Open Journal of Geology, 2020, 10, 448-489
https://www.scirp.org/journal/ojg
ISSN Online: 2161-7589
ISSN Print: 2161-7570

First Skull of Medium Sized Titanosaur in Indo-Pakistan Subcontinent Found from the Latest Maastrichtian Vitakri Formation of Pakistan; Associated Cranial and Postcranial Skeletons of *Gspsaurus pakistani* (Poripuchia, Stocky Titanosauria, Sauropoda) from Pakistan and India

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How to cite this paper: Malkani, M.S. (2020) First Skull of Medium Sized Titanosaur in Indo-Pakistan Subcontinent Found from the Latest Maastrichtian Vitakri Formation of Pakistan; Associated Cranial and Postcranial Skeletons of *Gspsaurus pakistani* (Poripuchia, Stocky Titanosauria, Sauropoda) from Pakistan and India. *Open Journal of Geology*, **10**, 448-489.
https://doi.org/10.4236/ojg.2020.104020

Received: March 16, 2020
Accepted: April 14, 2020
Published: April 17, 2020

Abstract

Titanosaurs' crania are rare in the global world. Further titanosaur crania associated with postcrania are again negligible which prevented for its higher and lower level phylogenetic studies. The titanosaur skulls were also extraordinarily rare in Indo-Pakistan subcontinent, but the recent discoveries of holotypic skull, braincase and associated postcranial skeleton of *Gspsaurus pakistani* is anatomical wealth. Further its exemplar' skeletons from Top Kinwa and Mari Bohri of Pakistan and Chota Simla from India provide more information which can be used for comparison. Here the holotypic partial skull with braincase and associated postcranial skeleton and also its exemplars and referred materials with key elements of *Gspsaurus pakistani* are being presented which have international significance and contribute to understanding the evolutionary relationships, higher and lower level phylogenetic studies and paleobiogeographic history of the vertebrates of Indo-Pakistan subcontinent.

Keywords

Titanosauria, Stocky Poripuchia, Skull, Skeletons, *Gspsaurus*, Indo-Pakistan

1. Introduction

Among the countries of South Asia, the dinosaurs are known only from India and Pakistan. From India dinosaurs are known from about 2 centuries since 1828 [1]-[7], while from Pakistan dinosaurs were known recently first time in 2000 [8]. Since 2000 to so far 3 thousand bones/pieces of fossilized bones were found from Pakistan which have many significant remains at international level. Five taxa of titanosaurs from Pakistan were established like *Pakisaurus*, *Sulaimanisaurus* and *Khetranisaurus* of Pakisaurids and *Marisaurus* and *Balochisaurus* of Balochisaurids [9]. Many fossils were referred to *Marisaurus* [10] [11] [12] [13] [14], *Balochisaurus* [13] [14] [15] and *Pakisaurus* [16]. *Saraikimasoom* and *Gspsaurus* were established on snout and partial skulls [17]. *Nicksaurus* and *Maojandino* were established on cranial and associated postcranial materials [18] [19]. Recently four titanosaur taxa were recognized from Indo-Pakistan [20] [21] [22] [23] [24], *Vitakridrinda* [25] and *Vitakrisaurus* [25] [26] [27] large sized theropods, *Induszalim* [25] [28] [29], *Pabwehshi* [30] and *Sulaimanisuchus* [25] [26] mesoeucrocodiles, and many other biotas [31] [32] from latest Cretaceous of Pakistan. All these vertebrate fossils are collected from 25 localities in eastern Sulaiman (middle Indus) Range and their locations are shown in maps [14]. A titanosauriform or basal titanosaur *Brohisaurus kirthari* [33] is also known from the Jurassic-Cretaceous boundary about 145 million years old. Due to lack of snout or anterior skull materials from Indo-Pakistan, here the detail description of snout, cranial and postcranial materials from Pakistan are being presented.

The titanosaur skulls were extraordinarily rare in Indo-Pakistan subcontinent before the recent discoveries of cranial and associated postcranial remains from Pakistan. Further there is a more urgent issue of comparison to fossils of titanosaurs that were collected from contemporaneous localities in Pakistan and India, due to the holotypic cranial and associated postcranial skeleton (**Figures 1-4**) of *Gspsaurus pakistani* stocky titanosaur which provides the overlapping facility with holotypic and referred fossils from other localities of Indo-Pakistan. Considering a skeleton of Alam 19 crania and postcrania, the holotypic braincase and postcranial skeleton (**Figure 4**) of *Maojandino alami* were included and added in the holotype of *Gspsaurus pakistani* based on many evidences which are also provided in the following section. The possible skeleton of Top Kinwa 16 (**Figure 5**) was referred to *Gspsaurus pakistani* due to correlation of key tibia and other elements. *Gspsaurus* skull provides the facility of comparison with the skull of *Saraikimasoom* and braincases and teeth from India. Further *Gspsaurus* vertebral and appendicular skeleton provides comparison facility with holotypic caudal vertebrae and limb elements of *Marisaurus* (**Figure 6**), *Balochisaurus*, *Pakisaurus* and *Sulaimanisaurus*/*Isisaurus.* In this comparison, the *Gspsaurus* materials seem to be more similar with *Marisaurus* holotypic vertebral and limb elements. Due to this reason, [21] referred this material to *Gspsaurus.* Further the vertebral and appendicular elements of *Gspsaurus* found different from *Balochisaurus*, *Pakisaurus* and *Sulaimanisaurus*/*Isisaurus*. In this way *Balochisaurus* holotypic vertebral and appendicular elements found more similar to Saraikimasoom north Kinwa exemplar. Due to this reason, [22] referred these materials

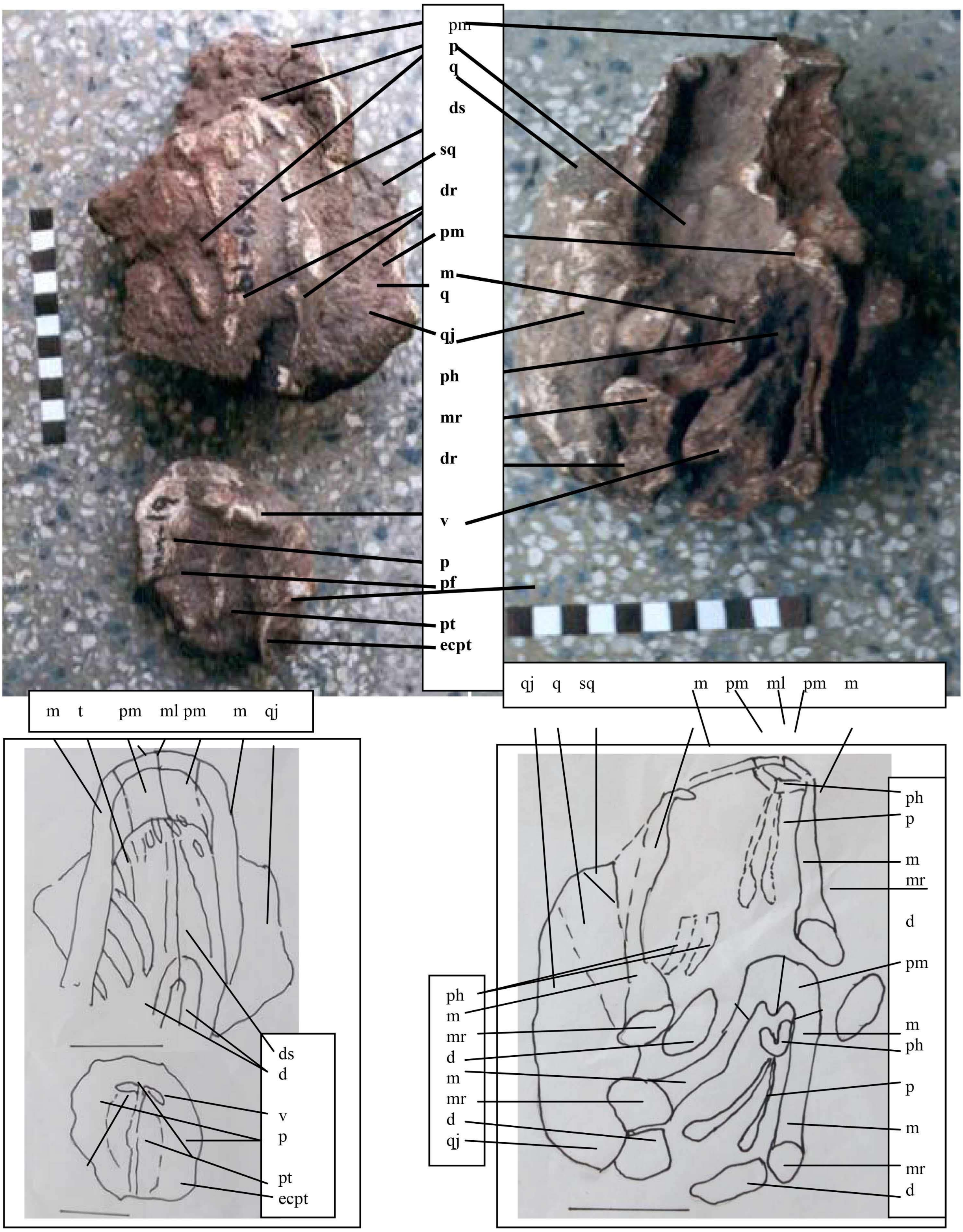

Figure 1. Images and line drawings of *Gspsaurus pakistani* holotypic skull MSM-79-19 and MSM-80-19 in ventral and posterior cross sectional views. Scale, each black/white digit is 1 cm. Scale bar in line drawing represents 5 cm. Abbreviations: d, dentary; dr, dentary ramus; ds, dentary symphysis; ecpt, ectopterygoid; ml, midline contact; m, maxilla; mr, maxillary ramus; p, palatine; ph, palatal dorsal hook; pt, pterygoid; q, quadrate; gj, quadratojugal; sq, squamosal; t, teeth; v, vomerine. *Gspsaurus pakistani* includes holotype in **Figures 1-4**.

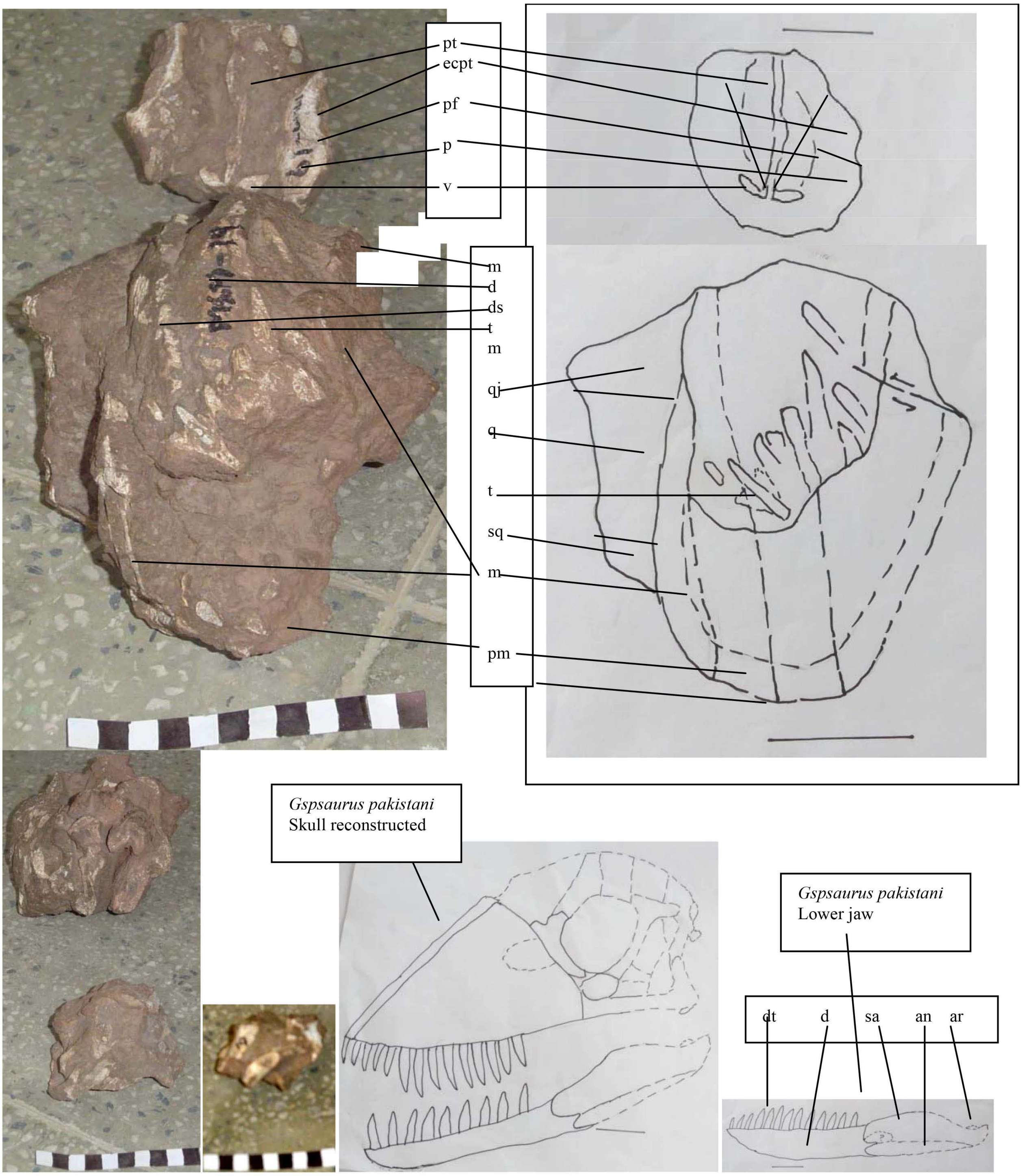

Figure 2. *Gspsaurus pakistani* holotypic skulls MSM-79-19 (larger specimen) and MSM-80-19 (smaller specimen) found from Alam locality. Skull and mandible reconstruction after fossils and estimation. Scale in image, each black or white digit is 1 cm. Scale bar in line drawing represents 5 cm. Abbreviations: d, dentary; dr, dentary ramus; ds, dentary symphysis; ecpt, ectopterygoid; ml, midline contact; m, maxilla; mr, maxillary ramus; p, palatine; ph, palatal dorsal hook; pt, pterygoid; q, quadrate; gj, quadratojugal; sq, squamosal; t, teeth; v, vomerine.

to *Saraikimasoom.* The major key elements like diverse tibiae and caudal vertebrae are used for distinction, besides the cranial materials. Here the holotypic

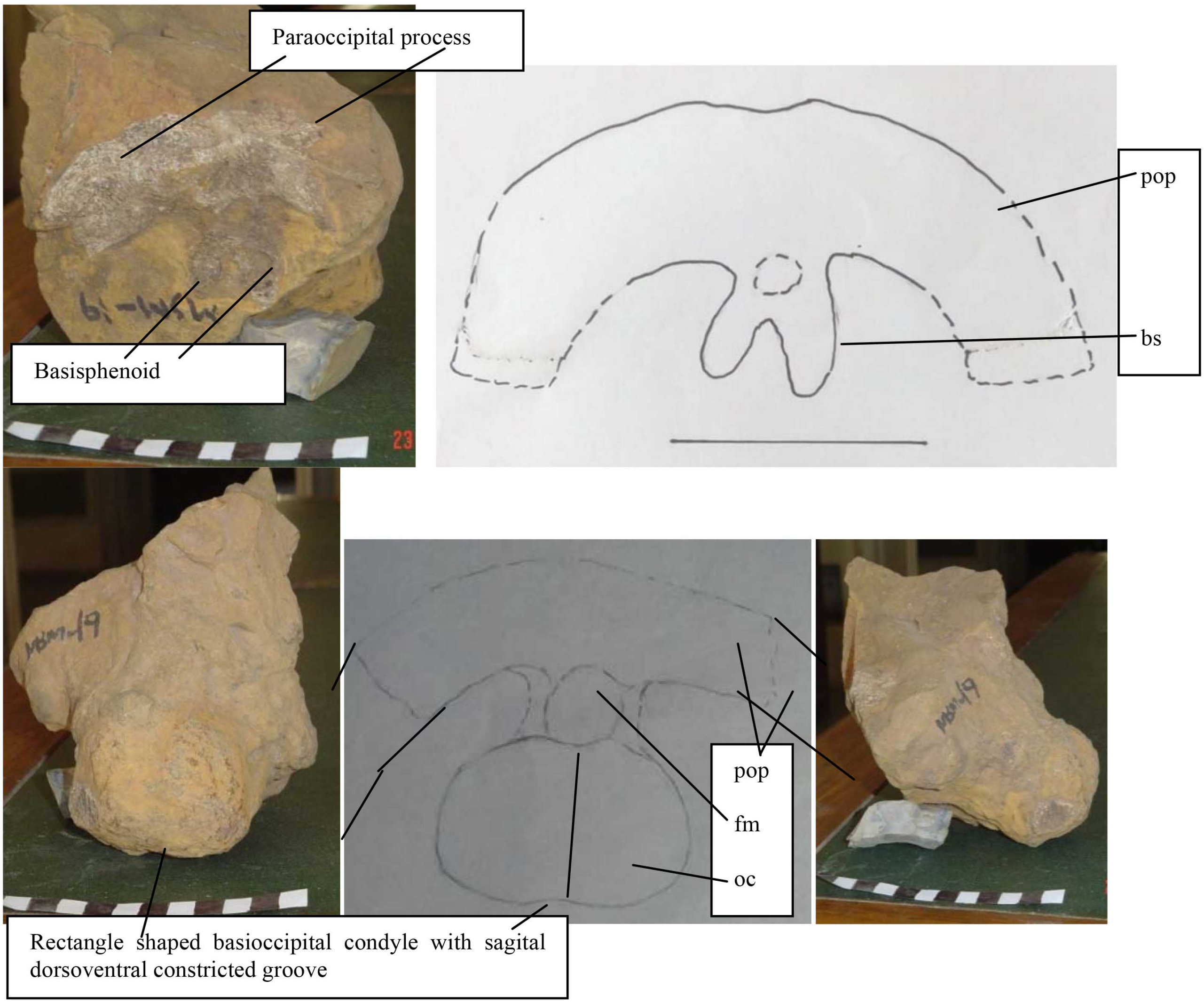

Figure 3. *Gspsaurus pakistani* holotypic braincase MSM-62-19 from Alam 19 in anterior, posterior and lateral views. Scale in image, each black or white digit is 1 cm. Scale bar in line drawing represents 5 cm. Abbreviations: bs, basisphenoid; oc, oocipital condyle; fm, foramen magnum; pop, paraoccipital process; GSP, Geological Survey of Pakistan; MSM, Muhammad Sadiq Malkani. The formal specimen numbers are like GSP/MSM-62-19 but briefly represented by MSM-62-19 in literature. The central number 62 represents the serial number of specimen/fossil, and last number 19 represents locality number of Alam locality. Further at places the locality name with locality number are mentioned as like Alam 19, here Alam is the locality name and 19 is the locality number. At places 19 or 19c which means central Alam, the south Alam is represented by 19s and north Alam is represented by 19n.

skull with braincase and associated postcranial skeleton and also referred skeletons and materials with key elements of *Gspsaurus pakistani* are being presented which have international significance and contributes to understanding the evolutionary relationships and paleobiogeographic history of the titanosaurs from Indo-Pakistan subcontinent and provide facility for comparison with coeval fossil remains from Indo-Pakistan subcontinent and also with global world.

2. *Gspsaurus pakistani*

The systematic paleontology of *Gspsaurus pakistani* is as follows.

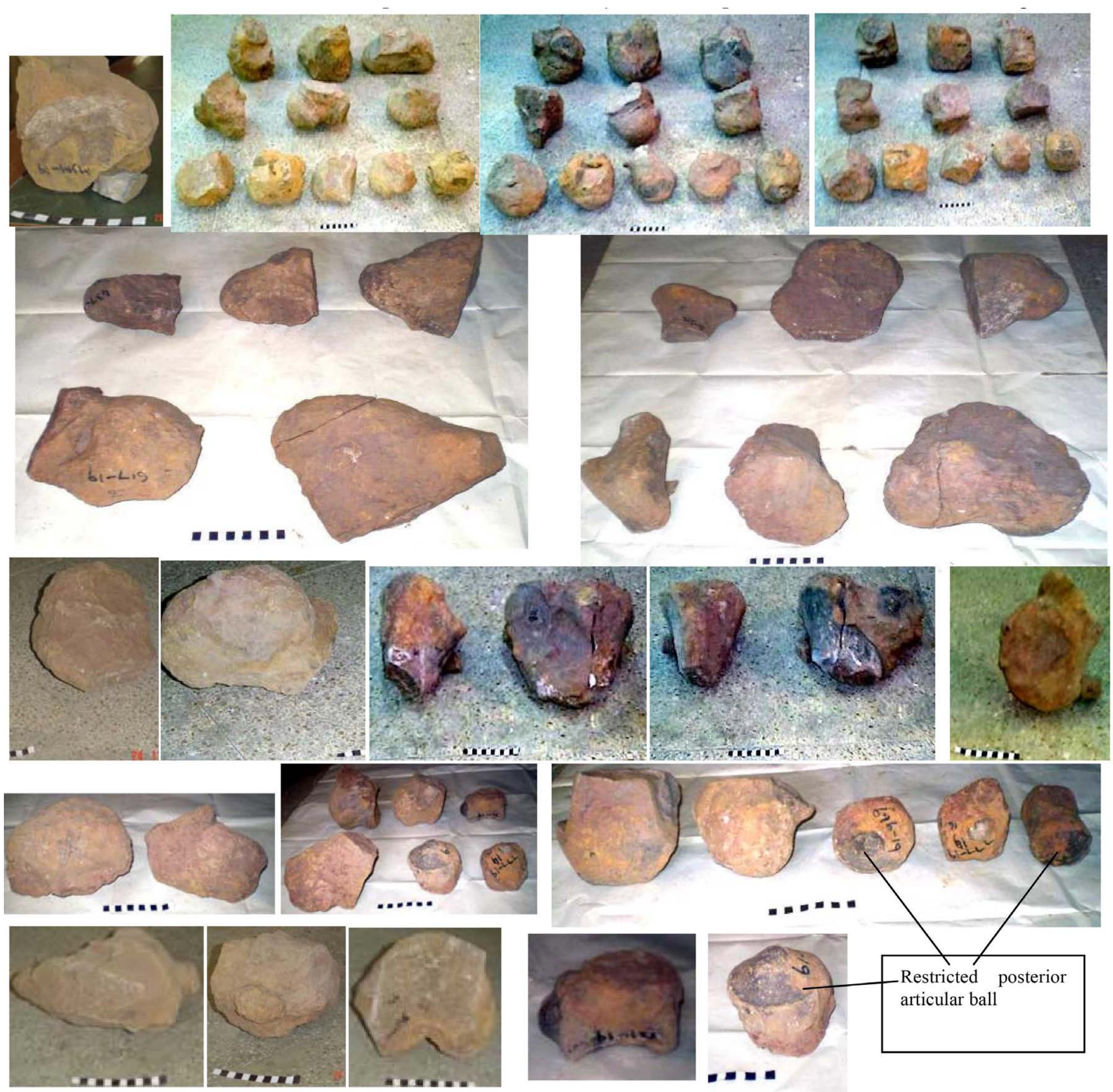

Figure 4. *Gspsaurus pakistani* holotype (rows 1 - 5). The holotype (rows 1 - 5) of *Maojandino alami* found from Alam type locality. Present research and [21] included these materials (rows 1 - 5) in the holotype of *Gspsaurus pakistani*). Row 1, photo 1/p1, braincase MSM-62-19 in anterior view; p2, 3, 4, subrow 1, cervical vertebrae MSM-107-19, MSM-108-19 and MSM-109-19; subrow 2, dorsal vertebrae MSM-110-19, MSM-111-19 and MSM-112-19; subrow 3, caudal vertebrae MSM-113-19, MSM-114-19, MSM-115-19, MSM-116-19 and MSM-117-19. Row 2, p1, subrow 1, cervical vertebrae MSM-437-19, MSM-220-19, MSM-502-19; subrow 2, dorsal vertebra MSM-617-19, partial ilia MSM-216-19; p2, subrow 1, proximal radius MSM-215-19; proximal left tibia MSM-119-19; proximal left femur MSM-213-19; subrow 2, distal left tibia MSM-569-19; view; distal right tibia MSM-710-19; distal left femur MSM-118-19. Row 3, p1, 2, proximal left tibia MSM-119-19 in lateral and dorsal views; p3, 4, distal right tibia MSM-710-19 and distal left femur MSM-118-19 in 2 views; p5, right subrectagular distal tibia MSM-710-19 in ventral view; Row 4, p1, left and right partial distal scapula MSM-1100-19, MSM-217-19; p2, subrow 1, caudal vertebrae MSM-219-19, MSM-218-19 and MSM-221-19; subrow 2, partial distal right scapula MSM-217-19; caudal vertebrae MSM-696-19, MSM-777-19; p3, caudal vertebrae MSM-219-19, MSM-218-19, MSM-696-19, MSM-777-19, MSM-221-19. Row 5, p1, 2, 3, vertebral process MSM-146-19 in 3 views; p4, 5, restricted posterior articular ball MSM-221-19 and MSM-696-19. Scale, Each black or white digit is 1 cm.

Dinosauria [34];
Saurischia [35];

Figure 5. *Gspsaurus pakistani* referred skeleton of Topkinwa exemplar. Row 1, a pair of coosified sacral vertebrae MSM-137-16 in 4 views; dorsal vertebrae MSM-131-16 and MSM-132-16 in 3 views. Row 2, caudal vertebrae MSM-34-16 and MSM-35-16 in lateral and ventral views; distal caudal vertebra MSM-153-16 in 2 views showing anteroposteriorly long and shallow neural spine on cylindrical centrum. Row 3, a pair of left and right distal scapulae MSM-250-16, MSM-176-16; a pair of left and right proximal ulna (upper) MSM-175-16, MSM-240-16; distal ulna (lower) MSM-74-16; distal ulna MSM-74-16 in 2 views. Row 4, distal radius MSM-160-16 in 3 views; acetabulum in 2 pieces MSM-147-16 and MSM-148-16. Row 5, proximal right tibia biconvex lense shaped MSM-73-16 in 3 views; left and right proximal fibulae MSM-76-16 and MSM-77-16 in 2 views. Row 6, convex part of sternal MSM-1014-16, sternal part MSM-604-16; part of ilia MSM-557-16, part of ilia or spine with glenoid or wound mark MSM-150-16, vertebral process/distal rib/distal spine/metatarsal/metacarpal MSM-391-16; distal cervical ribs MSM-328-16, MSM-329-16 and MSM-767-16; mosaic type osteoderms MSM-83-16 and MSM-1035-16; platy oval ungual MSM-776-16. Scale each black digit is 1 cm. For other plates pl. See figures of [10].

Sauropoda [36];
Titanosauria [37];
Poripuchia [22];
Gspsauridae [17];

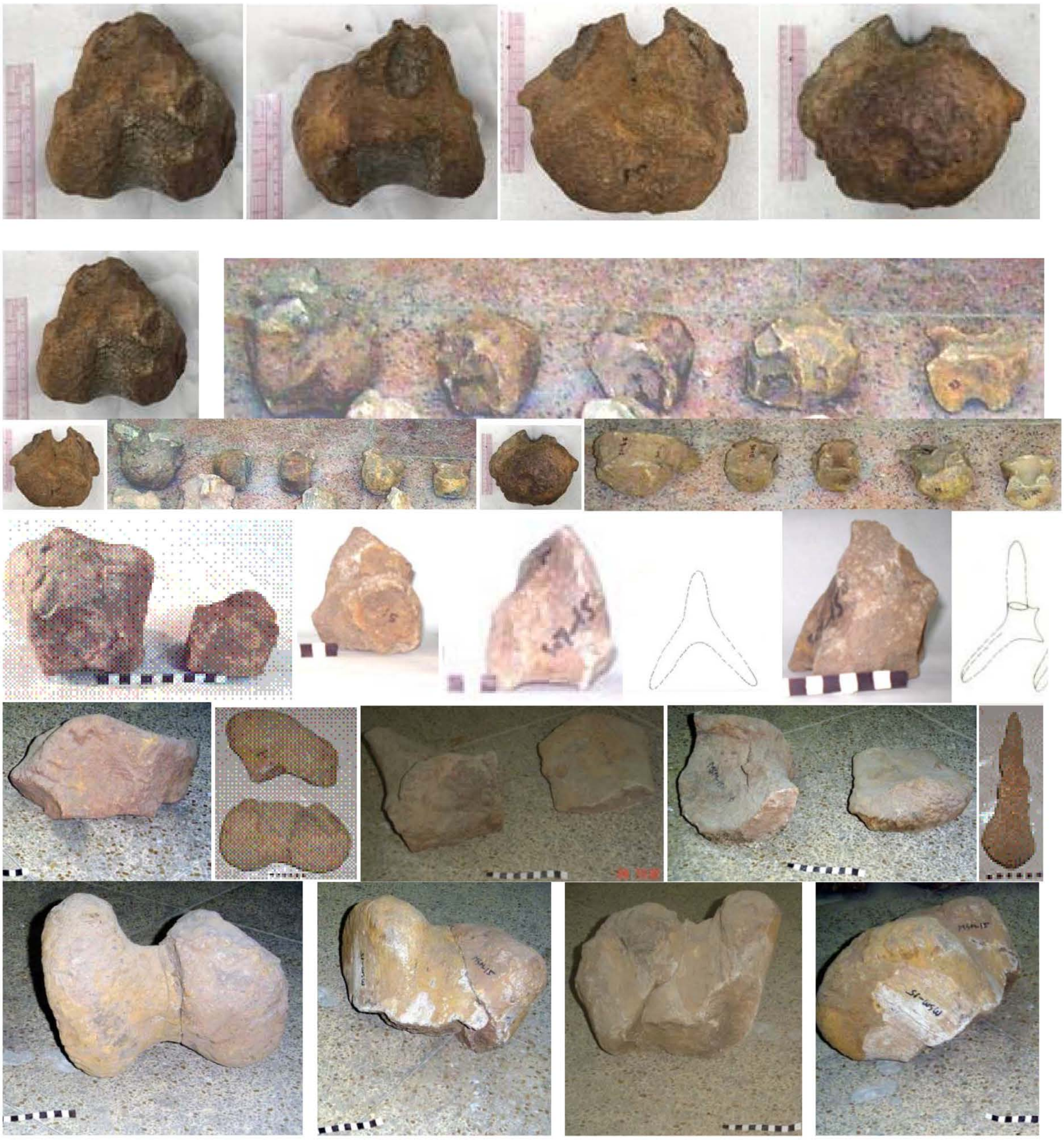

Figure 6. *Gspsaurus pakistani* Mari Bohri exemplar. The holotypic skeleton (row 1 to 6) of *Marisaurus jeffi* which was found from Mari Bohri locality. Here it is being referred to *Gspsaurus pakistani* due to some overlapping and common features. Row 1, biconvex first caudal vertebra GSP/MSM-7-15. Rows 2, six caudal vertebrae GSP/MSM-7-15 MSM-29-15, MSM-30-15, MSM-31-15, MSM-32-15, MSM-33-15 [9]. Rows 3, six caudal vertebrae GSP/MSM-7-15 MSM-29-15, MSM-30-15, MSM-31-15, MSM-32-15, MSM-33-15 in 2 views. Row 4, caudal vertebrae MSM-815-15, MSM-808-15; special trirays distalmost caudal centrum MSM-507-15 in anterior, posterior and lateral views. Row 5, p1, distal right scapula MSM-163-15; p2, proximal femur MSM-169-15 (upper) and distal femur MSM-70-15 (lower); p3, 4, proximal pubis MSM-165-15 and distal pubis MSM-164-15 in 2 views; p5, distal pubis MSM-164-15 in another view. Row 6, holotypic distal femur MSM-70-15 in 4 views. Scale, each black or white digit is 1 cm. For biconvex vertebra the scale is in cm and inches, total scale 15 cm; For other caudal vertebrae (rows 2 and 3) pl. See figures of [9].

Gspsaurus [17] [19];
Gspsaurus pakistani [17] [19];

(**Figures 1-8**).

The holotypic skull remains, braincase, cervical, dorsal and caudal vertebrae,

Figure 7. *Gspsaurus pakistani* referred materials from south Kinwa 4 (rows 1 - 4), Darwaza 8 and Rahi Wali 10 (row 5). Row 1, atlas-axis complex MSM-82-4 [11] in four views. Row 2, 3, 4, associated caudal vertebrae in lateral and ventral views MSM-36-4, MSM-37-4, MSM-38-4, MSM-39-4, and MSM-39(a)-4. Row 5, mid scapular blade with ridge MSM-838-4; right mid and distal scapula MSM-198-4; proximal and mid femur MSM-208-4; and osteoderm ellipsoidal plate MSM-85-4 in 3 views. Row 6, caudal vertebra MSM-40-8 in 4 views; and proximal humerus MSM-237-10 in 2 views; model of *Gspsaurus pakistani* (by cooperation of Mr. Nick Allen British Journalist). Scale each black or white digit is 1cm. For scale pl. See [10].

Figure 8. *Gspsaurus pakistani* fossils from mid-Bor locality, about 300 m southward from main Bor stream in the central Bor stream. A, Row 1, cervicodorsal vertebra MSM-120-2, dorsal vertebrae MSM-121-2, MSM-122-2, MSM-123-2, MSM-124-2, MSM-125-2 in 3 views. Row 2, p1, cervical vertebra MSM-359-2, dorsal vertebra MSM-441-2; p2, 3, 4, a pair of sacral vertebrae MSM-135-2; p5, 6, 7, caudal vertebrae MSM-41-2 and MSM-42-2 in lateral, posterior and ventral views; p8, caudal vertebra MSM-360-2; p9, trirays distal caudal centrum MSM-302-2. B, column 1, a femur (proximal and distal femur MSM-178-2 and MSM-182-2); column 2, proximal ulna/distal scapula MSM-573-2, proximal ulna MSM-271-2, and proximal ischium MSM-184-2; column 3, proximal tibial shaft cross sectional part MSM-850-2, mid-shaft cross sectional part MSM-559-2, humerus parts MSM-287-2, distal ulna MSM-852-2; column 4, proximal tibia MSM-181-2, partial proximal humerus MSM-363-2, distal humerus MSM-362-2; C, p1, anterolateral part of sternal MSM-565-2 and sternal part MSM-1004-2; p2, coracoid MSM-560-2; p3, distal part of cervical rib MSM-187-2; p4, distal dorsal rib MSM-301-2; p5, neural spine MSM-792-2; p6, distal rib/neural spine MSM-784-2; p7, subrow 1, proximal metacarpals MSM-295-2, MSM-279-2, MSM-685-2, MSM-566-2, MSM-278-2, MSM-686-2, MSM-1029-2, MSM-688-2; subrow 2, distal metacarpals MSM-277-2, MSM-1028-2, MSM-285-2, MSM-370-2, MSM-684-2, MSM-687-2, MSM-361-2, MSM-683-2; p8, metatarsal MSM-643-2 (upper), and metatarsals MSM-1031-2 and MSM-1030-2 (lower). Scale each black digit is 1 cm. For scale pl. See [10].

and sternal plate/partial ilia, proximal radius, proximal left tibia, proximal left femur, distal right and left tibia left distal femur, partial distal right scapula, a pair of left and right partial distal scapula, neural spine and diapophysis (**Figures 1-4**) and many specimens partially covered by brown muds stored in GSP museum. Previously the braincase MSM-62-19 was assigned to *Vitakridrinda* theropod and [1] included in *Gspsaurus* lectotype and now it is being added in the holotype of *Gspsaurus pakistani*. The skull, palatal and braincase along with postcranial skeleton were referred to *Marisaurus jeffi* [9] [10] [12] and later on skull is established as the holotype of *Gspsaurus pakistani* [17] [19] and the braincase and postcranial materials from Alam 19 were established as holotype (**Figure 4**) of *Maojandino alami* ([19]; pages 6 and 10). The holotypic braincase and associated postcranial skeleton (**Figure 4**) of *Maojandino alami* is being added here in the holotype of *Gspsaurus pakistani* due to following reason of association. Now all these materials (**Figures 1-4**) are established as holotype of *Gspsaurus pakistani*. The holotype of *Gspsaurus pakistani* is established due to close finding of skull on right place just below the skull position on in situ skeleton and size matching. Further *Gspsaurus pakistani* braincase and postcranial elements were mostly found as close with each other in a few meter as surface finds on host shale of Vitakri Formation and considered as associated due to consistent size and no duplcation, while some vertebrae were articulated as line forming along strike in the host shale at the time of collection. The field study show that these materials are associated [7] due to following reason. Some vertebrae are found aligned according to strike direction in about 10 m length and appendicular elements were some 3 m down slope. However, some vertebrae were little transported down slope. There is no any duplication from this site. The field evidence indicate all these materials are found in situ host formation and excavation can reveals remaining preserved assemblages. The nature of matrix, relative size and collection from one locality represents association and belongs to same adult animal. However a partial articulated skull [12] is found 50 meter downward apart from the axial and appendicular elements and relative size show one animal but the skull matrix is slightly different than braincase and postcranial materials ([10]; page 59).

The referred materials found from Top Kinwa 16 (**Figure 5**), Mari Bohri 15 (**Figure 6**), south Kinwa 4 (**Figure 7**), Rahi Wali 10 (**Figure 7**), Darwaza 8 (**Figure 7**) and mid Bor 2 (**Figure 8**) localities from Pakistan. A Caudal vertebra K20/317 and probably some limb bones (except scapulae which is referable to *Isisaurus colberti* due to more long articular surface for coracoids than *Gspsaurus*, braincase GSI K27/497 referable to *Pakisaurus balochistani* because of W-shaped holotypic basioccipital condyle of *Gspsaurus* from Pakistan) from Bara Simla of *Antarctosaurus septentrionalis* [4] which later on named as *Jainosaurus* (=*Antarctosaurus*) *septentrionalis* [38] due to *Antarctosaurus* specific to Argentina (South America), here being referred to *Gspsaurus pakistani* due to tall and ventrally reduced caudal vertebra. Further associated limb bones from Chota Simla India discovered by Matley in 1930 and reported as *Titanosaurus* by [5] and restudied and assigned to *Antarctosaurus* (*Jainosaurus*) *septentrionalis* by [39]. Here this Chota Simla associated left limb bones like left humerus (NHMUK R5932), left radius (NHMUK R5933), left femur (NHMUK 5903) left tibia (NHMUK 5903) left fibula (NHMUK R5903) and right forelimb bone like right humerus (NHMUK R5931) are being referred to *Gspsaurus pakistani* due to overlapping of key and typical biconvex lense shaped expanded proximal tibia (**Figure 4**) (**Figure 5**). The caudal vertebra NHMUK R16481 [39] is referred to *Pakisaurus balochistani* due to tall, almost straight sided and ventrally not reduced.

Reference [39] considered humerus as key element for the referral of Chota Simla material to *Jainosaurus* (=*Antarctosaurus*) *septentrionalis* based only two titanosaurs from Indo-Pakistan, While it is now confirmed by the discovery of 4 key or typical tibiae and also 4 typical caudal vertebrae, atleast three or four type of cranial materials and also diverse other elements revealing atleast 4 taxa of titanosaurs from Indo-Pakistan. Further the *Jainosaurus* (=*Antarctosaurus*) *septentrionalis* is based on braincase, vertebra and appendicular elements which also show dual affinity like the scapula with longer articular surface for coracoids resemble with Isisaurus scapula, and braincase is referable to Pakisaurus due to its D-shaped occipital condyle which is differentiated from W-shaped occipital condyle of *Gspsaurus* and *Saraikimasoom* stocky titanosaurs.

Overlap between the bones of the Chhota Simla skeleton and those of other Cretaceous Indian sauropod species are limited [39] but the present research revealed that the Chota Simla typical key element tibia has overlapping with tibiae of *Gspsaurus pakistani* from Pakistan. This is the reason the Chota Simla limb skeleton of [5] are being referred here to *Gspsaurus pakistani*.

Fortunately, the Chhota Simla material includes a humerus, which is a key element that differentiates *Jainosaurus septentrionalis* from the contemporaneous *Isisaurus colberti* [39] but the present research revealed that the two distinct types of humeri which can not be used for distinction of four taxa and present research further revealed key tibiae (**Figure 8**) that differentiates four recognized titanosaur taxa like *Isisaurus* (slender tibia with distal end transversely broad; **Figure 8**), *Pakisaurus* (slender tibia with distal end transversely more broad than *Isisaurus*; **Figure 8**), *Gspsaurus* (stocky tibia with convex lense shaped proximal tibia; **Figure 8**), and *Saraikimasoom* (more stockier tibia with subcircular proximal tibia with almost equidimensional anteroposterior and transverse widths; **Figure 8**). It is necessary to mention that there are only two types of humeri were reported from Indo-Pakistan, so they can not be considered key elements among four recognized titanosaur taxa.

In addition, the Chhota Simla material includes a caudal centrum, which overlaps with *Isisaurus colberti* [39] but this caudal centrum is being referred to *Pakisaurus balochistani* due to tall, flat sided and ventrally waisted. To qualify assignment of this Chota Simla skeleton to *Jainosaurus cf. septentrionalis* pending further resolution of these issues [39] and now this issue is resolved and overlapping of tibia and other materials with *Gspsaurus pakistani* holotypic and referred materials from Pakistan revealed their affinity to *Gspsaurus pakistani*.

The caudal vertebra NHMUK R16481 [39] is not part of Chota Simla skeleton and referred to *Pakisaurus balochistani* due to tall, almost straight sided and ventrally not reduced. It is necessary to mention that the caudal vertebrae especially squarish mid caudal with no ventral reduction are associated with slender flattened tibiae with broad anteroposteriorly distal tibia of *Isisaurus*, the tall mid caudal with no ventral reduction are associated with slender flattened tibiae with more broad anteroposteriorly distal tibia of *Pakisaurus*, while the caudal vertebrae especially slightly tall mid caudal with ventral reduction are associated with stocky convex lense shaped proximal tibiae of *Gspsaurus* and the caudal vertebrae especially broad mid caudal with ventral reduction are associated with more stockier subcircular and almost equidimensional transverse and anteroposterior widths of proximal tibiae of *Saraikimasoom*.

Gspsaurus pakistani skeleton from Top Kinwa 16 includes dorsal vertebrae, a pair of sacral vertebrae, caudal vertebrae, distal caudal vertebra, convex part of sternal, sternal part, a pair of left and right distal scapulae, a pair of left and right proximal ulnae, distal ulna, part of ilia, acetabulum, proximal stocky tibia, a pair of proximal fibulae, cervical ribs, neural spine, mosaic type osteoderms, and oval ungual or osteoderms or sacral vertebrae (**Figure 5**). This Top Kinwa exemplar skeleton (**Figure 5**) is referred to *Gspsaurus pakistani* due to some overlap of typical key tibia and some other holotypic postcranial elements of *Gspsaurus pakistani*. The non-overlapping portion of the Top Kinwa skeleton broadens the distribution and diagnosis of the species and its distinction from the other Cretaceous titanosaurs of Indo-Pakistan landmass.

Gspsaurus pakistani exemplar from Mari Bohri 15 (**Figure 6**) include caudal vertebrae (including first biconvex caudal), distalmost caudal special centrum, distal right scapula, proximal femur and distal femur, proximal pubis and distal pubis/ischium (**Figure 6**), all this material was found at the same time, same locality and same formation (with same size). *Marisaurus jeffi* was based on caudal vertebrae [9]. Later on the vertebral and postcranial skeleton (**Figure 6**) from Mari Bohri locality was considered as holotype [40] of *Marisaurus jeffi* because all these materials (**Figure 6**) found at the same time, same formation, same locality, same size and no duplication. *Gspsaurus pakistani* exemplar of Mari Bohri (**Figure 6**) overlap with its holotypic caudal vertebrae and also limb bones (**Figure 4**). So based on the morphology of holotypic and referred caudal vertebrae and limb bones as overlap and used the non-overlapping portion of the skeleton to broaden the diagnosis of the species and its distinction from the other Cretaceous titanosaurs of Indo-Pakistan landmass.

Gspsaurus pakistani referred fossils from south Kinwa 4 include atlas-axis complex, caudal vertebrae, distalmost caudal vertebra, mid scapula with ridge, partial femur, anterior chevron, and large oval ungual. Here *Gspsaurus pakistani* exemplar of South Kinwa 4 (**Figure 7**) overlap with the caudal vertebrae of holotypic and referred vertebrae of *Gspsaurus pakistani*. So based on the morphology of holotypic and referred caudal vertebrae as overlap and used the non-overlapping portion of the skeleton to broaden the diagnosis of the species and its distinction from the other Cretaceous titanosaurs of Indo-Pakistan landmass. *Gspsaurus pakistani* also referred proximal humerus (**Figure 7**) from Rahi Wali 10 due to distinct medial head from the humerus of other taxa from Indo-Pakistan, and caudal vertebra (due to tall and ventral reduction) (**Figure 7**) from Darwaza 8 localities of north western limb of Dhaola Gambrak range.

Gspsaurus pakistani referred fossils (**Figure 8**) from mid-Bor 2 locality were collected about 300m southward from main Bor stream in the central Bor stream. Here *Gspsaurus pakistani* exemplar of mid Bor overlap with the cervical, dorsal, sacral and caudal vertebrae, femur, distal stocky tibia. In this site collection there are a few problems for assignment. First a few bones of upper Bor 2 site which is found about 100 - 200 m eastward from mid Bor 2 site are included here in the mid Bor 2 collections. It may be possible the femur or tibia or a few bones may be found from upper Bor 2 site. The vertebral series of mid Bor 2 site show a partial skeleton of *Gspsaurus* or *Saraikimasoom*. This skeleton affinity to either *Gspsaurus* or *Saraikimasoom* is pending for further vertebral studies. Secondly the key stocky tibia shows affinity to *Gspsaurus* and the key one or two mid caudals show affinity to *Saraikimasoom*. So the resolution of affinity of bones from mid Bor is pending for further studies. Here provisionally the mid Bor materials referred to *Gspsaurus pakistani* due to typical tibia. The holotypic and referred specimens are housed in the Museum of the Geological Survey of Pakistan, Quetta.

Geological horizon and age: The fossils of *Gspsaurus pakistani* found from the latest Maastrichtian (68 - 66 Mya/Million years ago) Vitakri Formation sediments [41] [42] from Pakistan and Lameta Formation sediments from India [7], proving India and Indus basin of Pakistan were the mosaic during the Late Cretaceous, however the Balochistan basin, Kohistan-Ladakh arc were the part of Tethys and Hindukush-Karakoram were the part of Asia.

Etymology: The genus *Gspsaurus* honors the Geological Survey of Pakistan (GSP). The Species name *Gspsaurus pakistani* honors the country of origin Pakistan [17] [19]. The pronunciation of *Gspsaurus* is G.S.P.saurus.

2.1. Diagnosis of *Gspsaurus pakistani*

Gspsaurus pakistani a medium sized and stocky sauropod dinosaur sharing with the Titanosauria as vertebrae lacking hyposphene-hypantrum articulations, procoelous caudals (except first biconvex caudal), forward insertion of neural arches on caudals, and prominent olecranon process on ulna. *Gspsaurus pakistani* a medium sized and stocky sauropod dinosaur sharing with the Poripuchia [31] [42] as the distal and also distalmost caudals are procoelous besides the anterior and middle procoelous caudals which is the character of Lithostrotian. The Poripuchia is the most inclusive clade of Titanosauria containing all caudal procoelous (except first biconvex caudal in some taxa). The Poripuchia is the most inclusive clade of Titanosauria containing *Pakisaurus* and *Isisaurus* pakisaurids, and *Gspsaurus* and *Saraikimasoom* gspsaurids titanosaurs. Poripuch is the Saraiki language word means full tail (with procoelous vertebrae).

Gspsauridae definition or main characters based on genus and species *Gspsaurus pakistani*. However Gspsauridae major differentiation characters from Pakisauridae are as U-shaped anterior upper jaw profile, anterior dentary rounded (no chin forming), highly vascularised and pneumatic rostrum and dentaries bones, broad reversed V-shaped ventral palatal processes laterally attached to upper maxillary ramus or upper jaw ramus, while dorsally attached to dorsal palatal process junction, V-shaped dorsal palatal hook attached on the contact of maxilla and premaxilla on both sides, slender and circular to slightly oval teeth with slender indices 3 - 5; conical and pointed teeth converge and taper on all sides from base toward tip (opposite of pakisaurids teeth which have almost same thickness except tip); ratio of mid transverse width above and below of mid caudal centrum varies from 1 to 2, the ventral view of mid caudal centra are strongly compressed, stocky tibia; proximal view of proximal stocky tibia circular to oval shaped (as opposite in Pakisauridae the flattened shaped proximal tibia), distal tibia is transversely more wide than anteroposteriorly width or distal tibia is anteroposteriorly less wide than transverse width (as opposite in Pakisauridae distal tibia is anteroposteriorly more wide than transverse width).

Gspsaurinae definition and main features based on genus and species *Gspsaurus pakistani*. Gspsaurinae the most inclusive clade of Titanosauria containing *Gspsaurus pakistani* but not *Saraikimasoom vitakri*. Gspsaurinae major differentiation features from Saraikimasoominae are as V shaped anterior dentaries symphyses profile or V shaped anterior junction of dentary rami (as opposite, Saraikimasoominae have broad U-shaped anterior junction of dentary ram), dentary symphysis, orientation, angled 15˚ or more anteriorly to axis of jaw ramus (as opposite, Saraikimasoominae have dentary symphysis, orientation, vertical or perpendicular to axis of jaw ramus), relatively large sized skull (as opposite, Saraikimasoominae have relatively small sized skull), relatively large, more slender, recurved conical, circular to slightly oval teeth (as opposite, Saraikimasoominae have relatively robust, small, slightly recurved conical, and circular to slightly oval teeth), Relatively large size (in thickness, width and length) dentary rami (as opposite, Saraikimasoominae have relatively small size dentary rami), ventral view of mid caudal centra compressed, mid caudal centra with the ratio of mid transverse width above and below varies from 1 to 1.5 (Saraikimasoominae have significantly reduced ventral view of mid caudal centra, mid caudal centra with the ratio of mid transverse width above and below varies from 1.5 to 2), and relatively large sized stocky tibia.

Gspsaurus pakistani autapomorphies are as small sized spongy skull (but larger than *Saraikimasoom*). Teeth are circular to subcircular, slender, slightly recurved and conical like-the thickness of diameter decreases gradually from base to tip (while the *Pakisaurus* and *Rapetosaurus* have teeth with almost constant thickness from base to tip but except tip). Teeth are longer than *Saraikimasoom* teeth. Teeth slender indices vary from 3 - 5 (while *Pakisaurus* and *Ra-*

petosaurus teeth have Slender Indices more than 5). Some teeth are cone blunted showing wear facet, some teeth tips are rounded and a few have pointed tip. Palatal shelf process is deep and has about 45˚ limb inclination (while *Saraikimasoom* have shallow inclination upto 25˚). Palatal shelf between the ventral palatal process and dorsal hook process form left and right maxillary canals. Dorsal palatal processes formed hook with its limbs contacted on the suture of maxilla and premaxilla. Dorsal hook limb processes form reverse triangular premaxillary canal. Broad U shaped upper teeth row and V shaped lower teeth row (while *Saraikimasoom* have both lower and upper jaws as U-shaped teeth rows). Reversed gentle V-shaped ventral palatal processes with expanded rectangle shaped distal ends which are contacted with the maxilla. V-shaped small dorsal palatal processes or hook limb attached on the suture of maxilla and premaxilla. Dentary have long anteroposteriorly symphysis (while dentary with narrow anteroposteriorly symphysis found in *Saraikimasoom*). Anterior dentary is rounded and has no chin. Dentary symphysis is an extension of dentary ramus in the almost same direction (while it is perpendicular to dentary ramus axis in *Saraikimasoom*). Dentary ramus anterior depth is slightly less than mid length (while *Saraikimasoom* have anterior dentary with slightly more depth than mid dentary). Dentary with long anteroposteriorly symphysis is angled 15˚ or more anteriorly to axis of jaw ramus (while *Saraikimasoom* have high angle anterior profile of dentary symphysis). Large braincase with subrectangle shaped occipital condyle with sagital dorsoventral prominent groove (while *Saraikimasoom* have relatively small braincase with feeble sagital groove, *Pakisaurus* and probably *Isisaurus* have D-shaped occipital condyle). First caudal is biconvex and broad with relatively less long than *Saraikimasoom*. Caudals especially mid caudals are slightly ventrally reduced upto ratio 1.5 (while *Pakisaurus* and *Isisaurus* have not ventrally reduced caudals, however in *Saraikimasoom* ventral reduction is prominent and ratio vary from 1.5 to 2). Trirays robust procoelous distalmost caudal (while *Saraikimasoom* have relatively less robust trirays procoelous distalmost caudal, *Pakisaurus* have horizontal groove in the mid of distalmost caudal). Distal scapula is quite expanded transversely than the distal scapula of *Saraikimasoom*, *Pakisaurus* and *Isisaurus*. Acetabulum has anteroposteriorly elongated fibrous structures. Acetabulum has D-shaped thick and long condyle or peduncle for pubis and relatively small and thin condyle or peduncle for pubis. Rectangle or subrectangle shaped cross section of shaft just below the femur head with transversely long and anteroposteriorly relatively less broad than *Saraikimasoom* (while the *Saraikimasoom* have more robust rectangle shaped cross section with thicker anteroposteriorly). Transversely thick biconvex lense shaped proximal tibia which anteroposterior width is slightly more than transverse width (while *Saraikimasoom* have subsquare shaped proximal tibia with equal transverse and anteroposterior widths, *Pakisaurus* and *Isisaurus* have flattened and transversely compressed proximal tibia). Distal tibia is transversely quite thick and quite expanded than *Pakisaurus* and *Isisaurus* (while *Pakisaurus* and *Isisaurus* have anteroposteriorly broad distal tibiae). The expanding nature of tibia shows close articulation with fibula (while relatively far articulation found in fibula and tibia when articulated). Proximal fibula orientation shifted the trend of proximal fibula from anteroposterior to almost mediolateral due to transversely expanded fibular condyle of proximal tibia (instead of anteroposterior or anteromedial to posterolateral orientation as in *Pakisaurus* and *Isisaurus*) when articulated with proximal tibia. Two types of armour bones and osteoderms are found, the first small rectangular mosaic type is relatively thin plate (*Saraikimasoom* have more thick armour mosaic plate) and secondly the large oval ellipsoidal plate with median cut or groove like *Malawisaurus* (while *Saraikimasoom* have ellipsoidal subcircular plate without median groove or cut).

2.2. Description of Fossils of *Gspsaurus pakistani*

Holotypic specimens MSM-79-19 consists of articulated upper and lower jaws with teeth, palatal processes, left quadrate, partial quadratojugal, possibly lowermost portion of squamosal, mandible rami and teeth while MSM-80-19 shows palatal bones like posterior vomerine, fused palatine and pterygoid (Figure 1, Figure 2) The exposed part of skull and dentary are pneumatic. The skull has mid line contact. The right premaxillary and right maxillary teeth are cemented on the anterior and lateral side of right dentary ramus. Left dentary ramus is covered by quadrate, quadratojugal, possible squamosal and matrix. Dentary symphysis seems to be strong, cover more distance from ventral to anterodorsally at articulation. The available dentary ramus shows length 12 cm, depth 4.5 - 5 cm and width (with splenial) 1.8 cm. The anteroventral marginal shape of dentary is gently rounded. Dentary symphysis is almost V shaped or anterior view of tooth row of dentary is V-shaped. Palatine lateral ramus is rod shaped and has narrow maxillary contact. The palatal process is reverse V shape which is hanged/hooked by small V shape dorsal palatal process. The ventral palatal processes are also bifurcated. The maximum thickness of palatal process is 8mm and width is about 2 cm. Maxilla has 1.5 cm thick alveolus ramus and the upper/dorsal portion which is about 0.5 cm thick. Preserved quadrate plate is about 1 cm thick and 10 cm long and 7 cm wide. On the dorsal of quadrate seems to be partial squamosal which is also about 1 cm thick. Quadratojugal is thick about 1 - 2.5 cm and dorsal process rotate at an angle of about 40 - 50 degree from anterior process of quadratojugal.

Rostrum and Skull: Holotypic partial snout and partial skull (MSM-79-19; Figure 1, Figure 2), central cranial palatal part (MSM-80-19; Figure 1, Figure 2) and braincase (MSM-82-19; Figure 3). The partial snout and partial skull (MSM-79-19; Figure 1, Figure 2) consists of articulated both fellow of premaxilla, maxilla (upper and lower jaws) with teeth, palatal ventral and dorsal processes, left quadrate, partial quadratojugal, possibly lowermost portion of squamosal, mandible rami and teeth. The central cranial palatal part (MSM-80-19; Figure 1, Figure 2) includes palatal bones like posterior vomerine, fused palatine and pterygoid (Figure 1) (Figure 2). The braincase (MSM-82-19; Figure 3) includes paraoccipital processes, basipterygoid/basisphenoid processes, foramen magnum and surrounding areas, and occipital condyle (**Figure 3**). These palatal elements and braincase are found just close to rostrum specimen [12]. The Alam locality has produced the associated materials of *Gspsaurus pakistani* including partial skull, braincase, cervical, dorsal and caudal vertebrae along with partial left femur, partial left and right tibiae, and partial radius, a pair of partial distal scapulae, partial ilium or sternal plate, etc. The field study show that these materials are associated due to following reason. Although fragmentary and disarticulated but it is associated because all of these material is found within one site of same locality and same horizon and same formation. Some vertebrae are found aligned according to strike direction in about 10 m length and appendicular elements were some 3 m down slope. However, some vertebrae were little transported down slope. There is no any duplication from this site. The field evidence indicate all these materials are found in situ host formation and excavation can reveals remaining preserved assemblages. The nature of matrix, relative size and collection from one locality represents association and belongs to same adult animal. However partial articulated skull specimens (MSM-79-19; MSM-80-19) are found 50 meter apart from the braincase, vertebrae and appendicular elements and relative size show one animal but their matrix is slightly different [9]. The anterior skull is compressed. This compressed horizontal width is 7 cm while in original it may be twice.

The premaxilla is a strip or belt like element with about 3 cm transverse width. The both fellow of premaxillary ascending process are preserved from anterior to preserved cross section. At cross section the premaxilla thickness increases from lateral to mid contact approaching 2 cm dorsoventral thickness measured at preserved cross section. The premaxilla formed a well developed contact with maxilla. The fellow of premaxilla meets with each other at mid line contact. At midline contact it forms a slight elevated, anteroposteriorly trending narrow ridge. The shape of premaxilla anterior margin seems to be without step. There are 4 premaxillary teeth. The right premaxillary teeth covering the anterior and anterolateral end of right dentary ramus. The lengths of premaxillary teeth vary from 1cm to 1.8 cm, width varies from 0.4 cm to 0.6 cm. Premaxillary tooth crowns apex are slightly curved toward lingual side and mid crowns convexing slightly towards labial side while the maxillary teeth convexing are parallel to premaxillary teeth *i.e.* the central or mid crown convexing towards anterior and upper crown are curved towards posterior/backward. One or two maxillary teeth are pointed while other two are blunted at tip showing wear facet. The premaxillary both fellows articulated with the dorsal maxillary process. The shape of anterior portions of premaxillary and maxillary tooth rows is slightly broad forming U-shape (**Figure 1**). The external naris seems to be retracted backward. The both fellow of premaxilla are unique gift and anatomical wealth of the most derived poripuch titanosaurs because so far most derived titanosaur lacks articulated skull elements except *Gspsaurus* and *Saraikimasoom*, while *Rapetosaurus* has fragmentary skull elements and also lack premaxilla. Most of the teeth are conical which means tapering gradually from base to tip. Teeth cross-sections vary from circular to sub circular.

The Maxilla is well exposed anteriorly (**Figure 1**) and on cross sectional view. It is triangular in shape. However no two major parts, the ventral and dorsal processes, is not started because there is no observed antorbital fenestra upto preserved rostrum. Maxilla has 1.5 cm thick alveolus ramus and the upper/dorsal portion which is about 0.5 cm thick. The maxilla has smooth and same thickness except the ventral ramus which is twice thick, rod shaped and also teeth bearing. There are two major parts, a horizontal tooth bearing lateral/posteroventral process and a prominent dorsal ascending process. The maxillary teeth are relatively more spaced and large than premaxillary teeth. The upper jaw teeth cover the right dentary ramus. The maxillary teeth are relatively more spaced than the maxillary teeth of *Saraikimasoom*. The preserved maxillary teeth are about 5 or 6. Most of the teeth are narrow and tapering gradually from base to tip. The teeth tapering from base to tip (except tip) while this gradual tapering is not observed in *Rapetosaurus*, *Pakisaurus* and *Nemegtosaurus*. Teeth cross-sections vary from circular to subcircular/sub elliptical/suboval. The first maxillary tooth length is 2.8 cm and width is 0.7 - 0.8 cm. Other tooth at a distance of about 2 cm (from first maxillary tooth) is again long and thick like first maxillary tooth. The anterior maxillary teeth show maximum length while premaxillary is relatively small and posterior maxillary teeth may be more relatively small. The premaxillary teeth are closely oriented and contacted with each other. The spacing between teeth is increasing toward posterior/back. Maxillary teeth are articulated with maxilla. However spacing between teeth is increasing toward posterior/back. Premaxillary tooth crowns apex is slightly curved toward lingual side. Some teeth are pointed and cone forming and some are blunted or having wear facet. Pulp cavity of 3 fragmentary teeth found in matrix associated with skull measured at base as 0.3 cm, 0.4 cm, and 0.7 cm maximum diameter on the basal part of crown, with total teeth thickness 0.7 cm, 0.8 cm, 0.9 cm and width 0.8 cm, 0.9 cm, 1.0 cm respectively. This shows slight oval nature of teeth. Further teeth thickness and width is maximum at the base and decreasing upward (toward tip). This property help to refer the *Titanosaurus rahioliensis* tooth to *Pakisaurus balochistani* which closely match to *Rapetosaurus krausei*. A tooth slenderness index is about 4. Teeth are long, narrow, slender, circular to slightly oval and slightly recurved (**Figure 1**, **Figure 2**).

The Palatal processes are divided into ventral and dorsal palatal processes. The dorsal palatal processes can be also called hook which are bifurcated forming cavity and left or right limb connected with the premaxillary-maxillary contact. The palatal process is reverse V shape which is hanged/hooked by small V shape dorsal palatal process. The ventral palatal processes are also bifurcated. The dorsal palatal processes form a V-shaped hook type bone which support ventral palatal process or pterygoid. The ventral palatal processes form reverse V shaped and trended towards lower portion of maxilla with general 45˚. The left and right palatal processes of ventral and dorsal palatal processes are mirror images with each other but tilted due to overall tilting of rostrum. The dorsal and ventral processes are convergent only in the median part. On dorsal aspects each fellow of dorsal palatal process contacted at the respective suture of maxilla and premaxilla. The dorsal palatal processes converged ventrally at mid portion of rostrum. At this junction the ventral palatal processes also converge to form a double junction. From this double junction the left and right lateral processes of ventral palatal started diverging and meet at respective maxilla. The ventral palatal processes form broad and reversed V-shape mehrab (arc convexing dorsally). The ventral most part of palatal is forming vaulted and dorsally convexing arc. Pterygoid flange is more than 4 cm wide, and thickness is about 1 cm. The wing of pterygoid contacts opposite elements in broadsheet. Pterygoids flanges meet with each other at gentle angle from horizontal. Palatal shelf on maxilla between the ventral palatal process and dorsal palatal process forms maxillary canals-left and right maxillary canals. Palatal shelf just below the left and right premaxillae and above the dorsal palatal processes forms one premaxillary canal. The premaxillary canal is dorsally enclosed by both fellow of premaxillae and ventrally and laterally enclosed by dorsal palatal processes. Premaxillary canal is reverse triangular and high angled V-shaped (**Figure 1**, **Figure 2**).

The palatine, lateral ramus shape is oval-shaped (narrow maxillary contact). The dorsal palatal hook formed tight V shaped, the angle is high. The left and right limb of dorsal palatal joined at the junction of premaxilla and maxilla contact. The hook limb thickness increases toward contact of junction of maxilla and premaxilla. Ventrally this dorsal palatal hook thickness decreases at the ventral curvature. The lower apex of curvature forms contact with ventral palatal process. Palatine lateral ramus is oval shaped and has narrow maxillary contact. The maximum thickness of vomerine palate is 0.8 cm and width is about 2 cm on one side, it is compressed laterally/transversely. The posterior width (possible) of vomer is 1.5 cm and maximum thickness is 0.6 cm. Palatine and ectopterygoid seem to be fused. The maximum horizontal transverse width from right to left tip of palatine and ectopterygoid is about 9 cm.

Preserved quadrate plate is about 1cm thick and 10 cm long and 7 cm wide. On the dorsal of quadrate seems to be partial squamosal which is also about 1 cm thick. The place for posterior fossa of quadrate is covered by matrix. Quadrate plate is slanting to downward and forward. Laterally it is articulated with quadratojugal. Quadrate fossa, depth seems to be shallow. The preserved quadratojugal is thick about 1 - 2.5 cm and dorsal process rotate at an angle of about 40 - 50 degree from anterior process of quadratojugal. The ventral surface is smooth. The anterior process length of quadratojugal seems to be long.

Dentary is preserved in articulation with the upper jaw. Left dentary ramus is covered by quadrate, quadratojugal, possible squamosal and matrix. Dentary teeth are not exposed and covered by anterior upper jaws. Dentary symphysis cover more distance anteroposteriorly (from posteroventral to anterodorsally) at articulation. The available dentary ramus shows length 12 cm, depth 4.5 - 5 cm and width (with splenial) 1.8 cm. The anteroventral marginal shape of dentary is long and gently rounded. Dentary symphysis is almost V shaped or anterior view of tooth row of dentary is almost V-shaped. This V-shaped dentary symphysis or lower jaw V-shaped teeth row of *Gspsaurus pakistani* is differentiated from the U-shaped dentary symphysis or lower jaw U-shaped teeth row of *Saraikimasoom vitakri*.

Gspsaurus have robust dentaries that are dorsoventrally expanded posteriorly and anteriorly like *Rapetosaurus* [43], *Nemegtosaurus* (ZPALMgD-I/9 [44]), *Quaesitosaurus* (PIN 3906/2 [45]), *Malawisaurus* (SMU MAL 174 [46]), and *Ampelosaurus* MD-E C3-336 [47]) and unlike the dentary of *Saraikimasoom* (MSM-142-4 [23]) which has shallow, thin, small and slender dentary. In each of these taxa (as well as in *Brachiosaurus* and *Camarasaurus*), minimum tooth counts range from 9 (*Ampelosaurus* MD-E C3-336 [47]) to 15 (*Malawisaurus* [46]) and 17 teeth count in *Saraikimasoom* [17]. *Gspsaurus* have V shaped anterior margin of dentaries symphysis while all of these taxa exhibit a gently curving dentary that meets in a broad, U-shaped symphyseal region. Similarly, in all alveoli are present along 60% - 80% of the dorsal margin of the dentary but it is not clear in *Gspsaurus* due to posterior dentary destroyed but expected like *Saraikimasoom* and *Rapetosaurus*. The restriction of the alveoli to the anterior 2/3 of the dentary also distinguishes *Rapetosaurus* and other titanosaurs from diplodocoid taxa in which the tooth row is restricted to the anterior one-third of the dentary.

The teeth of *Gspsaurus* are long and conical (conical means tapering gradually from base to tip), some rounded and blunted tip and some sharp pointed tip teeth. Tooth Slenderness Indices (length of crown divided by maximum mesiodistal width [48]) in *Gspsaurus* vary from 3 - 5, while this ratio exceed 5.0 in other titanosaurs including *Rapetosaurus* [43], *Ampelosaurus* [47], *Malawisaurus* [46], *Nemegtosaurus* [44] and *Quaesitosaurus* [45]). Tooth crowns, cross-sectional shape at midcrown are cylindrical to slightly oval.

Three types of teeth of titanosaurian sauropods are reported from Indo-Pakistan. The first type of circular to subcircular medium to large teeth [49] (5 Slenderness Indices) with almost constant thickness and diameter except tip may belong to *Pakisaurus balochistani*. The second type of circular to subcircular, medium to large teeth (3 - 5 Slender Indices) with gradually decreasing thickness/diameter from base to tip may belong to *Gspsaurus pakistani* and presented here. The third type of circular to subcircular, small teeth (3 - 4 Slender Indices commonly but rarely upto 5) with gradually decreasing thickness/diameter from base to tip may belong to *Saraikimasoom vitakri* [17].

Pterygoids have only been described for three titanosaurs: *Nemegtosaurus* [44], *Quaesitosaurus* [45] and *Rapetosaurus* [43]. All three share platelike pterygoids, with processes that radiate in the same plane. *Gspsaurus* (like *Rapetosaurus*) pterygoids meet at an angle of about 45˚, in contrast to the 25˚ convergence in *Saraikimasoom* and *Nemegtosaurus*. *Gspsaurus* and *Saraikimasoom* have pterygoid hook while the *Rapetosaurus* [43], *Nemegtosaurus* [44], *Quaesitosaurus* [45], and *Brachiosaurus* [50] are represented by lack or absence of a pterygoid hook. Among titanosaurian sauropods, *Saraikimasoom* (MSM-42-4

[23]) and *Gspsaurus* (MSM-79-19, MSM-80-19) uniquely share the dorsal palatal process (=pterygoid hook) and provide the unique structures at the posterior cross sectional view.

Braincase: The holotypic braincase MSM-62-19 (**Figure 3**) with basioccipital condyle and posterior most part of braincase shows decurved and much taller paroccipital processes match with titanosaur braincase (Mickey Mortimer, personal communication in 2012). The matrix of its braincase and basioccipital resemble with the matrix of holotypic materials of *Maojandino alami* titanosaur which is found few meters upward [19] represent its association as holotypic skeleton of *Maojandino alami* (**Figure 4**). This holotypic cranial braincase and associated postcranial skeleton of *Maojandino alami* (**Figure 4**) found from Alam 19 (19c) is being added here in the holotype of *Gspsaurus pakistani*. Now *Gspsaurus pakistani* have holotypic cranial and postcranial skeleton (**Figures 1-4**). This cranial and postcranial materials found from Alam 19 is considered associated due to finding on one site, on host shale of Vitakri Formation, with same fit size and no duplication. *Gspsaurus pakistani* braincase having high angle basal tubera do not matches with Indian titanosaurs but matches with high angle basal tubera of *Rapetosaurus* titanosaur from Madagascar. The *Gspsaurus pakistani* atlas breadth of anterior concavity is 7 cm (**Figure 7**) which is best fit to *Gspsaurus* braincase, this again confirm the assignment of braincase to *Gspsaurus pakistani* titanosaur. The *Gspsaurus pakistani* braincase size is almost same as Indian titanosaur *Antarctosaurus septentrionalis* braincase [4]. But the *Gspsaurus pakistani* braincase size is larger than *Saraikimasoom* vitakri braincase and also other three braincase from India. Further small sized braincase is justified for *Saraikimasoom vitakri* a small sized stocky titanosaur while large sized braincase is best fit to *Gspsaurus pakistani* a medium bodied stocky titanosaur. The ventrodorsally elongated foramen magnum is similar to *Saraikimasoom* braincase showing titanosaurian affinity. The *Gspsaurus pakistani* braincase have indistinguishable contact of each its part showing maturity of animal which also tele with the skull, vertebral and limb elements. The braincase recurved paraoccipital process also assign it to titanosaur. Basal tubera, breadth is narrower than occipital condyle. Basal tubera have high angle. The paroccipital processes oriented transversely and recurved downward. Anterior view of preserved braincase shows paroccipital process going to be down on the edges. The occipital condyle maximum transverse width at posterior is 6.5 cm, maximum dorsoventral height at posterior is 4.5 cm and its possible anteroposterior length seems to be 6 - 8 cm. The quadrangle shaped occipital condyles, median cut on dorsal and ventral views of occipital condyles forming W-shaped lower and reverse W-shaped upper views, the lateral side of occipital condyle is generally straight and not convex (unlike other Indian titanosaur braincases). The foramen magnum is 1 cm transverse wide and 1.5 cm ventrodorsal wide, measured by anterior view. The foramen magnum is generally oval shaped elongated ventrodorsally. The general oval shape and elongated dorsoventrally closely resemble to *Saraikimasoom* braincase and also braincases from India. The foramen magnum is laterally covered by thin wall bones. Braincase is relatively large size with high and recurved paraoccipital process. The right paraoccipital process is 5.5 cm and left paraoccipital process is well preserved about 3 cm and remaining 2.5 cm littlely preserved. The ventrodorsal width of paraoccipital process is 3 cm. The basal tubera is 3.5 cm long dorsoventrally. The basal tubera processes/rami are close to each other forming high angles from the vertical line resulting reverse close V-shape. The basal tubera have very high angle than any Indian titanosaur braincases and also theropods. The high angle of basal tubera of *Gspsaurus* braincase is more similar to *Rapetosaurus* but basioccipital condyle characters are different from *Rapetosaurus*. The occipital condyle is quadrangular and not D-shaped of Indian braincases. The occipital condyle is sagitally constricted and have groove while Indian braincases are not constricted. The ventral part is not convexed ventrally but has a median groove creating W-shaped profile in lower part. In this way the dorsal part is also forming mid concavity forming reverse W-shaped profile. The ventral part is not curved ventrally while Indian braincases have D-shaped convexities in the ventral part. Further a concavity in the mid of ventral view creating W-shaped profile in lower part, resemble slightly with S*araikimasoom* braincase. Further a concavity in the mid of ventral view creating W-shaped profile in lower part of *Gspsaurus* braincase, differ totally from all Indian braincases of titanosaurs. The concavity in the mid of ventral view creating W-shaped profile in lower part of *Gspsaurus* braincase (medium sized stocky titanosaur from Indo-Pakistan landmass), slightly feebly resemble with *Saraikimasoom* braincase (the small sized stocky titanosaurs from Indo-Pakistan). So *Jainosaurus* braincase is totally different than Pakistani medium sized stocky *Gspsaurus* titanosaurs and also small sized stocky *Saraikimasoom* titanosaurs. It may be possible and also expected that the *Jainosaurus* braincase may belong to slender and medium to large sized *Isisaurus* titanosaurs or *Pakisaurus* titanosaurs. *Isisaurus* and *Pakisaurus* are differentiated two genera of slender titanosaur pakisaurids family. The *Isisaurus* have square shaped mid caudals like *Sulaimanisaurus*, while *Pakisaurus* have tall midcaudals like *Titanosaurus indicus*. *Isisaurus* midcaudals cannot be similar to *Marisaurus* because *Marisaurus* mid-caudals are very heavy, large and also the mid caudal ratio is more than 1. But *Isisaurus* have relatively light, small and also mid-caudal ratio about 1. There may be 3 or 4 midcaudals of *Isisaurus* equal to 1 *Marisaurus* mid-caudals.

Vertebrae

The *Gspsaurus pakistani* is represented by atlas-axis, cervical, dorsal and caudal vertebrae. Some major characters are as below. Presacral bone texture spongy, with large open internal cells or camellate; Presacral centra, pleurocoels present; Atlantal intercentrum, occipital facet shape, expanded anteroventrally in lateral view, anteroposterior length of dorsal aspect shorter than that of ventral aspect; Axis centrum shape less than twice as long as tall; Cervical vertebrae, parapophyses shape and orientation well developed broad, and ventrally projected such that the cervical ribs are displayed ventrally; cervical ventral surface flat; Cervical centra midline keel absent; Cervical neural arch lamination may be well developed, with well defined laminae and coels; Cervical centra, articular face morphology opisthocoelous; Cervical pleurocoels, shape simple and undivided; Anterior cervical centra, height:width ratio less than 1; Mid-cervical centra, anteroposterior length/height of posterior face, 2.5 - 3.0; All neural spines are single (not bifid); Anterior dorsal centra, articular face shape opisthocoelous; Posterior dorsal centra, articular face shape opisthocoelous; Posterior dorsal neural arches, hyposphene-hypantrum articulations absent; Dorsal ribs, proximal pneumatocoels, present; anterior dorsal ribs, cross-sectional shape, plank-like, anteroposterior breadth more than three times mediolateral breadth; First caudal centrum, biconvex; Anterior caudal centra (excluding the first), articular face shape, procoelous which is the feature of Poripuchia because lithostrotian have procoelous anterior and mid caudals; First caudal centrum anterior articular surface is convex; First caudal centrum posterior articular surface is convex; Anterior caudal centra, length, approximately the same; Anterior caudal transverse processes, proximal depth, deep, extending from centrum to neural arch; Anterior caudal transverse processes, shape: triangular to oval; Anterior caudal centra, pneumatopores (pleurocoels) absent; Anterior and middle caudal centra, shape, quadrangular, heavy, ventrally waisted and have hollow or groove and both lateral sides converge downward; Anterior and middle caudal centra, ventral longitudinal hollow, present; Middle and posterior caudal centra, anterior articular face shape, procoelous; Posterior caudal centra, shape: cylindrical and ventrally waisted; Distalmost caudal centra, anterior articular concavity like procoelous and posteriorly trispinous; Chevron simple; Chevrons, "crus" bridging dorsal margin of haemal canal, absent.

Articulated atlas-axis complex: Articulated and fused atlas-axis complex MSM-82-4 (**Figure 7**) was found [11] which belongs to adult animal. Its neural arches and ribs are mostly damaged. Atlantal intercentrum and axial posterior articular surface are partially damaged. The assignment of present atlas-axis complex to *Gspsaurus pakistani* Titanosauria is based on the overlap of vertebrae and limb bones from South Kinwa locality and the atlas-axis broadness and other features resembling to *Gspsaurus pakistani* lectotype cervicals. The anterior cervical vertebrae of *Gspsaurus pakistani* show the parapophysis position on the posterior half of centrum, which matches with the present axis. The Camellate bone texture is found in cervical vertebrate of *Gspsaurus pakistani*, and the present axis. The cervical centra of *Gspsaurus pakistani* correlate with the present axis on their more broadness. Further from the Kinwa locality, the atlas-axis complex is found associated with some midcaudal vertebrae of *Gspsaurus pakistani*. Further the proportions of axis matches with the anterior cervical vertebrae. In this way the present atlas-axis complex is being referred to *Gspsaurus pakistani*. This articulated atlas-axis of *Gspsaurus* stocky titanosaur is the first from globe.

Atlantal intercentrum has a well-developed concavity for basioccipital condyle and also fit to large basioccipital condyle and large braincase. Lateral facet shape of atlantal intercentrum is not rectangular but expanded anteroventrally *i.e.* the anteroposterior length of ventral aspect is greater than that of dorsal aspect (**Figure 7**). Dorsal and lateral aspects have a cleavage (with dorsoventrally cleavage line) in the centre (**Figure 7**) foramen/internality which split the atlas into two parts. Atlantal intercentrum anteroposterior thickness is low *i.e.* 2.5 to 3 cm on the dorsal surface, and wider *i.e.* 4 cm in the ventral surface. The preserved concavity for basioccipital condyle is about 7 - 7.5 cm in transverse and 6.5 cm in dorsoventral aspect. This broad concavity is fit its large sized braincase MSM-62-19 with large occipital condyle (**Figure 7**). The basioccipital condyle maximum transverse width at posterior is 6.5 cm, and maximum dorsoventral height at posterior is 4.5 cm. There is also a sufficient room for rotation of skull. The lower part of anterior face is slightly expanded forward which creates the more thickness than the dorsal view. The Atlantal intercentrum is slightly broad than tall. It is non-camellate.

Atlantal pleurocentrum is located between the atlantal facet and the neural arch. It is also located between the atlantal intercentrum and axial intercentrum. It is covered on dorsally and laterally by matrix, anteriorly by atlantal intercentrum, posteriorly by axial pleurocentrum, and ventrally by axial intercentrum (**Figure 7**). It may be a remnant of the odontoid process. Atlas neural arch of left side is preserved and tentatively both are drawn (**Figure 7**). The both parapophyses are located on ventral aspects of atlas. The ribs started from parapophyses and extended posteriorly below the axis. The ribs of atlas (Atlantal Rib) are simple strip or belt type. This rib is single headed and pneumatic (**Figure 7**). In the case of atlantal pneumaticity, ribs have camellate pneumatic internal texture (**Figure 7**).

Axial ***intercentrum*** is fused with the axial pleurocentrum (**Figure 7**). Further it is anteriorly articulated with the lower part of posterior face of atlantal intercentrum. Ventrally it is partially exposed due to erosion or damage of atlantal ribs. The lower part of lateral arc is located forward or ahead relative to upper part. Compositely the lateral view of anterior articular surface and axial intercentrum form an arc, the lower part of which is located forward. The steep slope is found on the upper side and gentle slope in the lower side of this lateral arc. The ventral part of intercentrum is nearly smooth and flat. The axis centrum (Axial Pleurocentrum) (**Figure 7**) is short, broad and ventrally flat. The length of centrum is slightly greater than its height. Its width is relatively higher (about twice) than its length or height. It is unique among other known axes of sauropod due to its nature like small length and more broadness (ratio of centrum length and centrum width). On the basis of ratio of centrum length and centrum width, the *Gspsaurus pakistani* Axis resembles with the *Camarasaurus* but it is mostly differentiated among other characters. The posterior face is deeply concave for receiving strongly convex anterior face of following/third cervical vertebra. The cervical vertebrae (except atlas and axis) are opisthocoelous in *Gspsaurus pakistani* and also other titanosaurian sauropods. The central dorsal margin of centrum forms the basement of neural canal. A long and shallow pneumatic fossa/pleurocoel is located in the lower half of pleurocentrum. This pleurocoel is relative deep and wide in the posterior part and becomes shallow and narrow in the anterior part. Inclined thin bony septa/web seems to be found in the relatively shallow area of anterior part of pleurocoel. Foramina remained unknown due to matrix coverage. Large rectangular parapophyses are located in the central and posterior half of the ventral surface of centrum (**Figure 7**). The posteriormost part of parapophysis is subrounded in shape (**Figure 7**). Maximum breadth across parapophyses is 14.0 cm, gap between parapophyses is 2.5 cm, anteroposterior length of parapophysis is 5.5 - 6.5 cm, and transverse width of parapophysis is 5.0 - 6.0 cm. Axial pleurocentrum is ventrally flat. Odontoid process is not observed due to covering of matrix. Preserved posterior/back concavity rim is hemispherical and it is 5.5 cm dorsoventrally and 7 cm transversely preserved and have a pin like small ridge in the center, it may be due to matrix. The dorsal length of centrum (anteroposterior) is 8.0 - 10.0 cm, ventral length of centrum (anteroposterior) is 12.0 - 13.0 cm. height of preserved posterior concavity of centrum is 5.5 - 7.0 cm, height of anterior face of centrum is estimated 7.0 - 8.0 cm, maximum breadth of centrum is estimated 10.0 - 14.0 cm, minimum breadth of centrum is 7.0 cm, breadth across prezygapophyses is 6.0 cm, width of prezygapophysis is 3.5 - 4.5 cm, breadth across diapophyses is 19.0 cm. Neural canal are not clearly observed due to matrix.

Neural arch (Axial Neural arch) is mostly damaged. However prezygapophyses (**Figure 7**), and partial diapophyses (**Figure 7**) are preserved with this specimen. The contact of neural arch and centrum are fused. Prezygapophysis is triangular and robust. They form the side of the neural canal and are directed toward anteriorly. Axis prezygapophyses seem to be lower relative to other cervical vertebrae of *Gspsaurus pakistani*. Diapophyses are situated as lower as in the centre of centrum on the lateral aspect. The diapophysis is smaller than parapophysis. The transverse processes of axis are directed laterally. Axis diapophyses (**Figure 7**) processes are robust and slightly broad anteroposteriorly and extending from back of posterior concavity to forward about more than half of centrum length. Anterior centrodiapophyseal laminae/accessory lamina is a long and strongly well developed and found in the centre of the lateral side of centrum. The posterior centrodiapophyseal lamina was damaged and seems to be very short due to backward (posterior) position of transverse process. There is a transversely elongated cavity in between the dorsal part of posterior concavity ring and postzygapophysis (**Figure 7**). There is also a long cavity in between the anterior centrodiapophyseal lamina and postzygodiapophyseal lamina (**Figure 7**).

Here the Axial Pneumaticity is observed. There is a transversely elongated cavity in between the dorsal part of posterior concavity ring and postzygapophysis (**Figure 7**). There is also a long cavity in between the anterior centrodiapophyseal lamina and postzygodiapophyseal lamina (**Figure 7**). In this way there is possibility of many coels in the neural arch. The axis is spongy with large internal open cells (**Figure 7**). The pneumatic cavities arranged across the compression (**Figure 7**). The aerial parameter like width and depth are variable and tentatively are 1 cm and 2 cm respectively measured at the cross section on the dorsal part of atlas-axis complex.

Axes are known for several sauropod taxa. The axis (MSM-82-4 from Pakistan) of *Gspsaurus pakistani* is diagnostic and have identified proportional differences distinguishing from the axes of other sauropods. The *Gspsaurus pakistani* axis is also proportionally distinguished from Nand Axis [51], now when I have gspsaurid stocky titanosaur axis which is different than Nand axis from India. So now there is possibility that Nand axis may belong to *Pakisaurus* pakisaurids due to slightly tall axis nature. According to [51], axial remains are not yet known for *Isisaurus*, and presacral remains are not yet known for *Jainosaurus*. The postaxial cervical vertebrae of *Isisaurus* do not exhibit the marked external pneumatic structures present in the Nand axis, which suggests that it pertains to a different species. It is anticipated that the Nand axis pertains to a titanosaur with a high degree of external pneumatization apparent throughout the cervical series [51]. So the above statement of [51] conveys that Nand axis is expected to belong to *Pakisaurus balochistani* pakisaurids the slender titanosaurs.

Cervical vertebrae: Cervical vertebrae (except atlas-axis complex) parapophysis is becoming anteroposteriorly elliptical, and position is shifting from posterior to mid portion and then anterior portion of centra as the centra proceeding posterior in series upto last cervical. The parapophyses seems to directed downward in anteriormost and directed outward in the remaining cervical vertebrae (**Figure 4**). It begins to travel anteriorly as the series going posteriorly. The rectangular nature of parapophysis is becoming oval as the series going backward or posteriorly of cervical series. The centra have almost flat and slightly concave ventral surface because anterior cone and posterior articular surfaces are trending to lower level than central surface of centra. Centra are broad, long and less tall and opisthocoelous. The proportion of anterior cervical vertebrae matchs closely with the *Gspsaurus* axis and is different from *Pakisaurus* axis. Pleurocoel is small, shallow and elongated. The centra are constricted in the middle and successively increase in length. The broadness and length is increasing much backward. The transverse processes seem to be directed laterally. The neural canal is uniformly rounded to sub rounded in all the cervicals. The neural spine is single (not bifid). The cervical vertebrae have camellate/pneumatic texture. The cervical ribs are broad v-shaped more than 90˚. These cervical ribs are pneumatic (large open internal cells).

Dorsal vertebrae: The dorsal vertebrae have relatively less long (than cervical) and slightly broad centra (**Figure 4**) (**Figure 5**) with smooth ventral surface, open wide pleurocoel and small lateral surface below the pleurocoel, as characterised by the first cervicodorsal vertebrae and may be found in other anterior dorsals. There is no hyposphene-hypantrum in any of the collected opisthocoelous dorsals. The neural spine is undivided. The thick neural spine of presacral vertebra, thick oval ball type (knot type) distal ends which is anteroposteriorly compressed and spongy.

Caudal Vertebrae: All the collected caudal vertebrae are strongly procoelous (except first biconvex caudal which is broad and relatively less long than *Saraikimasoom* biconvex first caudal) (**Figures 4-7**). The first caudal centrum is biconvex and matches with the *Saraikimasoom vitakri* from Pakistan, *Pellegrinisaurus* from Patagonia, Argentina and *Neuquensaurus* from Argentina, South America, and *Alamosaurus* from USA, North America. This feature shows southern and also northern hemisphere distribution. Reference [52] mentioned biconvex first caudal in *Neuquensaurus* from South America while [53] mention procoelous first caudal feature in *Neuquensaurus*. The centrum is not biconvex in *Paralititan* from Egypt, Africa, as in the titanosaurids *Alamosaurus* from USA, *Neuquensaurus* and *Pellegrinisaurus* from Argentina [54]. Measurements of some caudal vertebrae are shown in tables 4a, 4b and 4c of [9]. The chevron facets are not found on the anterior most caudal and distalmost caudals. Anterior caudals are broad and heavy while the anterior and mid caudals are tall to slightly tall or squarish and heavy but ratio varies from 1.3 to 1.5 (in the case of *Isisaurus* the mid caudals are light and squarish and ratio about 1); anterior caudal centra (except some anteriormost caudals) and mid caudals with broad ventral groove U-shaped (while V-shaped in *Saraikimasoom vitakri* due to strong ventral reduction) on posterior parts due to well developed posterior chevron facets. Lateral surfaces on ventral view are clearly observed in the anterior (except some anterior most) and mid caudals due to mid-dorsal width greater than ventral width; posterior caudals are long and cylindrical with anterior circular articular and posterior circular articular region (restricted ball or ball having peripheral depression on the bass of ball just after the posterior articulated ring). The distalmost caudal centrum may be trirays and distinguished, it include anterior concavity but posteriorly two dorsal spine like prezygapophyses and one thick spine downward like postzygapophysis or its orientation may be changed. These distalmost trirays caudal can not be considered neural arch of vertebrae because it has no adjustment way for neural canal and also no neural spine. The size and shape of these distalmost caudal show fitness as the last trirays caudal. The trirays distal caudal centrum is procoelous and relatively stocky (than *Saraikimasoom* distal caudal centrum) having anterior prominent concavity like other caudals and posteriorly feeble ball with two prezygapophyses trending upward and one postzygapophysis trending downward or vice versa. It creates specialty and uniqueness (**Figure 6**). The posterior convexity of posterior centrum is prominent ball like with some rounded neck like depression in the anterior base. The chevron facets are located in the anterior and middle caudals. The neural arch is situated on the anterior half of the caudal centra. The distal caudals are elongate cylindrical and anteroposteriorly wide and low neural spine (laterally compressed and low). Prominent ridge facets occur which seems like blunted in anterior caudals and joined with neural arch. The restricted condyle of *Gspsaurus pakistani* matches slightly with reduced articular posterior condyles of caudal centrum of *Mendozasaurus neguyelap* [54]. Further in *Gspsaurus* the distal caudal condyle is prominent and displayed in the middle while in *Mendozasau-*

rus neguyelap [55] the condyle is reduced and displaced dorsally. *Gspsaurus* (and *Saraikimasoom*) have ventrally reduced caudal vertebrae like *Adamantisaurus mezzalirai* [56]. *Gspsaurus* have slightly tall to squarish mid-caudals with joined transverse process and neural arch, and ventrally slight to moderately reduced, while *Saraikimasoom* have broad to squarish mid-caudals with separated transverse process and not extended to neural arch, and strongly reduction of ventral surface of mid-caudals. Caudal series varied from anterior to end tail as broad (anterior caudals), tall to slightly tall (mid caudals), slightly tall to squarish (end of mid caudals), cylindrical (distal caudals) and ending trispinous cap. Relatively broad ventral groove on posterior parts of anterior caudals (except some anteriormost caudals) and mid caudals due to well developed posterior chevron facets. The measurements of caudal vertebra are shown in Table 4a, b, c of [9]. The anterior/mid caudals of *Gspsaurus* from Pakistan matches closely to *Rapetosaurus* of Madagascar.

Appendicular and limb elements

Sternal Plate: The partial sternals collected from Top Kinwa (convex part of sternal MSM-1014-16, sternal part MSM-604-16; **Figure 5**) and Mid Bor (anterolateral part of sternal MSM-565-2 and sternal part MSM-1004-2; **Figure 8**) localities. Sternal anterolateral edge is rugose, expanded and thick. These rugosities show connecting with the scapular coracoid region. The plate is slightly concave on the ventral and dorsal sides. The anterolateral thickest part of sternal plate is constricted longitudinally in the central or middle longitudinal line showing behavior as cleavage of upper and lower ridge plates. From this thick corner the thickness is consistently reduced in the medial and posterior side. The medial part is medially convex to meet with its fellow sternal plate. The plate is slightly expanded at medial margin.

Scapula: A pair of partial scapula (left and right partial distal scapulae MSM-1100-19 and MSM-217-19; **Figure 4**) from Alam, a pair of left and right distal scapulae (MSM-250-16, MSM-176-16; **Figure 5**) from Top Kinwa, distal right scapula (MSM-163-15; **Figure 6**) from Mari Bohri, and mid scapula with ridge (MSM-838-4; **Figure 7**) and right mid scapula MSM-198-4 (**Figure 7**) from south Kinwa were collected so far. The middle part has convexity on dorsal side and concavity in the medial side generally forming D-shape. Mid Scapula have medial tuberosity which is transversely divided or bifurcated by a fracture or groove (**Figure 7**). The width of middle part are remarkably less than distal ends (the acromial process) or may be about half of distal tibial end. Distal blade is stocky and expanded and represents broadening and thickening at the distal end forming a most deep and spoon shape glenoid for humerus head, and then slight bend and then rugosity on expanded surface for the attachment of coracoid situated and then again a bend happed and after the bend the relatively less expanded acromian situated (**Figure 6**). Distal scapula and coracoid are separate. Distal scapulae are relatively more expanded (largest) in size (**Figures 4-6**). The acromian size seems to be moderate to high and acromial edge is slightly expanded. The distal scapula of *Gspsaurus pakistani* seems not to be deflected laterodorsally (like *Saraikimasoom vitakri*) *i.e.* it is straight or slightly deflected medially, while the distal scapula of *Pakisaurus balochistani* and *Isisaurus colberti* pakisaurid are deflected laterodorsally. *Gspsaurus pakistani* distal scapulae are relatively more stocky than *Pakisaurus balochistani and Isisaurus colberti*. The distal scapulae of *Gspsaurus pakistani*, *Saraikimasoom vitakri* and *Pakisaurus balochistani* have relatively short articular surface for coracoid (**Figures 4-6**) while *Isisaurus colberti* has relatively long articular surface for coracoid. The *Gspsaurus pakistani* distal scapula (**Figure 6**) of Mari Bohri 15 anteroposterior width is 36 cm while depth is 18cm which is maximum at glenoid. The stocky ratio width/length of Mari Bohri exemplar of *Gspsaurus pakistani* becomes 0.5. The *Gspsaurus pakistani* distal scapula (**Figure 6**) of Topkinwa 16 anteroposterior width is 25 cm while depth is 12 cm which is maximum at glenoid. The stocky ratio width/length of Topkinwa 16 exemplar of *Gspsaurus* is about 0.48. The *Pakisaurus balochistani* distal scapula of Kinw 4, anteroposterior width is 32 cm while depth is 12.5 cm which is maximum at glenoid (**Figure 6**). The stocky ratio width/length becomes 0.39 for *Pakisaurus balochistani*. So the ratio of *Gspsaurus* and *Pakisaurus* show high difference.

Humerus: The proximal humerus MSM-237-10 from Rahi Wali 10, and proximal and distal humerus (MSM-363-2, MSM-362-2) from mid Bor 2 were found so far. A pair of humeri (left humerus (NHMUK R5932; right humerus (NHMUK R5931) from Chota Simla are being referred to *Gspsaurus pakistani* due to typical biconvex lense shaped proximal tibia overlapping. The humerus is expanded at proximal and distal ends with rugose articular rough surfaces (**Figure 7**), however the proximal end is more than twice of mid shaft and distal end is partially destroyed but also expected to be twice of mid shaft. So here provided information of humeri based on referred materials. Wilson *et al.* (2011) estimated low width of distal end than proximal end of humeri but it is expected to be equal or subequal. The humerus is expanded both proximally and distally. Its proximal and also possibly the distal end is about 2.5 times more than the mid shaft. The proximal view of proximal end is arc shaped and crescentic. The humerus has a gentle convexing arc with head on the convexing axis of the posterior view of proximal humerus. The humerus head portion of proximal humerus is relatively thicker than the surrounding area of proximal humerus. The head is expanded and extruded from humerus as well developed ball shape. The deltopectoral fossa shaped as reversed or inverted triangle. The shaft is oval with straight plane surface posteriorly. The distal humerus has arc type concavity for the adjustment of olecranon process. The deltopectoral crest is medially inset which is mostly oriented close to vertical or slightly oblique to vertical. The lateral bulge is located on the deltopectoral crest. The proximal humerus has most prominent lateral process than medial process. The humerus head and posterior convexity peak axis lies in medial third which makes the medial limb very short (transversely) and lateral limb most long (transversely). The deltopectoral fossa is very shallow. In this way dorsal margin of humerus shows very low angle arc. The proximal profile view forms convexity axis for left and right limbs. This axis or convexity line is shifted further medial side show its differentiation among other humeri in Indo-Pakistan. Further the humerus of *Gspsaurus pakistani* have no V-shaped smooth plain area just below the head on the posterior view while *Saraikimasoom vitakri* have V-shaped smooth plain area just below the head ball on the posterior view. The left humerus (NHMUK R5931) has incomplete length 95.2 cm, proximal width 22.8 cm and distal width 25.6 cm, and complete width midshaft 14.8 cm [39].

Further *Jainosaurus* (=*Antarctosaurus*) *septentrionalis* was attributed braincase, vertebrae, humeri, scapulae, fibula and femur which show dual affinity like braincase and vertebrae referable to *Pakisaurus balochistani*, one scapula to *Isisaurus colberti*, humeri have no distinct information. Only distal humeri have distinct information like expanded radial condyle or not expanded. The distal humerus with not expanded radial condyle is attributed to *Isisaurus colberti* while the distal humerus with expanded radial condyle is attributed to *Pakisaurus balochistani*, *Saraikimasoom vitakri* and possibly to *Gspsaurus pakistani*. Conclusively the referral of cranial and postcranial materials is problem for *Jainosaurus* (=*Antarctosaurus*) *septentrionalis* while for other recognized four titanosaurs from Indo-Pakistan is relatively easy because *Isisaurus* and *Pakisaurus* pakisaurids slender titanosaurs and *Gspsaurus* and *Saraikimasoom* gspsaurids stocky titanosaurs have associated materials which provides facility to assign cranial and postcranial materials.

Radius: The proximal radius MSM-215-19 from Alam, distal radius MSM-160-16 from Top Kinwa from Pakistan and left radius (NHMUK R5933) from India are being referred to *Gspsaurus pakistani*. The left radius (NHMUK R5933) has length 52.0 cm (estimated), proximal width 7.0 cm and midshaft width 5.2 cm [39]. The proximal end is oval with one pole wide and one pole relatively narrow. The distal ends of radius are elongated subrectangular. Its terminal ends on elongated axis bears different morphology. The prominent anterior end or anterolaterally end is relatively narrow with rounded end process while the posterior end or posteromedially is relatively broad with rounded process. The proximal view of proximal end show slight concavity or depression on proximal view, may be due to adjustment of radial condyle of humerus. In this taxon, the radial condyle of humerus is well expanded and exposed anteriorly, so its contact with radius created depression on proximal view of proximal end of radium. The proximal part of radius becomes strongly swollen or becomes broad about twice of shaft. Proximal shaft is oval and elliptical with one end narrower than other end which is broader. However the distal shaft close to distal end is oval bearing both broader ends. The anterior view of distal radius has constricted elongated ridges or 2 parallel ridges bifurcated by a long and narrow depressions. The distal end of radius is rugose and slightly convex. This distal end is oval or subrectangular with both ends broader or strongly rounded margins. The distal ends are beveled with more than 20˚ angle from horizontal. Proximal and distal radius have proximal groove for the adjustment of large expanded radial condyle.

Ulna: A pair of proximal ulna (MSM-175-16, MSM-240-16) and a distal ulna

MSM-74-16 (**Figure 5**) from Top Kinwa, proximal ulna MSM-271-2 and distal ulna MSM-852-2 from mid-Bor locality were found (**Figure 8**). The proximal ulna is rugose and bears a prominent olecranon process. The proximal ulna represents a triradiate structure. This triradiate limbs are relatively long but have relatively less width. The ulna is gracile. There is a marked concave depression on the proximal lateral side to cradle the head of radius. It has also depression on the medial side also. The posterior side have slight depression and almost smooth. The ulna gradually tapers toward down. Ulna has well developed olecranon process. Relative lengths of ulnar proximal condylar processes are unequal. Distal ulna is divided and broad concavity on one side and convexity on another side. Distal ulna has rugosities on the ventral view.

Metacarpals: Many metacarpals were colleceted from mid Bor (**Figure 8**). Metatarsals are elongated and robust. Distal and proximal condyles are not divided.

Ilium and acetabulum: A partial ilium MSM-216-19 (**Figure 4**) and acetabulum (MSM-147-16, MSM-48-16) (**Figure 5**) were collected. The preacetabular process is thick and triangular. On one side it is concaving arc shaped while on other side the corner is relatively more expanded. It is moderately massive, robust and platy. The acetabulum is arc shaped with well developed glenoid. Its glenoid surface has anteroposteriorly elongated fibrous structure. The acetabular pubic peduncle is wider than ischial peduncle.

Pubis: The proximal pubis MSM-165-15 and distal ischium MSM-164-15 (**Figure 6**) collected from Mari Bohri locality. The iliac symphysial region is preserved but the dorsoventrally width becomes less than glenoid area. The proximal pubis bears a large glenoid surface for femur head. The glenoid is 13 cm wide. Total preserved proximal surface is 17 cm while ischial symphysial region is destroyed. The proximal side of pubis is broad, cylindrical to sub oval and sigmoid and distal part is platy and straight. Distal pubis has a ventral ridge. On one side the pubis has thicker end. The pubis of *Gspsaurus pakistani* is different from *Isisaurus colberti* [6]. The *Gspsaurus* pubis iliac symphysial part is low and reduced while the *Isisaurus* have elevated iliac symphysial. Further *Gspsaurus* pubis shows close occurrence of low iliac symphysial and adjoining wide and thick glenoid (**Figure 6**).

Ischium: A proximal ischium MSM-184-2 (**Figure 8**) from mid Bor locality was collected. The ischium MSM-184-2 is plate like and relatively thin (while pubis is thicker). Ischium has low and slightly expanding articulation surface for the peduncle of the ilium, followed by a relatively less curved and thin embayment for acetabular glenoid and then small and thin part for the attachment of pubis. Iliac symphysial is small to moderately long and thin (slightly expanded), and glenoid low, thin and very long, while pubis symphysial is low, thin and inclined. This ischium of *Gspsaurus* is strongly different than *Isisaurus*. It has attachment for acetabulum, glenoid and attachment for pubis. The attachment for pubis is relatively rougher. The iliac peduncle is small unlike *Isisaurus colberti* which have extremely elongate iliac peduncle.

Femur: Many femora are collected like holotypic partial femur (proximal left femur MSM-213-19 with left distal femur MSM-118-19; **Figure 4**) from Alam, referred partial femur (proximal femur MSM-169-15 with distal femur MSM-70-15; **Figure 6**) from Mari Bohri, and proximal and mid femur MSM-208-4 from south Kinwa. A left femur (NHMUK 5903) from Chota Simla skeleton [5] [39] with associated left limb bones is assigned to *Gspsaurus pakistani* based on associated typical convex lense shaped tibia. The left femur (NHMUK R5903) has length 128.8 cm, proximal width 35.8 cm, distal width 35.5 cm and midshaft width 20.6 cm [39]. The Mari Bohri femur is largest among these femora. The Mari Bohri and Alam femora are incomplete to represent upper one third medial deflection of proximal femur, while Chota Simla femur is almost complete. The proximal one third deflection with straight line is found in Chota Simla femur. The South Kinwa proximal femur seems to be non-deflected may be due to erosion and further its head is small and perpendicular to shaft. The proximal end of femur extends dorsomedially as extended and expanded subrounded head. The greater trochanter forms the proximolateral corner of the proximal femur. A prominent dorsoventrally longitudinal ridge started from the posterolateral corner of greater trochanter and may extend down upto mid femur. The feeble fourth trochanter is relatively situated upward or proximally becomes close to bend of head as represented by south Kinwa femur. The shaft of the femur is straight in anterior and lateral views represented by south Kinwa femur. At midshaft, the femur has oval or elliptical cross-section whose transversely oriented long axis may be nearly 2 times or slightly more the length of its anteroposteriorly oriented short axis while it is 3 times in *Pakisaurus balochistani* femur. The distal end is bifurcated in two condyles as tibial and fibular condyles both have rugosities on ventral view. The ventral view of distal condyle has concavity or rounded groove between the two condyles while humerus has no concavity or rounded groove between the two condyles. The tibial condyle is relatively deeper and narrower than fibular condyle (including epicondyle), while the fibular condyle (including epicondyle) is relatively wider than tibial condyle. The tibial condyle is wheel like. The fibular condyle is posteriorly divided in two sub condyles (one more expanded and one less expanded). Femoral distal condyles, articular surface shape expanded onto anterior portion as well as lateral and medial portion of femoral shaft close to distal ends. It has rugosities on the proximal and also distal ends. In distal view, the tibial and fibular condyles are beveled anterolaterally like *Saraikimasoom vitakri* and unlike *Oceanotitan* [57] which show medially-posterolaterally probably due to deformation. The tibial condyle is deeper and anteroposteriorly expanded than the fibular one. The tibial condyle transverse width is less than the width of fibular condyle including epicondyle. The epicondyle is well developed and separated from the fibular condyle by a well-defined proximodistal groove. There is no notch in between the head and greater trochanter. The distal ends of femur have rugosities which extended on shaft. The prominent feature observed here is the rectangle shaped cross section of uppermost part of shaft just below the greater trochanter. This rectangle shape is transversely more elongated and larger than the *Saraikimasoom* proximal femoral rectangle. This feature is clearly observed in a Mari Bohri proximal femur. The distal end (cumulative of tibial, fibular and epicondylar transverse width) is transversely wider or subequal the proximal end (head and greater trochanter). The distal condyles appear to have been sheared slightly anterolaterally relative to the shaft of the femur. This is natural and not an artefact of preservation. The tibial or medial condyle is larger but narrower than the lateral condyle (fibular condyle and epicondyle). The femora of *Gspsaurus* and *Saraikimasoom* gspsaurids have same characters only size is a matter, the *Gspsaurus* is medium sized and *Saraikimasoom* is small sized, both with relatively stocky thick bones (than *Isisaurus* and *Pakisaurus* of Pakisaurids). The *Saraikimasoom vitakri* show straight lateral profile of medial deflection while the *Pakisaurus balochistani* show wavy style lateral profile of medial deflection.

Tibia: Fortunately four different types of key tibiae [24] were discovered from Pakistan belonged to distinguish four taxa from Indo-Pakistan like *Isisaurus* (relatively less transverse width of flattened and slender tibia than *Pakisaurus*) and *Pakisaurus* (relatively more transverse width of flattened and slender tibia than *Isisaurus*) of pakisaurids (transversely narrow and slender tibiae), and *Gspsaurus* (biconvex lense shaped anteroposteriorly elongated stocky proximal tibia and transversely expanded distal tibia) and *Saraikimasoom* (subsquare shaped proximal tibia with about equal anteroposterior and transverse widths of stocky proximal tibia and transversely expanded distal tibia) of gspsaurids (transversely broad and stocky tibiae). These four diversities of key tibiae have discarded the hypothesis of only two titanosaurs taxa from Indo-Pakistan [5] [39] and solved the longstanding controversy and revealed four titanosaur taxa. Further the associated skeleton from Alam and north Kinwa cranial and postcranial associations helped a lot for the referral of cranial and postcranial materials from other localities of Indo-Pakistan. Secondly the lower Bor, Zubra peak, Mari Bohri, Sangiali and south Kinwa associated materials from Pakistan and Chota Simla associated materials of *Gspsaurus pakistani* and associated holotypic materials of *Isisaurus colberti* from Dongargaon, India helped a lot for the assignment of materials to titanosaurs from Indo-Pakistan.

The left tibia (proximal left tibia MSM-119-19 and distal left tibia MSM-710-19 (**Figure 4**) found from holotypic Alam locality skeleton, is almost complete (but middle portion and some distal portion are destroyed or may be found in undescribed assemblages). The proximal and distal right tibia is partially covered by thin mud layer but both are well diagnosed. The distinct and key tibia (proximal right tibia MSM-73-16; **Figure 5**) along with other associated elements like vertebrae and other limb bones (**Figure 5**) found from Top Kinwa assigned to *Gspsaurus pakistani*. The proximal tibia MSM-73-16 (**Figure 5**) found from Top Kinwa 16 is well preserved and well exposed. The third tibia (NHMUK 5903) is reported from Chota Simla left limb skeleton [5] [39]. The outlines of holotypic proximal tibia from Alam holotypic locality show same character and proportion as Top Kinwa right tibia and Chota Simla left tibia. This is the reason for referring. These tibiae are being described as below.

The anteroposterior width of proximal end of proximal tibia MSM-73-16 (**Figure 4**) (**Figure 5**) is about 24 cm and transverse width of proximal end is also about 15 cm. Its preserved shaft cross section is at about 16 cm downward from proximal end and here measured cross section shows anteroposterior breadth 13 cm and transverse width is about 4 cm. The anteroposterior width of proximal end of proximal tibia MSM-119-19 is about 24 cm and transverse width of proximal end is also about 15 cm. Its preserved shaft cross section is at about 16 cm downward from proximal end and here measured cross section shows anteroposterior breadth 14cm and transverse width is about 4.5 cm may be slightly increasing due to mud coating. The left tibia (NHMUK R5903) has length 81.0 cm, proximal width 16.4 cm, distal width 19.6 cm and midshaft width 7.6 cm [39]. The proximal width of all these three tibia are very close also show affinity to same taxon. The dorsal view of proximal end has rugose surface with subrounded concavity or slight depression for the attachment of distal tibial condyle of femur.

The proximal view of proximal end of tibia is thick biconvex lense shaped, while its anteroposterior width is more than transverse width. In this tibia, a prominent dorsoventrally longitudinal ridge started from the fibular condyle and extends down upto mid tibia; this dorsoventral longitudinal ridge is running sub-parallel to anterior profile of shaft. The proximal expanded end and shaft of tibia of *Gspsaurus pakistani* is relatively more thicker transversely than the slender tibiae of *Pakisaurus balochistani* and *Isisaurus colberti.* While the biconvex lense shaped expanded proximal end and subrectangle to suboval shaped shaft of tibia of *Gspsaurus pakistani* is relatively less thicker transversely than *Saraikimasoom vitakri* tibia which have subsquare shaped proximal tibia of equal transverse and anteroposterior widths. The convex lense shaped proximal tibia of *Gspsaurus pakistani* matches with *Mendozasaurus neguyelap* [55]. The distal end of tibia of both *Gspsaurus* and *Saraikimasoom* have quite transversely subrectangle shaped to suboval, longer transversely than anteroposteriorly long distal ends of tibiae of *Pakisaurus* and *Isisaurus* which have anteroposteriorly broad distal tibia. The distal end is strongly expanded transversely, a morphology typical of many titanosauriforms [58] [59] [60] [61], although differing from the almost equidimensional of the tibia of the somphospondylans *Antarctosaurus* [62] and *Paluxysaurus* [63], and transversely broad distal end of tibia of *Pakisaurus balochistani* [24] and *Isisaurus colberti* [24] pakisaurids.

The distal part of tibia is twisted 90 degrees from mid shaft towards its distal end, where it is much broader transversely than anteroposteriorly. The anterior part of fibular condylar ridge articulated closely (mutually) with proximal fibula when in articulation. Bounded between cnemial crest and fibular condyle there is low, concave, triangular surface bears pockmarked bone [39] indicative of a ligamentous connection to the anterior crest of the fibula. Tibia has a rugose proximal end surface that becomes concave and slightly depressed centrally, due to attachement of distal tibial condylar end. The fibular condylar ridge extends down distally as a ridge in *Gspsaurus* (unlike *Pakisaurus* [24] and probably *Isisaurus* from Indo-Pakistan [24]. The distal end of the tibia is quite robust. The distal end represents the articular surface for the ascending process and posteroventral process. Tibial anterior ascending process is relatively less broad.

Fibula: A pair of proximal fibulae (left and right proximal fibulae MSM-76-16 and MSM-77-16; **Figure 5**) found from Top Kinwa skeleton and left fibula (NHMUK R5903) reported from Chota Simla. The Chota Simla left fibula (NHMUK R5903) has length 83.0 cm, proximal width 8.1 cm, distal width 9.1 cm and midshaft width 7.1 cm [39]. Proximal fibula has rugosities on proximal part on dorsal view only, while the proximal fibula of *Pakisaurus pakistani* has rugosities on proximal part on dorsal view and dorsoventrally elongated rugosities also extended into adjoining medial and lateral part also. Proximal fibula have medial scar for attachments of tibia. The shape of fibular proximal tibial scar is well marked and deepening anteriorly. There is a relatively less ridge in the medial scar, starting from close to center of proximal surface and trending obliquely downward. There is a more prominent ridge in on medial proximal surface and trending obliquely downward. The shaft cross section just below the scar is oval. The lateral trochanter of fibula (NHMUK R5903) of *Gspsaurus pakistani* is positioned close to the anterior profile of shaft of mid fibula, while the lateral trochanter of mid fibula GSP/Sangiali-1122 of *Saraikimasoom vitakri* is positioned at the centre of shaft.

Metatarsals: Many metatarsals were collected from mid Bor (**Figure 8**). Metatarsals are elongated, broad and have rugose articular surfaces. Distal condyle is wide, have rugosities and shape is slightly divided and has central concavity to adjust the large oval ungual for attachment or relevant phalange.

Osteoderms and armor plates: The mosaic type armour bones (MSM-83-16 and MSM-1035-16; **Figure 5**) found from Topkinwa 16. The mosaic type armour bone MSM-83-16 has 9 cm diameter and made up of irregularly shaped nodule/polygon ossicles of diameter ranging from half centimeter to 4 centimeters, separated by internal ducts of 1 - 3 mm wide. Further a large oval shaped ellipsoidal plate (MSM-85-4; **Figure 7**) collected from South Kinwa 4 [43] assigned as osteoderms *Gspsaurus pakistani* stocky titanosaur. The large oval shaped ellipsoid (MSM-85-4) correlated with *Malawisaurus* of Malawi, Africa [64]. Like these large oval and rugose osteoderms were also reported from Malawi [64], Argentina [65] and India [4] [66]. It suggests Indo-Pakistan connection with Africa during early Cretaceous. This large oval plate is which has slight concavity and rugosities on smooth ventral surface, and rugosities on lateral and dorsal surfaces. The dorsal surface has an asymmetrical low ridge directed posterodorsally. The ossicles on the ridge area are tightly packed and directing posterodorsally. This oval plate has median cut or groove on the dorsal aspect. The oval plate ventral surface is semi plain slightly convexing downward, with irregularly rugose ossicles and internal ducts pattern. The dorsal surface has well developed asymmetrical, low and sharp cone/ridge having possibly dorsoposterior directed tip. The ossicles on the ridge area are tightly packed and directing toward the tip of ridge making radial pattern, having centre at tip. In the centre of dorsal surface of plate has a transverse median concavity belt just in front of ridge. The remaining dorsal and lateral surfaces have irregular rugosities of ossicles and internal ducts. The length and width of ventral oval surface are about 21 and 13 cm respectively, and dorsoventral depth of dorsal ridge/cone is 13 cm *i.e.* from ventral surface to apex or tip of ridge/cone. Like this plate from Zubra Basti Nala belongs to stocky small sized titanosaur *Saraikimasoom* which helped its MSM-85-4 assignment to stocky titanosaur. The *Gspsaurus* has oval ellipsoidal plate with median groove or cut, while *Saraikimasoom* has subcircular shaped ellipsoidal plate without median cut or groove. The ventral surface of *Saraikimasoom* oval plate is slightly concave and smooth having corroded rugosities on circular ventral surface. The *Gspsaurus* oval plate shows slight convexity and well developed, irregular rugosities on oval ventral surface, and it bears a transverse median concave belt on dorsal surface. The reference [67] proposed that these both oval plates being assigned to pes toes of titanosaurian sauropods because its shape, length, width, rugosities, robustness and general outlines closely matches with the ungual found in pes footprints found from Pakistan [31].

3. Conclusion

Due to lack of rostrum and snout of titanosaurs from Indo-Pakistan (South Asia), this finding of holotypic partial skull, rostrum, braincase and associated vertebral and appendicular and limb elements of *Gspsaurus pakistani* and its exemplars have also associated skeletons from Top Kinwa and Mari Bohri of Pakistan and Chota Simla of India and many referred materials from many localities of Indo-Pakistan subcontinent provided stable and significant features with key elements for comparisons, higher and lower level of phylogenetic studies of titanosaurs in the globe. These fossils from Pakistan are onsidered significant which have no parallel from India [68], so these geoheritage and paleobioheritage and their sites from Pakistan need to be protected [69] [70] [71] [72] [73].

Conflicts of Interest

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

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