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First Jurassic Dinosaur fossils found from Kirthar Range, Khuzdar District, Balochistan, Pakistan

M. SADIQ MALKANI
Paleontology and Stratigraphy Branch, Geological Survey of Pakistan,
Sariab Road, Quetta, Pakistan

ABSTRACT: *First Kimmeridgian (Late Jurassic) dinosaur fossils have been discovered in the lowest horizon of Sembar Formation just near the contact of Zidi/Chiltan Limestone, in the Sun Chaku locality of Karkh area, and Lakha Pir Charo locality of Zidi area, Khuzdar district, Balochistan, Pakistan. Fossils from the lowest part of the Sembar Formation in Kirthar Range, Pakistan, provide the first remains of Late Jurassic Titanosaurian dinosaur from Pakistan. However, the specimens collected to date include the poorly preserved, fragmentary and incomplete cross section of femur, metatarsals/metacarpals, ribs and proximal portion of fibula and distal portions of neural spines/diapophysis/zygapophysis. To acknowledge the tribe and locality, Brohisaurus kirthari, a new genus and species of Titanosauria, is erected on the basis of characters observed which are elliptical/eccentric nature of femoral cross section, well developed of proximal scar on proximal fibula, possible pneumatic cavities in the anterior ribs, massiveness in the distal ribs, less arced D shape cross section of rib and some resemblance of proximal fibula and ribs cross section to the Late Cretaceous Pakistani Titanosaurs. The degree of elliptical nature is different from Late Cretaceous dinosaur fauna of Pakistan.*

This discovery of Jurassic dinosaur fossils from Pakistan is expected to develope great interest in local and global scientific community which will open new avenues of research such as exploration of any age of Mesozoic dinosaurs and their phylogeny and paleobiogeography. Dinosaurs were dominant land animals during most of the Mesozoic era from 225 to 65 million years ago, but became extinct at its end. Thick piles of Mesozoic sedimentary rocks are exposed in many parts of Pakistan and it is encouraging for the exploration of every age of Mesozoic dinosaurs.

Indo-Pakistan initially interlocked with the Gondwana landmasses of Africa, South America, Australia, Antarctica and Madagascar early in the Mesozoic, drifted northward during the Cretaceous to collide with Laurasian landmasses during the Cenozioc. Indo-Pakistan thus appears to have experienced a 100-million-year period of isolation during a 9,000 kilometer migration across the equator that can be expected to have influenced the character of its native biota. Fossils from this period of biogeographic isolation are relatively scarce. So far, the Late Cretaceous (Maastrichtian) Lameta Formation of India has served as the sole source of information on Cretaceous vertebrates of the Indo-Pakistan subcontinent. But new discoveries including a variety of large vertebrate that indicate five new genus and species of herbivorous Titanosaurian Sauropod and one new genus and species of carnivorous

Abelisaurid Theropod Dinosaurs and Baurosuchid Pabwehshi Pakistanensis (Mesoeucrocoreptilia) fossils. These discoveries of Jurassic and Cretaceous Arhosaurian reptiles from Pakistan act as a milestone for assessing paleobiogeography and phylogeny.

INTRODUCTION

First Kimmeridgian (Late Jurassic) dinosaur fossils have been discovered first time in Pakistan in the lowest horizon of Sembar Formation just near the contact of Zidi/Chiltan Limestone, in the Sun Chaku locality (coordinates; 27° 50' 40" N; 67° 09' 66" E) of Karkh area, and Lakha Pir Charo locality (coordinates; 27° 37' 35" N; 67° 02' 10" E), of Zidi area, Khuzdar district, Balochistan, Pakistan (Fig. 1). The Sun Chaku locality is 15 kilometers from Karkh village and 85 kilometres east of Khuzdar. It is accessible through fair-weather road. Charo locality is 15 kilometers south of Bhalok village and 60 kilometres east of Khuzdar.

Late Jurassic/Kimmeridgian dinosaur fossils occur in the lowest horizon of Sembar Formation and comprised dominantly shale which is enriched by iron nodules in both localities and have a light yellow color in the Charo area. Jurassic dinosaur fossils are found as fragmentary in the residual colluviums and bed rock dipping about 30 degree east at Sun Chaku and 25 degree east at Lakha Pir Charo locality. Present study is based upon surface collections. Fossils from the lowest part of the Sembar Formation in Kirthar Range, provide the first remains of the Late Jurassic Titanosauria from the Pakistan. However the specimens collected to date include the poorly preserved, fragmentary and incomplete cross section of femur, metatarsals/metacarpals, ribs and proximal portion of fibula and distal portions of neural spines/diapophysis/zygapophysis.

This discovery of Jurassic dinosaur fossils from Pakistan is expected to develope great interest in local and global scientific community which will open new avenues of research such as paleobiogeography and phylogeny. A more precise taxonomy, anatomy, phylogeny, skeletal variation, track ways evolution, etc., of dinosaurs will be clear after articulated collections. Dinosaurs were giant reptiles, these animals were quite anomalous from normal evolutionary pattern of other species and genera and so big in size that they are of great interest for taxonomists, taphonomists, vertebrate paleontologists and ecologists. Dinosaurs were dominant land animals during most of the Mesozoic era from 225 to 65 million years ago but became extinct at its end. One of the unresolved mysteries of geological sciences is the existence of world's largest reptiles the dinosaurs on planet earth during the periods of Triassic to Cretaceous and then their abrupt extinction at the end of Cretaceous. Thick piles of Mesozoic sedimentary rocks are exposed in many parts of Pakistan and the Cretaceous-Tertiary boundary is well exposed at many localities and it is encouraging for the exploration of every age of Mesozoic dinosaurs and related problems like extinction, taxonomy, paleobiogegraphy and phylogeny.

Indo-Pakistan initially interloked with the Gondwana landmasses of Africa, South America, Australia, Antarctica and Madagascar early in the Mesozoic, drifted northward during the Cretaceous to collide with Laurasian landmasses during the Cenozioc. Indo-Pakistan thus appears to have experienced a 100 million year period of isolation during a 9,000 kilometer migration across the equator that can be expected to have influenced the character of its native

biota. Fossils from this period of biogeographic isolation are relatively scarce. Thus far, the late Cretaceous (Maastrichtian) Lameta formation of India has served as the sole source of information on Cretaceous vertebrates of the Indo-Pakistan subcontinent (Wilson, et al., 2001). But new discoveries including a variety of large vertebrate that indicate five new genus and species of herbivorous Titanosaurian Sauropod and one new genus and species of carnivorous Abelisaurid Theropod Dinosaurs and Baurosuchid *Pabwehshi pakistanensis* (Mesoeucrocoreptilia) (Wilson et al., 2001) fossils. These discoveries of Jurassic and Cretaceous Arhosaurian reptiles from Pakistan provide a vantage point and act as a milestone for for the entering of Indo-Pakistan subcontinent into new hypothesis of Paleobiogeography and Phylogeny.

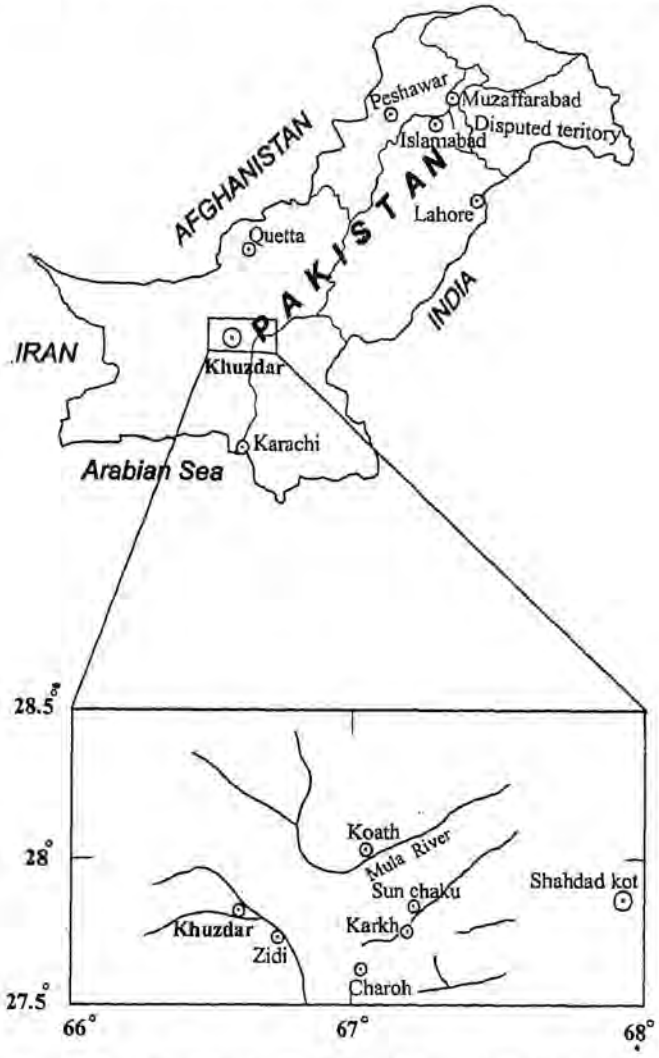

Fig. 1. Index map showing the Sun Chaku and Charoh localities, Kirthar Range, Pakistan.

GENERAL GEOLOGY

Sun Chakku and Charoh are located in the central part of Kirthar Range of Balochistan province, Pakistan. Sedimentary rocks ranging in age from Jurassic to Oligocene along with Quaternary surficial deposits occur in the area. Sedimentary bed rocks such as limestone, shale, marl and minor sandstone bodies are divided in to several lithologic units, which in ascending order are Jurassic Zidi Formation and Chiltan Limestone, Jurassic-Cretaceous Sembar Formation, Cretaceous Goru, Parh, Mughalkot, Fort Munro and Pab Formations, Cretaceous-Paleocene Khadro and Rakhi Gaj Formations, Paleocene Dungan Formation, Eocene Shaheed Ghat/Laki (Ghazij group) and Kirthar Formations and Oligocene Nari and Gaj Formations and Miocene-Pliocene Manchar Formation (Table 1).

The Quaternary deposits have been further subdivided in to Pleistocene Dada Formation. Such as recent Terrace gravel deposits, fan gravel deposits, colluviums deposits, sand, silt and clay deposits (non cultivated and cultivated lands) and modern channel deposits.

Stratigraphic sequence of the area is tabulated as follows:

TABLE 1. STRATIGRAPHIC SEQUENCE OF AREA

Age		Formation	Lithology
Q	Recent	Modern channel deposits Sand,	Gravel, sand, silt and clay
U		silt and clay deposits	Sand, silt and clay with minor gravel
A		(cultivated lands)	
T			
E	and	Sand, silt and clay deposits	Sand, silt and clay with minor gravel
R		(non-cultivated lands)	
N		Colluvium deposits	Boulder, pebbles, cobbles, with sand
A			silt and clay.
R		Fan gravel deposits	Poorly consolidated gravel, sand,
Y			silt and clay.
	Sub-Recent	Terrace gravel deposits	Poorly consolidated gravel, sand,
			silt and clay.
		Angular Unconformity	
	Pleistocene	Dada formation	Calcareous white clays.
		Angular Unconformity	
		Gaj Formation	Limestone, shale and sandstone
T	Oligocene	Nari Formation	Sandstone, limestone and shale.
E			
R		Disconformity	
T			
I		Kirthar Formation	Limestone, marl and shale.
A	Eocene	Shaeed Ghat/Laki Formation	Mainly shale with minor marl /
R		(Ghazij Group)	limestone and mudstone / siltstone.
Y	Paleocene	Dungan Formation	Limestone, marl and shale
		Disconformity	
		Rakhi Gaj Formation	Shale, mudstone, siltstone, sandstone & limestone
		Khadro Formation	Limestone with minor shale and sandstone
C	Late	Pab Formation	Sandstone with subordinate shale
R		Fort Munro Formation	Limestone, shale and coquina beds

CRETACEOUS		Mughal Kot Formation	Shale with minor marl/limestone and coquina beds
	Early	Parh Formation	Limestone with minor marl and shale
		Goru Formation	Shale and marl with minor limestone
JURASSIC	Late	Sembar Formation	Mainly shale with minor marl and mudstone Disconformity
		Chiltan Formation	Limestone with insignificant shale
		Zidi/Shirinab Formation	Limestone, shale, marl and minor sandstone

ANATOMY AND POSSIBLE PHYLOGENY

Present findings consist of fragments of appendicular skeleton such as femoral shaft cross section (Fig. 2, MSM-86-k), cross section of metatarsals and metacarpals, proximal part of fibula (Fig. 3, MSM-88-K), and fragments of axial skeleton such as pieces of ribs (Fig. 3, MSM-87-k, MSM-92-k, MSM-93-k, MSM-94-k) and possible neural spines/neural arch laminae (MSM-95-k, MSM-96-k). Only one piece of bone (MSM-96-K) is found in the Charoh locality and all other pieces of bones were found in the Sun Chakku locality.The exposures of this horizon are wide but upto now not followed for detailed sampling.

Systematic Paleontology (Taxanomy)
Dinosauria Owen, 1842
Order Saurischia Seeley,1888
Suborder Sauropodomorpha Huene, 1932
Infraorder Sauropoda Marsh, 1878
Family Titanosauridae Lydekker,1885
New Genus and Species, *Brohisaurus Kirthari*

Holotype: MSM-86-K, MSM-87-K, MSM-88-K, MSM-89-K, MSM-90-K, MSM-91-K, MSM-92-K, MSM-93-K, MSM-94-K, MSM-96-K, MSM-97-K, MSM-98-K, MSM-101-K, MSM-102-K, MSM-103-K, MSM-104-K, MSM-105-K, and MSM-106-K. Femoral, ribs, metatarsals and metacarpals cross sections, broken neural arch laminae/neural spine and proximal fibula (Figs. 2 & 3) have been discovered during this study. The type specimens are part of collection of fragmentary pieces, made in Sun Chaku locality on slope of small hill in the clay rich rocks.

Referred specimens: MSM-95-K, One broken piece of neural arch laminae was found from the clay rich horizon of Lakha Pir Charo area.

Horizon and locality: Lowest clay/shale horizon of Sembar Formation just at and near the contact of Zidi/Chiltan limestone and Sembar Formation, Sun Chakko Locality, Karkh area, Khuzdar district, Baluchistan, Pakistan.

Age: Late Jurassic (Kimmeridgian)

Diagnosis: All the holotypic and referred specimens are weathered, fragmentary, poorly preserved and replaced by ferruginous minerals. However, the ellipticity of femoral cross section, well-developed proximal scar on proximal fibula, simple slightly convexo-convex (biconvex) ribs; and pneumatic cavities in the anterior ribs are the best character to assign them Titanosaurs. The

new genus and species names are purely tentative.

Etymology: New Genus and Species name Brohi is derived from the Brohi tribe of the area, saurus means reptile and the species specific epithet represents the Kirthar range which is the host of Jurassic dinosaur.

DESCRIPTION

Appendicular Skeleton

Femoral cross-section: Broken femoral cross section (Fig. 2, MSM-86-K) having medio-lateral width of 12 cm and antero-posterior depth of 5.5 cm but its one side is weathered so it may be of 6 cm. So this eccentric ellipticity (12 x 6 cm) recalls the specimens belong to the Titanosaurs. Femoral cross section is not hollowed. Three smaller pieces of broken nature may belong to femora/humerus are shown in Fig. 1 (MSM-89-K, MSM-91-K, MSM-102-K).

Proximal Fibula: Proximal portion of fibula (Fig. 3, MSM-88-K) was found in Sun Chakko locality. Its width is 10 cm and depth is 4 cm. Its one side form a well-developed scar for attachment of proximal tibia. The fibular scar also recalls that the specimen belong to Titanosaurs.

Meta carpals/meta tarsals: Four or five brocken pieces of metacarpals and /or metatarsals were found in Sun Chako locality.These are rounded to subrounded in diameter. The thickest specimens diameter varies from 3.75 to 5.40 cm.

Axial Skeleton

Ribs: Five brocken pieces of ribs were found in the Sun Chakko locality. None of them show the tuberculum and capitulum. Three pieces (Fig. 3; MSM-87-K, MSM-92-K, MSM-94-K) belong to the central part of the ribs below the junction of tuberculum and capitulum. It is known by the greater width and pneumatic nature of ribs. One piece shows the distal ends and it is weathered and replaced by iron and mud but one piece seems to be massive.

Both the central rib cross section are weathered and fragmentary but show some indication of pneumatic cavity which is a characteristics of Titanosauria. Most of the fragments are nearly flat and straight and none show strong curvature. The shape of transverse section varies in different ribs and in different parts of the same ribs, from narrowly elliptical to plano-convex. The longest fragments measures 12 cm in length with a breadth of the proximal end of 8.5 cm and distal end of 7.5 cm. The widest fragment is 8.5 cm. The width of ribs cross-section vary from 8.5 to 7.5 cm and depth vary from 3 to 2.5 cm within a broben piece of 12 cm long.

Neural spine /diapophysial laminae: Two broken pieces (Fig. 3; MSM-95-K, MSM-96-K) may belong to neural spine or diapophysial lamina. MSM-95-K is curved and it has elongated lineation or grooves/rugosities for the attachment of muscles.

The entry of Pakistan into Kimmeridgian Titanusaurus does not change the temporal range of the lineage (Late Jurassic-Late Cretaceous) but it expands its spatial distribution to include Indo-Pakistan. Discoveries of early titanosaurids from Africa (Sternfeld,1911; Haughton,1928) and this new discovery from Pakistan (Indo-Pakistan subcontinent) and also Late Cretaceous advanced Titanosaurids and Saltasurids (Malkani & Anwar, 2000; Malkani et al., 2001) have given a new perspective to further attempts to explore and interpret the origin and evolution of Titanosauria (Sauropods Dinosaurs). This attempt to update the evolution and systematics of the Titanosaurus sauropods is based on a comparative analyses of femoral and ribs cross sections of early to advanced Titanosaurids.

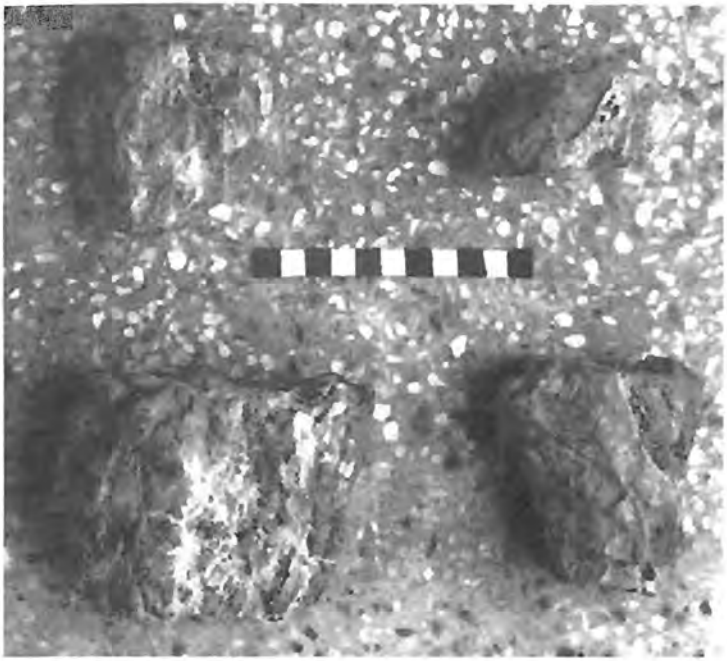

Fig. 2. Fragments of leg bone like femur/humerus in the upper row. Cross section of femur and fragment of leg bone like femur/humerus in the bottom row (scale is in centimeters).

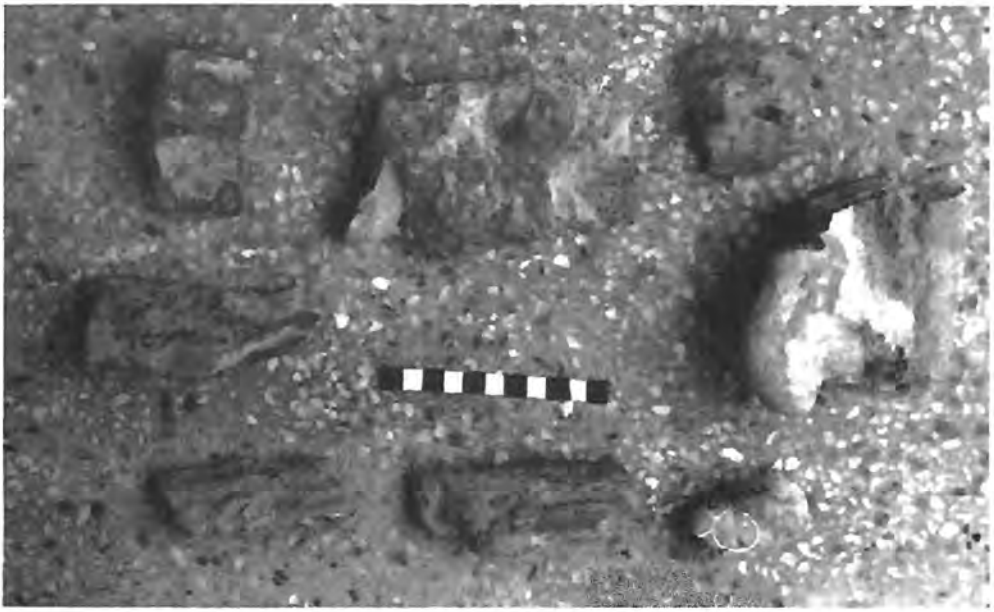

Fig. 3. Fragments and pieces of ribs in the top row and pieces of rib and proximal fibula in the middle row. Parts of neural spine/dipophysis/ zygapophysis and half egg/nodule concretion/like sexual organ in the bottom row (scale in centimets).

Tornieria from the upper Tendaguru beds of Tanzania is usually taken to be the oldest known member of the Titanosauridae (Sternfeld, 1911). It is known from several series of very robust limb and foot bones (McIntosh, 1990). The early Cretaceous species from Malawi, "Gigantosaurus" dixeyi (Haughton, 1928) based on caudal, pubis, scapula and sternal plate, is certainly a titnosaurid. However, it is not clear whether it belongs to Tornieria or not (McIntosh, 1990).

In Triassic, no definite sauropods trackways are known from their time period. Early and Middle Jurassic is marked by the narrow guage tracks, where wide gauge trackways are dominant during late Jurassic to late Cretaceous (Wilson et al., 1999).

Primitive sauropods femora show eccentricity between the medio-lateral and antero-posterior femoral but are only slightly elliptical (Diplodocus), The femur of Brachiosaurus has more eccentric profiles, and Titanosaurus (Saltasaurus) have the most elliptical sauropod femora.

The tentative evolutionary trends of Titanosaurs of Pakistan found in Late Jurassic (Kimmeridgian) and Late Cretaceous based on morphology of elliptical femoral cross section and pieces of dorsal ribs. The general evolving trend of femoral cross section started from circular to oval to suboval to less elliptical (ancestors) to well elliptical (about symmetric on antero-posterior axis found in Late Jurassic (Kimmeridgian Titanosaurs) to well elliptical (asymmetric on antero-posterior axis, more thicker on the medial side than the lateral side found in the Late Cretaceous Titanosaurs)

The general trend of cross section of dorsal ribs from Late Jurassic Titanosaurs to Late- Cretaceous Titanosaurs vary from the central part of dorsal ribs cross section vary from slightly convexo to convex (about symmetrical) observed in Late Jurassic Titanosaurs to plano convex (Asymmetrical) found in Late Cretaceous Titanosaurs and distal part of dorsal ribs may vary from plano-convex (symmetrical found in Late Jurassic Titanosaurs) to plano-convex (asymmetrical in Late Cretaceous Titanosaurs). From the above discussion, it can be found that there was more symmetry in the ellipticity of femur in Late Jurassic Titanosaurs than found in the Late Cretaceous Titanosaurs and same is true in the dorsal ribs cross section. Phylogenetic trend seems like Brohisaurus-Khetranisaurus/ Sulaimanisaurus/ Pakisaurus-Marisaurus/ Balochisaurus.

PALEOBIOGEOGRAPHIC IMPLICATION

The Kimmeridgian Late Jurassic fauna of Sun Chako and Charroh, Karkh areas, Kirthar Province give the impression of a continuous relation with the Kimmeridgian fauna of Tanzania and Malawi (Sternfeld, 1911; Haughton, 1928; Weishampel, 1990). As the elliptical/eccentric character of cross section of femur and massiveness of leg bones, pneumatic cavities in the anterior ribs and massiveness in the distal ribs and massiveness of metacarpals/metatarsals suggest relation to Titanusaurs tentatively named as *Brohisaurus Kirthari*. Supposed as the Kimmeridgian fauna of Pakistan is the same as the one in Tanzania and Malawi, Kimmeridgian Tornieria , the Indo-Pakistan connected with Africa and also belonged to the South America. However the detailed sampling in the South America and Madagascar are not sufficiently known yet to correlate well. Kimmeridgian Titanusaurs found in Pakistan as fragmentary and incomplete remains.

During the Late Cretaceous the great similarities with the fauna of the South America, however, is observed especially in

the case of Saltasaurids and Titanusaurids, both of them may included into Titanusauria and other archosaurian such as Baurusuchid *Pabwehshi Pakistanensis* (Wilson et al., 2001) and also *Vitakridrinda Sulaimani* Abelisaurid Theropod.

All these Indo-Pakistan subcontinent genera are distributed in Africa and South America during Late Jurassic and Early Cretaceous but also distributed in South America during Late Cretaceous. Evidence of close faunistic relation with other continents and regions has not yet been known may be due to less sampling density/issue.

At Tendaguru, Tanzania, Titanusaurus occur (Gigantosaurus=Tornieria) but other Sauropods predominate. Data yet known from the upper Cretaceous of Egypt and the Sahra indicate that the fauna has rather a different aspect but it contains a Titanusaurus (Huene & Matley, 1933).

Indo-Pakistan initially interlocked with the Gondwanan landmasses of Africa, South America, Australia, Antarctica and Madagascar early in the Mesozoic, drifted northward during the Cretaceous to collide with Laurasian landmasses during the Cenozioc. Indo-Pakistan thus appears to have experienced a 100 million year period of isolation during a 9,000 kilometer migration across the equator that can be expected to have influenced the character of its native biota. Fossils from this period of biogeographic isolation are relatively scarce. So far, the late cretaceous (Maastrichtian) Lameta formation of India has served as the sole source of information on Cretaceous vertebrates of the Indo-Pakistan subcontinent (Wilson et al., 2001). But now Pakistan has a variety of large vertebrate such as Titanusaurids and Saltasaurids, sauropods dinosaurs, Abelisaurids / Tyranosaurids theropods dinosaurs and Baurusuchids Mesoeucrocodylia. These discoveries of Jurassic and Cretaceous Arhosaurian reptiles from Pakistan provide an opportunity for assessing biogeography and phylogeny. Now Pakistan will act as a milestone for the entering of Indo-Pakistan subcontinent into new hypothesis of Paleobiogeography and Phylogeny.

A land corridor between South America and Indo-Pakistan is present in the two main paleogeographic reconstructions. Smith et. al. (1994) reconstruct a corridor between South America and Indo-Pakistan via Antarctica that existed until the Hauterivian (Early Cretaceous) at ca. 130 million years ago. Hay et al. (1999) reconstruct the same corridor but propose that it lasted until the campanian (Late Cretaceous) at ca. 80 mya. Both depict a land connection between Africa and South America until the Albian-Cenomanian (mid-Cretaceous) at ca. 100 mya, as well as a connection between Indo-Pakistan and Madagascar that persisted until roughly the same time. However, because these two paleocoastline reconstructions indicate different durations for the corridor stretching between South America and Indo-Pakistan, they predict different landmasses to show greatest faunal affinity with the Indian subcontinent. The paleogeography of Smith et al. (1994) suggests that Indo-Pakistan's Cretaceous fauna should display greatest similarity to that of Madagascar, whereas the paleogeography of Hay et al. (1999) suggests greatest similarity to South America and Antarctica. (Wilson et al., 2001).

From the Late Jurassic to Early Cretaceous, the Titanosaurs were dominant in Africa along with the other Sauropods. It could not compete the other dominant Sauropods genera in the Middle and Late Cretaceous. It may be a less sampling issue.

The data likes Kimmeridgian dinosaur in Pakistan suggest a direct land communication with the Tanzania and Malawi (African) countries during the kimmeridgian. However, in the later time it may isolated from Africa but it remain connected with South America through a corridor via Antarctica. Paleobiogeographic reconstruction by Smith et al. (1994) and Hay et al. (1999) have explained well about the Indo-Pakistan subcontinent connection during Late Cretaceous. But the reconstruction by Hay et al. (1999) best accommodates the available Late Jurassic and Cretaceous biota of the Indo-Pakistan.

CONCLUSIONS

The discovery of first Jurassic dinosaur fossils from lowest Sembar Formation, Kirthar province, Pakistan is of great significance as it has proved that these gigantic animals used to flourish on the western margin of the Indo-Pakistan subcontinent during the time it was connected with Africa and South America before drifting northwards. The discovery of fossils of first Jurassic dinosaurs has opened several new avenues of research for vertebrate paleonotologists, taxonomists, taphanomists and ecologists to study the evolution, phylogeny and abrupt extinction of these gigantic animals. It is, therefore, recommended that efforts should be made to collect and excavate more fossils from dinosaur localities in Pakistan to find articulated skeleton, which are useful for taxonomy and paleobiogeography and later its display at a proper place after reconstruction.

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