [68], none share derived characters with that clade". As regards to bone fossils of *Dravidosaurus blanfordi* [68] from India, the author of reference [64] (page 518) visited the site and could not see anything related to the stegosaurian plates.

From India, a single elongated tritoed track of sauropod [71] was reported from the uppermost limestone unit of the Maasttrichtian Lameta Formation of the Jetholi area, Kheda District, Gujarat, western India [71]. Later on [70] [72] interpreted it as a *Deltapodus* like (Thyreophoran type; stegosaurian affinity) track. The known stratigraphic range of *Deltapodus* is at present restricted to the Middle to Late Jurassic (Aalenian to Tithonian), although the skeletal record of stegosaurs extends into the Lower Cretaceous [73]. Considerable doubt (see also [64] [73]) has been cast on records of stegosaurs in the Late Cretaceous of India [68] [69]. Present research proposed this long tritoed pes footprint (with thick, broad and blunted claws) from India as a member of Stegosauria, Ornithopaonia, Ornithischia. This tritoed pes print from Gujarat, India is only prominent evidence of stegosaur (ornithischian) from India (Personnel communication with Prof. Dr. P. M. Galton in 2018).

3.3. Pterosaurs from South Asia (Indo-Pakistan peninsula): Revised Summary

Pterosaurs (bone and Ichno taxa) are revised and summarized below.

3.3.1. Pterosaurs Found in Pakistan

A bone taxa [40] and an ichnotaxa [38] of pterosaur were found in Pakistan.

***Imrankhanuqab qaeddiljani* [40] Pterosaur found from the latest Maastrichtian Vitakri Formation of Pakistan (Bone taxa)**

Recently reference [40] formally described *Imrankhanuqab qaeddiljani* based on typical articulated synsacrum, left and right ilia and coosified spongy bony mass (GSP-UM/Sangiali-1175) (Figure 2 of [40]; Figure 13 of [41]) found in the latest Cretaceous (latest Maastrichtian) Vitakri Formation of mid Sangiali type locality (**Figure 1**) of Balochistan, Pakistan. *Imrankhanuqab* is the best diagnosed pterosaur from Indo-Pakistan subcontinent. Its detail description can be seen in [40].

Revised hierarchy of *Anmolpakhiperus alleni* [38] Pterosaur (Ichno taxa)

Systematic paleontology

Pterosauria; Pteropaonia [38] (Ichnogroup); *Anmolpakhiperus* [38] (Ichnogenus); *Anmolpakhiperus alleni* [38] (Ichnospecies) (Figure 14 of [38])

Revised Diagnosis: *Anmolpakhiperus alleni* [38] was previously reported as a member of Pteropaonia [38], while its higher classification was not mentioned. The higher classification of Pteropaonia [38] is Pterosauria. Its footprints are long, narrow and parallel. Its holotypic footprints are about 20 - 30 cm long and 8 - 10 cm wide, representing left fore limb and right hind limb footprints. Footprints are parallel with each other resemble pterosaur tracks from South Korea. *Anmolsauroperus alleni* was formally described in [38] and previously it was informally described as *Anmolpakhi alleni* [32] and *Anmolpodus alleni* ([35], page 431). It was described in [32] [38].

3.3.2. Pterosaur Found from India

Rhamphorhynchus: Reference [74] reported pterosaur from the lower Jurassic Kota Formation and assigned bones to *Rhamphorhynchus.* GSI. 17868 (Plate 37 of [74]), including radius and ulna, 4th metacarpal and first phalange of wing finger and a clawed digit (but interpreted by [75] as manus). Further, [75] mentioned, "It is unfortunate that either the proximal or the distal end of all elements is missing or worn".

Campylognathoides indicus: Reference [75] considered premaxilla with teeth and nasal part (ISI 48) from limestone ledge 13 cm*10.2 cm as holotype and dissociated post-cranial bones like ulna, proximal carpal, lateral carpal, distal carpal, left scapula, coracoid, fragment of right scapula and second phalange of wing finger (ISI 49) as referred material of *Campylognathoides indicus* which is collected from lower Jurassic Kota Formation. He mentioned due to the lack of overlapping elements (except incomplete ulna), the comparisons between GSI (Rao and Shah collection) and lSI (Jain collection) specimens are difficult. He summarized that no definite pterosaurs are known from India. There is, however, a doubtful fragment reported by [55] from the Kotah, Rajasthan which is now being considered as small theropod, and another by [74] from Lower Jurassic Kota Formation. He considered the *Rhamphorhynchus* sp. indet as synonym of *Campylognathoides indicus.* Four premaxillary teeth are preserved. Anterior three teeth are alike in shape and size, while fourth tooth is enlarged. Anterior teeth have fine vertical ridges. Tooth base is rather broad and its relation to length is I:1 1/2. Teeth are slightly recurved backwards. Length of premaxilla from anterior tip to labial end is 4.7 cm, and up to the preserved end of the nasal process is 6.8cm. Each tooth is 4 mm long and 2.7 to 2.8 mm wide at the base [75].

3.4. A Look at Paleontology, Stratigraphy and Mineral Potential of Pakistan

A look at these disciplines of Geology of Pakistan is presented below.

3.4.1. Paleontology of Pakistan (A Look on Recent Exploration and Discoveries)

Each province of Pakistan is rich in paleontology. Previously, numerous tertiary and quaternary fauna were reported by scientists from different provinces. Recent paleontological exploration added more than 60 taxa from Cambrian, Paleozoic, Mesozoic and Cenozoic strata. In Azad Kashmir Cambrian fish *Muzaffarabadmachli* [38] was found. In North Punjab, rhinoceros *Soantherium bari* (here), ichnotaxa *Malakhelisauroperus* [38] of ornithischian, *Samanadrindoperus* [38] of large theropod and *Himalayadrindoperus* [38] of small theropod dinosaurs found from Jurassic Samanasuk Limestone. In South Punjab, fish *Kahamachli* [38], crocodiles *Asifcroco* [38] and *Sakhibaghoon* [76] and sauropod ichnotaxon *Dgkhansauroperus* [38] were found. In Sindh referred tooth of the Maastrichtian terrestrial mammal *Mirvitakriharan haji* [38] was found. 51 taxa [37] [38] were found from Balochistan Province.

Plant paleontology of Pakistan

Plant and wood fossils were reported in terrestrial strata of different ages [1]-[9]. Recently *Baradarakht goeswangai* [38], a large tree from Balochistan Province, was found in Late Cretaceous Dhaola Member of Pab Formation of middle Indus, Pakistan.

Invertebrate paleontology of Pakistan

Invertebrate fossils were reported from marine and terrestrial strata of different ages [1]-[9]. Recently from Balochistan Province, the 4 invertebrates reported in lower Indus basin are Artipoda Trilobita *Moolatrilo chotoki*, bivalves/Pelecypoda *Pakiring kharzani*, Mollusca Cephalopoda Nautiloidea *Pakiwheel karkhi* and Arthropoda Myriapoda Echinodermata *Mulastar zahri*, and 3 invertebrates from middle Indus basin are Mollusca Cephalopoda Nautiloidea *Pakiwheel vitakri* and Arthropoda Chilopoda *Nisaukankoil beakeri* and *Phailawaghkankoil derabugti* [32] [38].

Vertebrate paleontology of Pakistan

Karakoram basin and Kohistan Ladakh basin were devoid of prehistoric vertebrates. Recently Balochistan Basin uncovered the large female rhinoceros *Pakitherium shagalai* with fetus or new born infant [32] [77] from the Eocene-Oligocene Shagala Formation of Balochistan Province. This is the first ever terrestrial vertebrate from the Balochistan Basin of Balochistan Province. Indus basin is rich in Mesozoic and Cenozoic vertebrates except the uppermost Indus (Khyber-Hazara-Neelam) basin.

Vertebrate paleontology of Upper Indus basin (Pakistan)

Before 2000, Upper Indus basin yielded reptiles (extinct turtles [78]), mammals such as perissodactyls (rhinocerotoids [79]-[82]), proboscideans (*Deinotherium* [83]), artiodactyls including walking whales [84], primates, creodonts and rodents from Miocene-Pliocene Potwar Group. Recent geological and paleontological exploration uncovered 5 taxa including Cambrian fish *Muzaffarabadmachli* [38], mammal *Soantherium* (here), ichnotaxa from the Jurassic Samanasuk Limestones are *Malakhelisauroperus mianwali* [32] [38] Ankylosauria (see above), Ornithopaonia [38] ornithischian dinosaurs, *Samanadrindoperus surghari* [32] [38] Megalosauria (see above) and *Himalayadrindoperus potwari* [32] [38] Allosauria (see above) of Theropaonia [37] theropod dinosaurs (see above). A new rhinoceros is as below.

Systematic paleontology

Perissodactyla [85]

Rhinocerotidae [86]

Soantherium bari new genus and new species (**Figure 9**)

Holotype: A fragmentary anterior dentary ramus including articulated teeth (**Figure 9**) un-numbered was hosted by Farhan Bari (see below).

Locality, horizon and age: Holotypic fossil was found by father of Farhan Bari from his land in Chak Sighu (**Figure 9**), near Chouantra (Chontra, Chauntra) village, Rawalpindi Tehsil and District, Punjab Province, Pakistan (personnel communication with Farhan Bari in 2024) and tentatively presented here. Geographical coordinates of Chountra are latitude 33˚21'14" North, and longitude 72˚55'50" East. Holotype may be derived from strata of Miocene-Pliocene Potwar Group [8] [9], probably Miocene Chinji shale interpreted from matrix color. Potwar Group hosts Chinji, Nagri and Dhok Pathan Formations [8] [9]. Miocene-Pliocene ranges from 23 to 2.6 Ma [8] [9].

Etymology; Genus *Soan*, is after the Soan river and valley, *therium*, Greek for beast. Species *bari*, honors the Farhan Bari, Sr graphic/web designer, residing in D-17, Islamabad, whose late father was working as senior advocate, high court, Islamabad; originally belonging to Chak Sighu (Communication in November 2024).

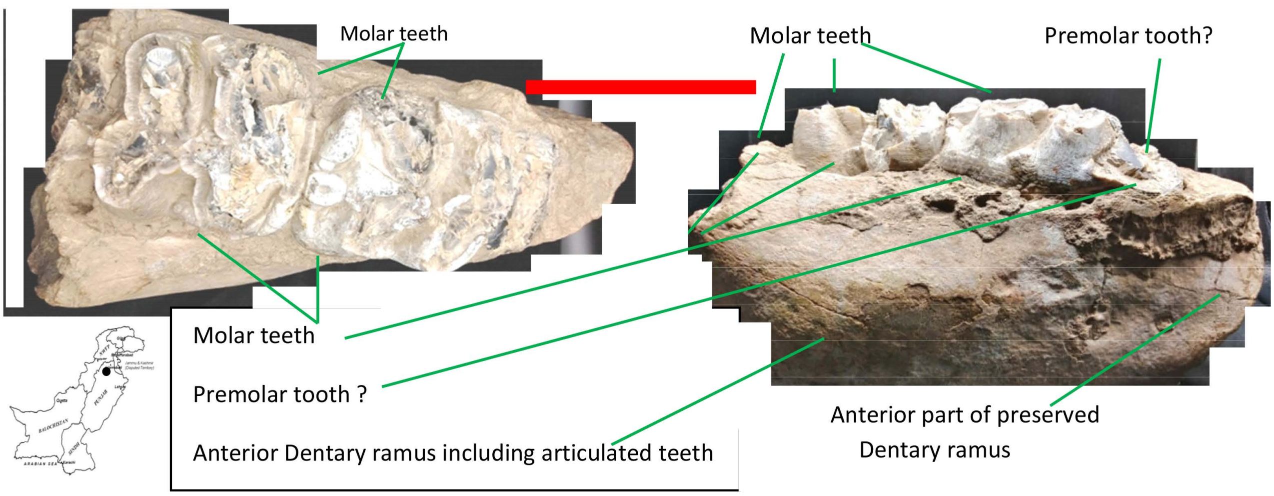

Figure 9. Anterior dentary ramus of *Soantherium bari* new genus and new species of rhinoceros. Red scale bar is 10 cm. Map of Pakistan showing Chak Sighu type locality (black circle), near Chontra/Chakri, Rawalpindi District, Punjab Province, Pakistan.

Diagnosis, comparison and description: This specimen belongs to a large rhinoceros (Perissodactyla [85]; Rhinocerotidae [86]). The occlusal view of lower molar of *Soantherium bari* represents parallel semi L-shapes (**Figure 9**) (which differentiates it from other rhinocerotoids), while the occlusal view of lower molar of *Buzdartherium gulkirao* has open U-shaped (Figure 3 of [32]). In general upper molar of most rhinoceros are pi-shaped, while lower molars have parallel L-shapes. *Soantherium bari* has subparallel fibrous lineations on dentary molar enamel. Anteroposterior and lingolabial maximum width of lower molars of *Soantherium bari* are subequal, representing subsquare shape (**Figure 9**), while *Teleoceras fatehjangense* has more anteroposterior width than linguolabial width (subrectangle shape). The length and width of dentary molars of *Soantherium bari* are distinct from other Rhinocerotidae of Fatehjang area, such as *Brachypotherium fatehjangense*, *Chilotherium blanfordi*, *Indotherium fatehjangense*, *Aprotodon fatehjangense* and *Gaindatherium browni*. Anterior dentary ramus with articulated 2 almost complete teeth and 2 partial teeth (**Figure 9**) of *Soantherium bari* are preserved. Its premolar is slightly preserved, 1st and 2nd molars are almost complete and 3rd molar tooth and alveolus is partially preserved. Preserved dentary ramus length is 33 cm, maximum preserved transverse width is 12 cm and maximum dorsoventral depth/height (without teeth crown) is 14 cm. 1st Molar Tooth crown (of almost 2 complete teeth) dorsoventral maximum length is 4 cm and anteroposterior length is 7 cm and transverse width is 7 cm. Its enamel is preserved well in the basal part of crown, where its enamel has anteroposteriorly elongated and subparallel fibrous lineations. Dentary ramus is slightly pneumatic and has anteroposteriorly and somewhat irregular fractures lineations. Dentary ramus dorsoventral depth is almost the same in the mid and posterior part, while reducing anteriorly.

Vertebrate Paleontology of Middle Indus Basin (Pakistan)

Before 2000, terrestrial Toi Formation of Early Eocene Chamalang Group, marine Habib Rahi, Domanda and Drazinda shales of Middle to Late Eocene Kahan Group and fluvial strata of Oligocene-Pliocene Vihowa Group and Pleistocene-Holocene Sakhi Sarwar Group uncovered numerous vertebrates dominantly mammals [87] [88]. Since 2000, at the start of the third millennium, the recent geological and paleontological exploration in Mesozoic and Cenozoic strata of middle Indus basin uncovered 41 vertebrate taxa including 40 fauna and 1 flora. Most of these discoveries were made by me (M. Sadiq Malkani), while I was partially involved in a few discoveries. These include 1 fish, 21 dinosaurs (14 titanosaurs, 2 small and 3 large theropods, 1 ichnotaxon of ornithischian and 1 ichnotaxon of sauropod), 6 crocodiles, 2 pterosaur (1 bone fossil taxon and 1 ichnotaxon), 1 snake, 1 bird, 8 mammals and 1 plant/tree which are being summarized as below with original description reports along with relevant updated reports for easy approach. 1 fishes represented by *Kahamachli harrandlundi* [32] [38]. 27 reptiles (bone taxa) represented by 14 titanosaurs such as *Gspsaurus pakistani* [37] [42], *Maojandino alami* [38] [42], *Ikqaumishan smqureshi* [41] [42] and *Imrankhanshaheen masoombushrai* [42] of Gspsauridae, *Saraikimasoom vitakri* [37] [42] and *Nicksaurus razashahi* [38] [42] of Saraikimasoomidae [42], *Balochisaurus malkani* [38] [42], *Qaikshaheen masoomniazi* [41] [42] and *Marisaurus jeffi* [38] [42] of Balochisauridae and *Pakisaurus balochistani* [37] [42], *Khanazeem saraikistani* [39] [42] (informally named *Anokhadino mirliaquati* first appeared in unpublished record with its etymology in 2019 on pages 49-50 of [89] and published record in 2022 on page 49 of [90] and page 554 of [76] which is a synonym of formally described *Khanazeem saraikistani* [39]), *Imrankhanhero zilefatmi* [41] [42], *Sulaimanisaurus gingerichi* [16] [37] [42], and *Khetranisaurus barkhani* [16] [37] [42] of Pakisauridae; 5 theropod dinosaurs (see above revised diagnosis and also **Table 1**) including 3 medium to large bodied theropods (Vitakrisauridae abelisauroids) such as *Vitakridrinda sulaimani* ([37] [42] and research here), *Vitakrisaurus saraiki* ([37] [42] and research here), and *Shansaraiki insafi* [39] [42], and 2 small bodied theropod (Noasauridae) dinosaurs represented by *Saraikisaurus minhui* (revised diagnosis) and an indeterminate species (see above); 1 large pterosaur *Imrankhanuqab qaeddiljani* [40]; 1 large snake *Wadanaang kohsulaimani* [37]; and 6 crocodiles *Pabwehshi pakistanensis* [52], *Induszalim bala* [30] [36] [37], *Sulaimanisuchus kinwai* [37], *Mithasaraikistan ikniazi* [37], *Asifcroco retrai* [30] [32] [38], and *Sakhibaghoon khizari* [76]. 1 bird represented by *Wasaibpanchi damani* [37] [38]. 8 mammals (including small to largest land mammals) represented by *Mirvitakriharan haji* [32] [38], *Khansultan masoomrashidi* [42], *Bolanicyon shahani* [32] [38], *Artiocetus clavis* [88], *Rodhocetus balochistanensis* [88], *Sulaimanitherium dhanotri* [32] [77], *Buzdartherium gulkirao* [32] [38] and *Gomphotherium buzdari* [32] [38]. 3 ichnotaxa reported are *Pashtosauroperus zhobi* [32] [38] Hadrosauria, Ornithopaonia [38] ornithischian (see above), *Dgkhansauroperus maarri* [32] [38] of Poripuchian titanosaur Sauropaonia [37] [38] sauropod dinosaur (see below) and *Anmolpakhiperus alleni* [32] [38] of Pteropaonia [38] pterosaur (see above).

Revised diagnosis & hierarchy of Ichnospecies *Dgkhansauroperus maarri* [37]

Systematic paleontology

Dinosauria; Sauropoda; Titanosauria; Poripuchia [37]; Sauropaonia [38] (Ichnogroup); *Dgkhansauroperus* [38] (Ichnogenus)**;** *Dgkhansauroperus maarri* [38] (Ichnospecies) (Figure 14 of [38]).

Revised Diagnosis: Maastrichtian *Dgkhansauroperus* pes track is functionally pentadactyl, longer than broader, mesaxonic, with digit length decreasing from digit I to digit V. Its pes track claws are narrow and elongated. Its pes track claws of digits I, II and III are directed anterolaterally and digit IV is directed somewhat laterally, while fifth digit is reduced and may be clawless or has reduced claw. Its pes track claws length increases from claw I to claw III and then decrease to claw IV. Its claws I and II are relatively slender, while claws III and IV are robust. Its pes track claws I, II and III have uniform thickness and at the distal end reduced to cone forming, while claw IV is reducing gradually toward distal end. Its pes track is maximum thick at the level of distal end of digit V. Pes track heel impression is sub-oval and transversely long, while forming broad rounded posterior end. Its pes track has well preserved claws impressions while upper Jurassic *Brontopodus plagnensis* from France lacks claws on digits I-III, *Brontopodus* isp. and *Parabrontopodus barkhausensis* pes lacks well preserved claws impressions. Its pes track has relatively long and narrow claws, while pes from the Late Cretaceous

Nemegt Formation from Mongolia [91] has short and narrow claws length. Of its typical, unique morphology and Maastrichtian age, further finding of coeval dominant titanosaur bones from vicinity (in Pakistan), close resemblance to track from Nemegt Formation of Mongolia [91] which also yielded titanosaur *Nemegtosaurus*, the trackmaker *Dgkhansauroperus* may belong to wide gauge poripuchian titanosaur. *Dgkhansauroperus* is first sauropod most probably titanosaurian ichnotaxon from Indo-Pakistan subcontinent.

Some important information about dinosaurs of Pakistan

Dinosaur bones were first discovered in India, most probably in 1828, by British Army Captain W.H. Sleeman, who appeared in 1844 [43]-[45]. Dinosaur femur bone was first discovered in mid Sangiali locality of Barkhan District, Balochistan Province, Pakistan, in early 2000 by M. Sadiq Malkani of Geological Survey of Pakistan [10] and consequently Pakistan appeared for the first time on the world dinosaur map. The first dinosaur femur bone discovered from Pakistan belongs to *Qaikshaheen masoomniazi* [41] of Titanosaur (a group of latest, largest and last land herbivore dinosaurs). *Marisaurus* is first sauropod informally described in 2003 (then referred crania, now part of holotype of *Gspsaurus*) from Pakistan [11]. *Gspsaurus* is first formally described sauropod (in 2021) from Pakistan. The armor bones discovered from Pakistan in 2003, reported first time in Asia [13]. *Pabwehshi* is the first Mesozoic vertebrate reported from Pakistan [46]. First time the name of Pakistani dinosaur *Marisaurus* appeared in 2003 [11] but this publication was submitted later than the conference paper 2004 [14] which presented the first proposed Pakistani dinosaur *Pakisaurus* (page 412 of [38]). *Vitakridrinda* was the first theropod (carnivorous dinosaur) in Pakistan. The name appeared for the first time in 2003 [12] and its bones were discovered in Vitakri and Mari Bohri areas of Barkhan District, Balochistan Province, Pakistan in 2001 by M. Sadiq Malkani, Geological Survey of Pakistan. *Imrankhanshaheen masoombushrai* was the last titanosaur dinosaur reported from Pakistan in 2024. *Saraikimasoom* and *Nicksaurus* were the smallest titanosaurian sauropod dinosaurs in Indo-Pakistan subcontinent. *Marisaurus*, *Gspsaurus* and *Maojandino* were the largest titanosaurian sauropod dinosaurs in Indo-Pakistan peninsula. *Saraikisaurus minhui* was last theropod dinosaur reported from Pakistan rediagnosed in present paper. *Saraikisaurus* and an indeterminate species from Pakistan were the smallest theropod dinosaurs in South Asia. *Vitakridrinda*, *Vitakrisaurus* and *Shansaraiki* were among the largest theropod dinosaurs in Indo-Pakistan subcontinent. Pakistan is first and unique in global work uncovering 19 species of dinosaurs in the shortest area (2.5*2 = 5 km^2) and also in the shortest time horizon spanning a few thousand years in Vitakri Formation (67 - 66 Ma) revealing dinosaur paradise and mass extinction. About 100 small, medium and large sized bones from mid Sangiali were also first observed and discovered by me (M. Sadiq Malkani) in late 2000 and these bones were sent to Museum of Paleontology, The University of Michigan, USA for preparation. About 1500 bones were collected by me during early 2001; among these 6 bones were sent to Museum of Paleontology, The University of

Michigan, USA for preparation. About 1200 bones were collected during mid 2001 by me. Some bones were collected later and however most of the observed bones by later field's works were left in the fields for further study. Total about three thousand bones were recovered from Pakistan since 2000. Among these, more than 500 bones were documented from Pakistan, while about 500 medium sized bones and about 2000 small bones fragments which were not documented so far. These bones may include some significant cranial and neural arch fragments. These bones are hosted in the museum of Geological Survey of Pakistan, Quetta, Pakistan. Among the documented bones, the dominant bone numbers such as 422 bones belong to titanosaurian sauropods (see Tables 8-11 tables of [42]), 54 bones belong to theropods, 14 bones belong to mesoeucrocodiles, 1 bone to pterosaur, 7 bones to snake, 7 bones to bird and 2 bones to mammals (see in tables in [40]) were collected from Vitakri Formation. Further collection of small fossils from potential dinosaur paradise area of Vitakri dome (with very low dips 0˚ - 10˚) with the best exposures and accessibility may yield crania and postcrania of diverse vertebrates, along with medium to large complete or almost complete bones may be useful for comparison and ratios. Type localities of the latest Maastrichtian terrestrial Vitakri ecosystems of Vitakri dome and Mari Bohri are shown in (**Figure 1**).

3 batches of Pakistani dinosaurs, paleobiogeographic link and phylogeny

First batch of dinosaurs from Pakistan appeared informally in 2003-2010 [12]-[16], [20]-[24] and formally described in 2021 [37] [38], second batch of dinosaurs appear informally in 2014-2020 [27]-[30], [32]-[36] and formally described in 2021 [37] [38] and third batch appear and formally described in ([39] [41] [42] and research here). Among 14 titanosaurs named from Pakistan, the *Pakisaurus*, *Khanazeem*, *Imrankhanhero*, *Gspsaurus*, *Ikqaumishan* and *Qaikshaheen* have referred typical elements from India (Table 8, Table 9, Table 11 of [42]) revealing one joined land during Late Cretaceous like those of recent. These recent discoveries revealed interesting paleobiogeographic evolution of Indo-Pakistan subcontinent [92] due to long and lengthy flight initiated from Gondwana and colliding with Laurasia [8] [9] [26] [30] [31] [92]. Most of these fauna revealed paleobiogeographic link with Madagascar, Africa, Australia and South America (Gondwanalands). These discoveries provide facility for comparison, biodiversity, paleobiogeography, biotic evolution and phylogeny with broader character data set [41] [42] [93] including updated and new characters of titanosaurs from globe and also from Pakistan to see their interrelationships.

Vertebrate Paleontology of Lower Indus Basin (Pakistan)

Lower Indus basin comprised the Nagarparker Shield (part of Indo-Pak shield), eastern Kirthar foldbelt (Sind) and western Kirthar foldbelt (Balochistan Province). Before 2000, Kirthar foldbelt yielded Paleocene vertebrae of crocodiles [94] and Miocene mammals (proboscideans, chalicothere, creodonts, amphicyonids, large hominoid and small primate [95]) from eastern Kirthar foldbelt. Recent exploration in lower Indus basin yielded 7 holotypic taxa and 2 referred taxa of vertebrates. Eastern Kirthar foldbelt yielded Maastrichtian referred tooth of terrestrial mammal *Mirvitakriharan* [38] (and Paleocene vertebrae of snake [96]). Western Kirthar foldbelt yielded Jurassic plesiosaur *Zahrisaurus* [32] [38] and sauropod ichnotaxon *Chiltansauroperus* [37] [38], Late Jurassic-Early Cretaceous ankylosaur *Brohisaurus* [12] [37], Late Cretaceous titanosaur *Nicksaurus* (referred distal thoracic rib) [42], theropod *Saraikisaurus* (referred limb bones) [37], marine crocodile *Khuzdarcroco* [38] and fish *Karkhimachli* [38] and Eocene seacow *Kilgai* [38].

Revised diagnosis and hierarchy of Ichnospecies *Chiltansauroperus nicki* [38]

Systematic paleontology

Dinosauria; Sauropoda; Sauropaonia [38] (Ichnogroup); *Chiltansauroperus* [38] (Ichnogenus)**;** *Chiltansauroperus nicki* [38] (Ichnospecies); (Figure 14 of [38])

Revised Diagnosis: *Chiltansauroperus nicki* [38] was reported as a member of Sauropaonia [38], while its higher classification is mentioned here which was previously not reported. *Chiltansauroperus nicki* was formally described in [38] and previously informally described as *Chiltanpaer nicki* [38]. Its digits and unguals are slender. Its central ungual directed anteriorly while 1st and 2nd unguals directed medially and 4th and 5th unguals directed laterally. Its description was presented by [32] [38]. *Chiltansauroperus* is first sauropod ichnotaxon from Indo-Pakistan subcontinent.

Terrestrial and Marine fauna recently discovered from Pakistan

Recently discovered all the above mentioned fauna and flora are terrestrial except the plesiosaur *Zahrisaurus* [38], fishes *Muzaffarabadmachli* and *Karkhimachli* [38], mammals *Kilgai* [38], *Artiocetus* [88], *Rodhocetus* [88] and *Sulaimanitherium* [32] [77], invertebrates [38] (except pelecypod *Pakiring* [38] which is terrestrial) and crocodile *Khuzdarcroco* [38] (while *Pabwehshi*, *Induszalim*, *Sulaimanisuchus*, *Mithasaraikistan*, *Asifcroco* and *Sakhibaghoon* were fresh water crocodiles). Many land wood fossils and fresh water invertebrates especially bivalves were found in the Chamalang, Vihowa and Sakhi Sarwar Groups of Indus basin and Shagala Group especially in Shagala-Kamardin Kareez area of northern Balochistan Basin. Further fresh water bivalves/pelecypods and other invertebrates were found in the Vitakri Formation especially in Vitakri dome area (**Figure 1**). Marine invertebrates such as ammonites, belemnites, nautiloids, gastropods, corals, arthropods, bivalves, starfish, nummulites, alveolina, assilina and others were found in Mesozoic and Cenozoic.

3.4.2. Stratigraphy of Pakistan; Correlation Chart of Upper/Middle/Lower Indus

Pakistan includes Indus Basin (upper, middle and lower basins; **Figure 10**) which is a part of Gondwana, Hindukush-Karakoram basin which is a part of Asian continent, and Kohistan-Ladakh magmatic arc and Balochistan basin and arc are products of Tethys sea and part of Arabian-Iranian plate [39] [92]. Indus basin is

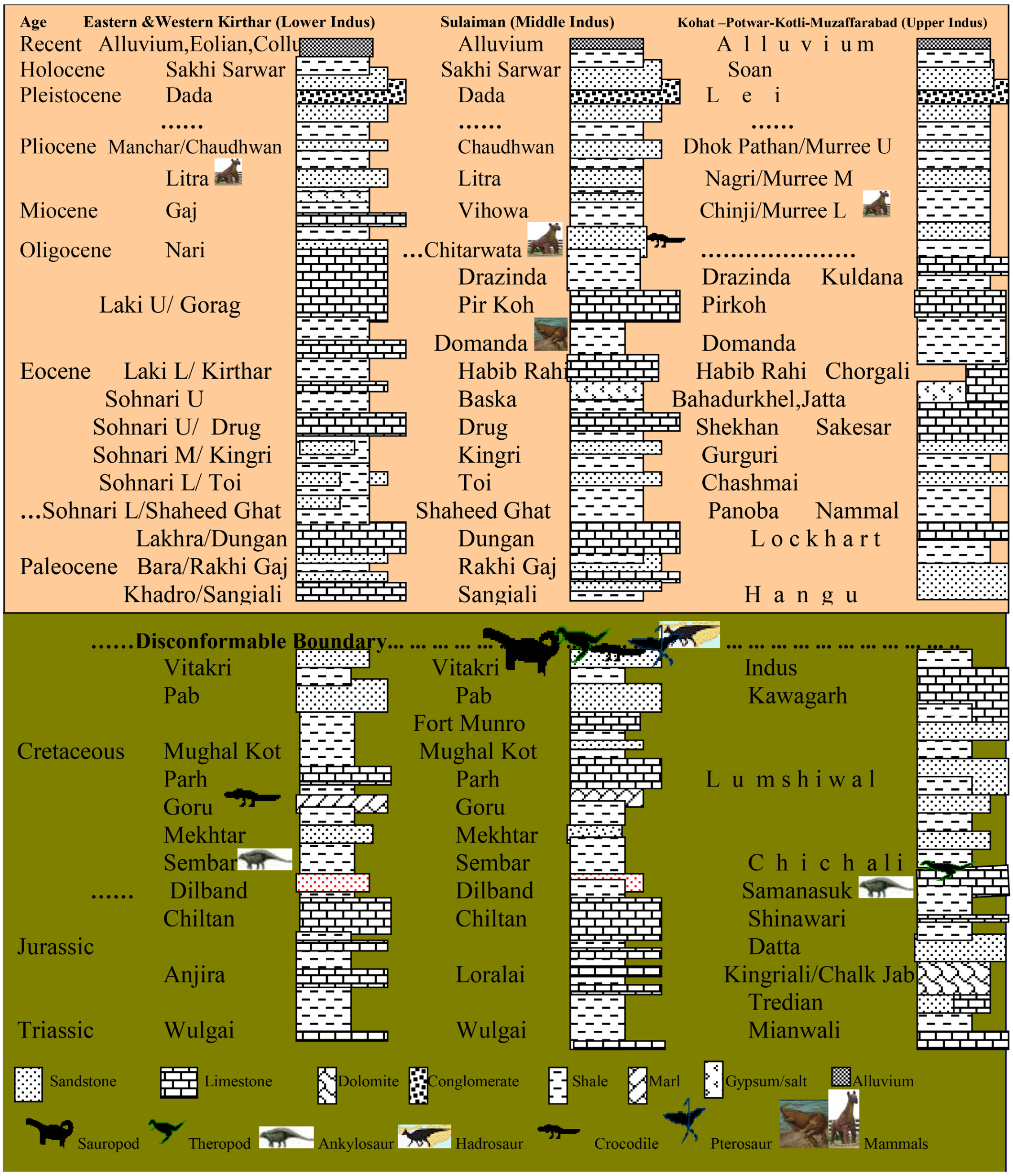

Figure 10. Revised stratigraphic correlation of North/Upper Indus (Kohat-Potwar-Kotli-Muzaffarabad) basin, Middle Indus (Sulaiman) basin and South/Lower Indus (Eastern and Western Kirthar) basin of Pakistan [8] [9] [41] [76] [91] [100].

sutured via western Indus suture with Balochistan basin, and northern Indus suture with Kohistan-Ladakh magmatic arc which further contacted with Hindukush-Karakoram basin via Karakoram suture [92]. Balochistan basin and arc hosts the Late Mesozoic to recent sediments and also continued volcanism [8] [9] [26] [97]-[99]. The Hindukush-Karakoram basin hosts the Precambrian to recent stratigraphy [8] [9], and Kohistan-Ladakh basin mostly hosts the Cretaceous sediments, igneous and metamorphic rocks [8] [9]. Uppermost Indus (Khyber-

Hazara-Neelam) basin and Upper Indus (Kohat-Potwar-Kotli-Muzaffarabad) basin host the Precambrian to recent rocks and stratigraphy [8] [9] [41] [99], middle Indus/central Indus/Sulaiman basin host Permian to recent strata with some igneous and metamorphic rocks [8] [9] [22] [23] [26] [40] [41] [76] [91] [99] [100] including Kirana shield rocks exposed at the boarder of middle and upper Indus basins, and lower Indus/south Indus/Kirthar basin also host the exposed Permian to recent strata with some igneous and metamorphic rocks including Nagar Parker Precambrian shield granite [8] [9] [26] [41] [101] [102]. Stratigraphy of Pakistan was previously presented by many geoscientists [1]-[7]. The revised stratigraphy of Pakistan has been presented more recently [8] [9], which presented updated stratigraphy of different basins with many new entries and corrections in previous data incorporated, such as the exact positions and contacts of Toi, Drug and Baska formations, lower Goru sands exposures, variations of different lithologies and their thickness, and Hangu Formation with its junior synonym Patala formation. Here, a revised stratigraphic correlation chart of the upper, middle and lower Indus basins is presented (**Figure 10**).

3.4.3. Mineral Resources of Pakistan; Vital Potential for Development of Pakistan

Pakistan has rich mineral potential, which demands proper utilization of minerals and rock commodities for the development of provinces and Pakistan and earns foreign exchange. Mineral resources of Pakistan were reported by many geoscientists since 1949 [103]-[107] and more recently reported by [108]-[110]. Mineral resources of each province were presented such as Balochistan [97]-[99] [111]-[114], Khyber Pakhtunkhwa [108]-[110] [115] [116], Gilgit Baltistan and Azad Kashmir [112]-[114] [117] [118], North and South Punjab [23] [112]-[114], [119], Saraikistan/South Punjab [23] [112]-[114] [119], Sindh [112]-[114] [120]. Mineral resources of each basin were presented such as Balochistan basin [97]-[99] [111]-[115], Hindukush-Karakoram basin [109], Kohistan-Ladakh basin [109], Khyber-Hazara-Neelam basin (uppermost Indus) [109], Kohat-Potwar-Kotli-Muzaffarabad basin (upper Indus) [109], Sulaiman Basin (middle Indus) [22] [23] [26] [90] [100] [109] [119] and Kirthar basin (lower Indus) [26] [101] [102] [109] [120]. Recently coal deposits [108]-[110] [121]-[123] including drilling logs of Sor Range-Deghari and Harnai-Gochina-Sangan-e-Pain (north and western extremity of Sibi trough) [42], gypsum [23] [26] [108]-[110] [124], including complete chemical analyses of different gypsum deposits ([42] and references therein), fluorite and celestite [23] [108]-[110] [125]-[127], silica sands [23] [42] [108]-[110], and iron deposits [22] [23] [26] [42] [108]-[110], especially Dilband ironstone [42], marble, construction material and dimension stones [23] [26] [112] [113] [108]-[110] were also reported from different localities of Pakistan. Vast and huge gypsum, limestone and shale deposits for more cement industry installation and other uses are discovered from Koh Sulaiman Range of Rajanpur, Dera Ghazi Khan and Taunsa Districts of South Punjab, and adjoining Balochistan areas [40] [108]-[110]. Further exploration and development of Indus placer gold transported (by glacial and water) from primary source rocks located in Karakoram-Hindukush ranges, Kohistan-Ladakh magmatic arc, Karakoram and northern Indus sutures, Indo-Pakistan shield igneous rocks to Indus river alluvial sands which started from Gilgit Baltistan-Chitral to Attock to Mianwali, Bhakar, Layah, Taunsa, D.G.Khan, Rajanpur, Kashmor to Hyderabad to coast; and also Indus tributeries (Jhelum, Chanab, Ravi, Sutluj) as alluvialsands; Thal, Cholistan, Thar, long coast/sea shore line, Hamun Mashkel and Chagai desert sands; and placer sedimentary rocks from Oligocene to Holocene (see in **Figure 10**) (such as Potwar, Soan, Vihowa, Sakhi Sarwar and Manchar Groups; [8] [9]) for the development of provinces and country Pakistan. Besides gold, the rare earths and other heavy and resistant minerals such as gold, magnetite, ilmenite, rutile, zircon, monazite (rare earths and thorium bearing principal mineral), xenotine, sillimanite, garnet, gems and others can be explored in these areas and excavated from anomalous areas if feasible. Density and gravity based separation plants for gold (being high density 19 g/cm^3) and other heavy minerals from alluvial sand can work cheaply. Last but not least, reference [128] conveys lessons and future paths for us to increase the development of minerals/rocks in the title "Pakistan mineral potential: prince or pauper". Try should be made to cease the imports and use own country's raw materials and minerals, and to increase the production and export like cement, gypsum, marble, construction stones, dimension stones, gems, jewellery and other minerals and rocks commodities.

4. Conclusions

This report provides an overview of theropods, ornithischians, and pterosaurs from India and Pakistan. More than 60 taxa of prehistoric biota are known from recent paleontological collections. The stratigraphy of Pakistan is represented by Precambrian to Recent sediments, with subordinate igneous and metamorphic rocks. Pakistan has high and significant mineral and rock potential, but it needs more attention for its development to fulfill local requirements and earn foreign exchange.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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