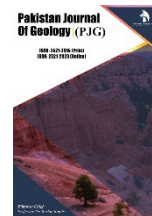


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RESEARCH ARTICLE

A NEW TITANOSAURIAN SAUROPOD, *Safisaur niazensis* (MALKANI, 2025), FROM THE SEDIMENTS OF KOHAT, THE FIRST DIPLODOCOID (FLAGELLICAUDATA; DICRAEOSAURIDAE) FROM PAKISTANNiaz Muhammad^a, Amtyaz Safi^b*^aDepartment of Microbiology, Kohat University of Science and Technology, 26000, Kohat, Pakistan.^bDepartment of Zoology, Diwan Dayaram Jethmal (D.J) Sindh Government Science College, Karachi, 74200, Pakistan.*Corresponding Author Email: amtyaz.safi@gmail.com

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ABSTRACT

We are currently revising the previous reports about the Pakistani titanosaurian diplodocid dinosaur (KUST-DM-NM-1/2025), found in Kohat, Khyber Pakhtunkhwa, from the Middle Jurassic to Early Cretaceous layers of the Shinawari Formation. *Safisaur niazensis* is the first dinosaur discovered in Khyber Pakhtunkhwa Province and the first diplodocid sauropod found in Pakistan, as initially reported in August 2025. The initial fossil included a bifid neural spine and other bones that resembled Dicraeosaurid (Flagellicaudata; Diplodocoidea) and also showed some unique features within Diplodocoid (Flagellicaudata; Dicraeosauridae). As a result, it was classified as a new genus and species, (*Safisaur niazensis* Malkani, 2025). The name *Safisaur* honors Amtyaz Safi from the Department of Zoology at Diwan Dayaram Jethmal (D.J.) Sindh Government Science College in Karachi, Pakistan, is involved in this discovery, and the term 'saur' means lizard or reptile. The species name, *Safisaur niazensis*, honors Niaz Muhammad, an Associate Professor in the Department of Microbiology at Kohat University of Science and Technology, who contributed to the discovery and fossil collection. In September to November 2025, additional fragmentary bones from the axial and appendicular regions were recovered from the same site. These included axial elements such as partial cervical, dorsal, and caudal vertebrae, neural arches, a distal thoracic rib, and a chevron, along with limb bones like a proximal femur and a metatarsal I. All these bones, including the holotype and other materials, belong to a single individual found at one specific location. The size consistency and lack of duplication confirm that these materials come from one individual. Consequently, we assigned a single holotype number: KUST-DM-NM-1/2025.

KEYWORDS

Dinosaur, Fossils, Kohat, Pakistan, *Safisaur niazensis*.

1. INTRODUCTION

Dinosauria is a diverse group of prehistoric reptiles that first appeared on Earth during the Triassic Period, roughly 243 to 233.23 million years ago (mya), and became the dominant land vertebrates following the Triassic-Jurassic extinction event (201.3 mya). Their dominance position persisted throughout the Jurassic and Cretaceous periods (Karl et al., 2025). The first dinosaur fossil was discovered in the mid-19th century by Sir Richard Owen, who also coined the term "dinosaur," which means "terrible lizard" (Brett-Surman et al., 2012).

The Indus Valley was a part of Gondwana and is currently an important region for the discovery of Mesozoic faunas, including dinosaurian, which have been recently explored through geological and paleontological explorations in Pakistan (Karl et al., 2024, 2025; Malkani, 2025c). The first dinosaur fossil from Pakistan was discovered by M. Sadiq Malkani in 2000 (Malkani and Anwar, 2000; Malkani et al., 2001). Since that, so far many discoveries of different taxa of dinosauria have been reported from Pakistan (Karl et al. 2024, 2025; Safi and Karl 2024; Malkani and Anwar 2000; Malkani et al. 2001, 2025a-d; Malkani 2003, 2025a). The Vitakri area of Barkhan District in Balochistan is renowned for its rich collection of dinosaur fossils. Various fossils of dinosaurians in Pakistan are recorded

in the Indus Basin, which is divided into three sub-regions: The Upper Indus (Kohat-Potwar Basin), the Middle Indus (Sulaiman Basin), and the Lower Indus (Kirthar Basin) (Malkani, 2015a, b). Several smaller theropods and a larger titanosaur, *Sagittarius*, were reported along with several footprints in the upper Indus (Kohat and Potwar Basin) (Figure 9). The middle Indus Basin (Suleiman) provides the latest Cretaceous titanosaur sauropod fossils, including abelisaurids and tetrasaurian theropods, mesocrocodyles, pterosaurs, and titanosaur sauropod bones (Malkani, 2015a and b; Malkani and Ge, 2016). The Kirthar Basin (Lower Indus) exhibits mostly the same lithological units as the Suleiman Basin during the Mesozoic, but differs in Cenozoic strata for example, the Paleocene is represented by the Ranikot Group. Khadro, Bara, and Lakhra developed the Upper Neocene Manchar Group/Vihowa Group (Malkani, 2024a; Malkani 2019). Suleiman Basin produced Maastricht *Pashtunosaurus* Ornithomimiform, *Dgkhansauropus marri* Sauropoda, and *Anmolpakhiperus alleni* Pteropoda (Malkani, 2021a; Malkani, 2021a; Malkani, 2003). Kirthar Basin gives Jurassic *Chilta ansaroperus nicki* Sauropoda (Malkani, 2021b). All these fossils found so far are housed in the Museum of the Geological Survey of Pakistan (GSP), Quetta, Pakistan, except for some fossils sent to the University of Michigan, USA, for preparation (Safi and Karl, 2024).

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Recently, between August and November 2025, bones assemblage, including a holotype and additional materials (KUST-DM-NM-1/2025) (Figures 4-9), were discovered in the KDA (Kohat Development Authority) area (Figures 1-3) of Kohat District, Khyber Pakhtunkhwa, Pakistan (Malkani, 2025a, c; Malkani et al., 2025a-d). These bone assemblages are likely from Jurassic strata, probably from the upper red/maroon part of the Shinawari Formation which dates to the Middle Jurassic (Malkani, 2025c; (Fatmi, 1973; Malkani, 2025a, c). The neural arch (Figures 4-7) features a bifid neural spine, showing similarities with Dicraeosauridae (Diplodocidae), primarily from the Middle Jurassic to the Early Cretaceous. This bifid neural spine and other neural arch features are distinct from those of other dinosaurs, leading to the naming of *Safisaur niazensis*, a member of Dicraeosauridae (Diplodocoidea) (Malkani, 2025c). This tall bifid neural spine (Figures 4-6 and 8-9) indicates a close relationship with Dicraeosaurids. The genus name *Safisaur* honors Amtyaz Safi (one of the authors), from the Department of Zoology at Diwan Diyaram Jethmal (D.J.) Sindh Government Science College in Karachi, Pakistan, is involved in this discovery. The species name *niazensis* honors Niaz Muhammad (one of the authors), an in the Department of Microbiology at Kohat University of Science and Technology, recognizing his contribution to this discovery and fossil collection. *Safisaur niazensis* features a V-shaped gap at the base of the two limbs of the bifid neural spine, with the limbs running parallel to each other. Most of the middle and upper parts of the bifid neural spine limbs are broken (Malkani, 2025c). This is the first dinosaur from Khyber Pakhtunkhwa Province, Pakistan and the second dicraeosaurid (Flagellicaudata diplodocoidean) sauropod identified from the Indo-Pakistan subcontinent (Malkani, 2025c). The first was *Tharosaurus indicus*, described from India by (Bajpai et al., 2023). *Safisaur niazensis* represents the second dicraeosaurid diplodocoid from the Indo-Pakistan region and the first from Pakistan (Figures 10-12).

Diplodocoidea is one of the most iconic clades of giant sauropod dinosaurs, known for their elongated necks and tails, as well as distinctive skull morphology. This group existed from the Middle Jurassic to the Late Cretaceous and was distributed worldwide, showing significant diversity in body plans, feeding strategies, and ecological niches. As herbivorous dinosaurs, diplodocoids co-occurred with other herbivores like macronarians and ornithischian dinosaurs (Paulina Carabajal et al., 2014; Foster, 2020; Melstrom et al., 2021). This clade includes three main families: Rebbachisauridae, Dicraeosauridae, and Diplodocidae (Van der Linden et al., 2025). Paleontological studies of diplodocoids have focused on skeletal morphology, biomechanics, phylogeny, and histology. Extensive research has also examined their growth and niche partitioning, suggesting they had specialized adaptations for low- to mid-level browsing (Van der Linden et al., 2025). Although less common, smaller, immature diplodocoids are known from the Morrison Formation and are assigned to flagellicaudatans like *Apatosaurus*, *Barosaurus*, *Diplodocus*, *Kaatedocus*, and *Suuwassea* (Curtice and Wilhite, 1996; Harris and Dodson, 2004; Foster, 2005; Whitlock et al., 2011a and b; Tschopp and Mateus, 2013; Melstrom et al., 2016; Hanik et al., 2017). While osteo-histological analyses are yet to be conducted, several diplodocoid holotypes—such as the *apatosaurine* “*Elosaurus*” *parvus* (Peterson and Gilmore, 1902), the diplodocine *Kaatedocus siberi*, and *Smitanosaurus agilis* (Whitlock and Wilson-Mantilla, 2020)—are likely not skeletally mature. Sauropod dinosaurs were the largest terrestrial vertebrates to ever live on land, and have been extensively studied since their discovery about 185 years ago (Owen, 1841a and b; Gomez et al., 2024; Van der Linden et al., 2025; Jensen, 1985; Bonaparte and Coria, 1993; Novas et al., 2005; Calvo et al., 2007; Pal and Ayyasami, 2022; Van der Linden et al., 2025). They are famous for their massive size and hyperelongated necks and tails (Vidal et al., 2020; Conti et al., 2022; Calvo, 2023; Moore et al., 2023). These giants dominated the dinosaur world during the Mesozoic, especially in the Jurassic and Cretaceous periods (Whitlock and Mantilla, 2020; Bajpai et al., 2023; Van der Linden et al., 2025). The first described diplodocoid, “*Titanosaurus*” *montanus*, was initially named without knowledge earlier use of the same genus name for a very different sauropod from India (Marsh, 1877a; Lydekker’s, 1877). This homonym was soon replaced with *Atlantosaurus montanus* (Marsh, 1877b). In the same publication, Marsh also named and described the second diplodocoid, *Apatosaurus ajax*. Later that year, *Amphicoelias altus* was described, followed in 1878 by *Diplodocus longus* (Marsh), then *Brontosaurus excelsus* (Marsh) in 1879, and after 11 years, *Barosaurus lentus* (Marsh, 1890; Cope, 1877).

2. MATERIALS AND METHODS

2.1 Geographical context

The present holotypic materials (KUST-DM-NM-1/2025) were recorded from excavations carried out in the Kohat Development Authority (KDA), City of Kohat, Khyber Pakhtunkhwa, Pakistan in the development of the work area from the dump of sedimentary materials, which were dug, and

the area was made plain for the construction of houses (Figures 1-3) (Malkani et al., 2025a-d; Malkani, 2025a). KDA is located in the north and northwest of Kohat city. The type specimen of these fossil bones (including a neural arch) is hosted by one of us, Dr. Niaz Muhammad (Associate Professor, Department of Microbiology, Kohat University of Science and Technology), Kohat, Pakistan.



Figure 1: Geographical location of Kohat in the (A) World, (B) Pakistan.

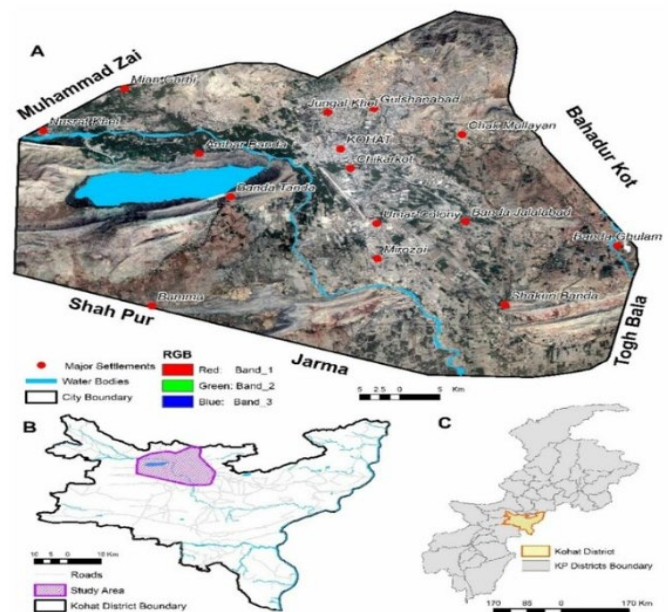


Figure 2: Geographical location of Kohat city; (A) SPOT 5 m resolution image showing Kohat city boundary and important settlements, (B) Kohat District showing the location of Kohat city, and (C) Khyber Pakhtunkhwa showing the location of Kohat District (Courtesy: Waqas Ahmed, 2018).



Figure 3: Geographical location and finding site of *Safisaur niazensis* (A) A black spot in the map of Pakistan showing KDA type locality, (B)

Excavated host rock of the finding site of the holotypic materials of *S. niazensis*.

3. RESULTS

3.1 Systematic Palaeontology

Clade: Dinosauria (Owen, 1842)

Order: Saurischia (Seeley, 1888)

Suborder: Sauropoda (Marsh, 1878)

Unranked: Neosauropoda (Bonaparte, 1986)

Super family: Diplodocoidea (Marsh, 1884)

Unranked Clade: Flagellicaudata (Harris and Dodson, 2004)

Family: Dicraeosauridae (Janensch, 1929)

Genus: *Safisaur* (Malkani, 2025)

Species: *Safisaur niazensis* (Malkani, 2025)

Referred specimens and holotype: (KUST-DM-NM-1/2025) (Figures 4-9): They represent axial elements—including cervical, dorsal, and caudal vertebrae, neural arches, distal thoracic rib, and chevron—as well as limb elements, such as a proximal femur and a metatarsal. The neural arches, which include articulated bifid neural spines, prezygapophyses, postzygapophyses, and diapophyses (Figures 4-6, 8-9), belong to a single individual. The holotype and all related fossil bones were recovered, collected, and stored from the dump of stones, soil, and other sedimentary materials in the Kohat Development Authority (KDA) in Kohat, KPK, Pakistan (Figures 4-9). Recognition of some bones is limited and based on shape, size, and features as described below. These materials were collected during August-November 2025. All these holotypic materials (KUST-DM-NM-1/2025) belong to a single individual because they were found at one locality and site, with consistent size and no evidence of duplication.

Type locality, type series, and horizon: The holotype and associated fossils from the same site as the holotype include a possible proximal femur, potential caudal vertebrae, and other bones (Figures 4-8). These were found in the KDA (Kohat Development Authority) Locality, with a grid reference of N 33.602729; E 71.468012, or latitude 33°36' North and longitude 71°28' East, in Kohat District, Khyber Pakhtunkhwa Province, Pakistan (Figures 1-3).

Age: These bone assemblages may be found from Jurassic strata (Figure 4-9) and most probably the upper red part of the Shinawari Formation which is middle Jurassic (Malkani, 2025c; Fatmi, 1973; Malkani, 2025a). The Kohat area belongs to the lateral extension of the Samana Range, which hosts the exposed Jurassic (oldest) and Cretaceous rocks in the core. The Early Jurassic Datta Formation (terrestrial sandstone) is thin in the Kohat area and surroundings. The Early to Middle Jurassic Shinawari Formation (shale, limestone, marl, and sandstone), which hosts Bathonian-aged upper part as red/maroon rocks (expected fossils host rocks as shown in Figure 3).

Etymology: Genus *Safisaur*, named in honor of Amtyaz Safi, Department of Zoology at Diwan Diyaram Jethmal (D.J.) Sindh Government Science College, affiliated with the University of Karachi, Pakistan. He is involved in this discovery and the naming of the *saur* for lizards/reptiles. The genus name *Safisaur* is pronounced as "*Safi-saur*." The species name, *Safisaur niazensis*, Niaz Muhammad, an Associate Professor in the Department of Microbiology at Kohat University of Science and Technology (KUST), for his contributions to this discovery and fossil collections. The species name *Safisaur niazensis* is pronounced as "*niaz-ensis*."

3.2 Diagnosis and Comparison

From the Kohat Development Authority (KDA) area of Kohat (Figures 1-3), several new fossil bones (Figures 4-9) were discovered, possibly from the Mesozoic strata (Figures 10 and 11). These bones were found in sedimentary materials within the Kohat Development Authority (KDA), Kohat. Some preliminary details and reports with pictures of these fossils were documented by Malkani et al. (2025a-d; Malkani, 2025a). They belong to the Middle to Late Jurassic strata (Figures 9-10). Such strata are commonly found in the core and limbs of the Samana Range and the Kohat area. The Samana Range is located in the northern part of Hangu District in KPK province. The strata of the Samana Range extend eastward beyond Kohat and Darrra Adam Khel and continue further east to Cherat and the Kala Chita area. The newly identified holotype, a neural arch (Figures 4-9), is highly pneumatic—a feature also observed in Maastrichtian neural arches from Balochistan. Its size similarly matches that of Maastrichtian

neural arches from Balochistan. The cross-sectional shape of the diapophysis on the dorsal vertebra also resembles that typical of the Latest Maastrichtian vertebral diapophysis. Additionally, a possible femur (Figure 7) is large and aligns with that of herbivorous dinosaurs. Fragmentary bones, mainly vertebral and occasionally limb elements, have become the basis for identifying *Safisaur niazensis*, a dicraeosaurid (Flagellicaudata; Diplodocoidea) sauropod dinosaur from the Jurassic strata, most likely the Middle Jurassic red member of the Shinawari Formation (Malkani, 2025a; Malkani et al., 2025b; Malkani, 2025a). *Safisaur niazensis* displays a V-shaped gap at the base of the two limbs of the bifid neural spine, with the limbs parallel to each other. Most of the middle and upper portions of the limb of the bifid neural spines are broken. It is the first dinosaur discovered from Khyber Pakhtunkhwa Province of Pakistan and the first Dicraeosauridae (Diplodocoidea) from Pakistan. From India, the first Dicraeosaurid diplodocoid *Tharosaurus indicus* was reported in 2023. The Indus Basin contains Mesozoic and Cenozoic oceanic and continental sequences (Malkani 2010; Karl et al., 2024, 2025) (Figures 10-11). *Safisaur* shares features with dicraeosaurids (Flagellicaudata), such as *Tharosaurus indicus*, *Lingwulong*, *Brachytrachelopan*, and *Pilmatueia*. All these taxa show common traits, including the deep bifurcation of cervical neural arches extending up to the dorsal margin of the neural canals, a bifid middle/posterior cervical neural spine, and a laterally directed middle/posterior dorsal transverse process. The diagnostic characteristics of this sauropod include automorphic features at a high taxonomic level shared with all known sauropods (Wilhite, 2005; Bonnan, 2005; Páramo et al., 2020; Rivera-Sylva and Espinosa-Arrubarrana, 2020). Several sauropod species classified within Diplodocoidea have fluctuated in and out of the clade. In Dicraeosauridae; the neural spines are bifurcated into two metapophyses in *Apatosaurinae*, and *Diplodocinae*. Dicraeosaurid cervical vertebrae tend to be smaller, lack deep pneumatic structures, and show dorsoventral elongation of the hemi-spinous processes, with extremes seen in *Amargasaurus* and *Bajadasaurus* (Van der Linden et al., 2025).

Safisaur niazensis is probably a medium-sized sauropod sharing characteristics with Diplodocidae, such as a shallow bifurcation of neural arches, more extensive pneumaticity, and complex pneumatic structures, particularly in neural arches and lateral expansion of each limb of the bifurcation in posterior dorsal vertebrae. *Safisaur niazensis* has a slightly broad and ventrally reduced caudal centrum, similar to the caudal centra of *Pilmatueia faundezi* from the Early Cretaceous of Argentina and *Brachytrachelopan mesai* from the Late Jurassic of Argentina, while *Tharosaurus* from India has a tall centrum (Coria et al., 2019; Rauhut et al., 2005; Bajpai et al., 2023). *Safisaur* has an expanded distal limb of the bifurcated neural spine of the anterior cervical, similar to MOR 592 Diplodocidae species and ANS 21122 *Suuwasseea* diplodocid (Harris and Dodson, 2004; Harris, 2006). But *Safisaur* has a subcircular terminal limb expansion (Figure 8, row 3, p1) of a bifurcated neural spine of anterior cervical vertebrae, while MOR 592 Diplodocidae species and ANS 201122 *Suuwasseea* have a subtriangular shape of the terminal limb. *Safisaur* features a shallow (dorsally emarginated) bifid neural spine bifurcated into two limbs that are closely aligned, with a medial cavity more reduced than in *Amargasaurus* from Argentina (Salgado and Bonaparte, 1991). In contrast, *Dicraeosaurus* from Tanzania, Africa (Janensch, 1914), and *Pilmatueia* have V-shaped, broad two limbs of spines and a broad, V-shaped medial cavity (Coria et al., 2019). *Safisaur niazensis* shows a relatively broader medial cavity between the two limbs of the bifid neural spine, whereas *Suuwasseea emilieae* a diplodocid from the Jurassic of Montana, USA, has a more closed medial cavity (Harris and Dodson, 2004). The two limbs of the bifid neural spine in *Safisaur niazensis* are tightly closed and directed dorsally towards each other, like those of *Suuwasseea emilieae* ANS 201122 diplodocid from Montana, USA (Harris and Dodson, 2004) and MOR 592 Diplodocidae species whereas in *Apatosaurus* and *Diplodocus*, the limbs are more spaced and directed dorsolaterally (Harris, 2006; Woodruff and Fowler, 2012). The limbs are tight in *Safisaur niazensis*, as well as in *Suuwasseea emilieae* and MOR 592 Diplodocidae species, but broader and more transverse in *Diplodocus* and *Apatosaurus* (Harris, 2006). The bifurcation of the neural spine in *Safisaur* is shallow and starts just above the dorsal margin of the diapophyses of posterior cervical or anterior dorsal vertebrae, similar to *Diplodocus*, *Apatosaurus*, and *Suuwasseea*, whereas in *Dicraeosaurus*, the bifurcation starts below the dorsal margin of the diapophyses of the anterior dorsal vertebra (Harris, 2006). The cross-section of each limb of the bifid neural spine in *Safisaur*'s posterior cervical or anterior dorsal vertebra is triangular, whereas it is elliptical in dicraeosaurids. *Safisaur* exhibits more extensive internal pneumaticity, similar to diplodocids, unlike the reduced pneumaticity seen in dicraeosaurids. The limbs are tight in *Safisaur niazensis*, more so in CM 555 *Apatosaurus excelsus* and looser in CM 84 (Woodruff and Fowler, 2012; Woodruff and Fowler, 2012). *Safisaur* has robust, sub-triangle-shaped bases (with a thicker medial portion) of each limb of the bifid spines. The distal ends of each bifid spine in posterior cervical or anterior

dorsal vertebrae are not expanded in *Safisaur* (Figure 4-9), unlike in diplodocid MOR 592 (Woodruff and Fowler, 2012). However, *Safisaur*'s distal ends are strongly laterally expanded, similar to MOR 592 (Woodruff and Fowler, 2012). Additionally, *Safisaur* may have a thoracic distal rib with a rounded end, exhibiting dorsoventral convexity on the lateral dorsal side. The chevron of *Safisaur* is transversely compressed, with two tightly oriented, robust processes. The robust metatarsal I (trapezoid-shaped, Figure 8) resembles *Suuwassea emilieae*, but *Safisaur*'s metatarsal I is more pneumatic.

3.3 Description

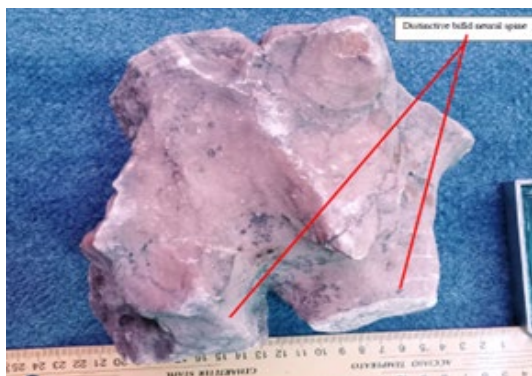
Axial elements: The collected axial elements include partial cervical, dorsal, and caudal vertebrae, neural arches, a distal thoracic rib, and a chevron (Figure 8). Some vertebrae, including centra with transverse processes, were identified (Figure 8). The centra are broad and feature transverse processes. One anterior caudal centrum (Figure 8) is broad, pneumatic, ventrally reduced, and has transverse processes laterally, along with chevron facets ventrally. Other centra (Figure 8) are also broad and pneumatic with transverse processes, though their parapophyses are unclear due to damage. The transverse processes are nearly horizontal and blunt. The centra are either ventrally concave or arced (Figure 8-9). One centrum of *S. niazensis* is slightly broad and somewhat ventrally reduced (Figure 8), similar to those of *Pilmateuia faundezi* from Argentina, while *Tharosaurus indicus* from India has a broader centrum without ventral reduction (Bajpai et al., 2023; Coria et al., 2019). The transverse processes in *S. niazensis* are nearly horizontal, whereas in *T. indicus* from India, they are curved downward (Bajpai et al., 2023). The neural canal of *S. niazensis* appears broader than that of *T. indicus*. The most complete neural arch (Figure 8) of a posterior cervical or anterior dorsal vertebra includes an articulated partial bifid neural spine, postzygapophyses, prezygapophyses, and diapophysis. The bifurcated neural spine is an important phylogenetic feature in Diplodocoidea due to its widespread occurrence (Woodruff and Fowler, 2012). Bifurcation is absent or just beginning in juveniles, but is well developed in adults (Woodruff and Fowler, 2012). In *S. niazensis*, the bifurcation is well developed, indicating an adult specimen. Additional pneumaticity in *S. niazensis* also supports its maturity. The bifid neural spine in *S. niazensis* has two thick limbs medially, whereas in *T. indicus*, the limbs are thick laterally (Bajpai et al., 2023). *S. niazensis* shows a robust, roughly triangular base with a thickened medial portion and bifid spine limbs. The neural spine branches in *Safisaur* are narrowly bifurcated. In *S. niazensis*, the two limbs of the bifid neural spine are separated by a medial cavity, but in *T. indicus*, the two parts are not separated by such a cavity (Figure 4) (Bajpai et al., 2023). Diapophyses are also found laterally on this neural arch. The prezygapophyses and postzygapophyses are subcircular (Figure 8). A distal part of a bifid neural spine limb from an anterior cervical vertebra (Figure 8) is subcircular and more expanded. In posterior cervical and anterior dorsal vertebrae, the distal parts of bifid neural spine limbs are straight and less or not expanded, with the posterior dorsal vertebrae limbs typically expanded laterally. A distal rib is rounded with a dorsal-ventral convexity on one side. The left and right post-zygapophyses of the cervical vertebrae are sub-circular, as they are away from the mid-line. The robust diapophysis of a cervical vertebra (Figures 4-8) is well developed. The chevron, which is transversely compressed, features two transversely compressed processes. Many features are compared above.

Limb elements: The limb elements include a proximal femur and a metatarsal I. The proximal femur is poorly recognized, based mainly on a greater trochanter-like inclination and a medial curvature. Metatarsal I is spongy, robust, and trapezoid-shaped, resembling the metatarsal of *Suuwassea emilieae* a diplodocid, but is more pneumatic. Its lateral side is more antero-posterior than the medial side (Harris and Dodson, 2004). The proximal articular surface is inclined mediodorsally, and the posterior surface is inclined medially, leading to a shorter medial antero-posterior length compared to the lateral, giving it a trapezoid shape.

Figure 4: A holotype (KUST-DM-NM-1/2025) (Neural arch) of *Safisaur niazensis*, found fragmentarily from the Kohat Development Authority (KDA) area of Kohat, Khyber Pakhtunkhwa, Pakistan. (Scale bar is 20 cm).



Figure 5: Holotype of *Safisaur niazensis* (Neural arch), different views (Dorsal, lateral, and posterior views). Scale bar is in cm.



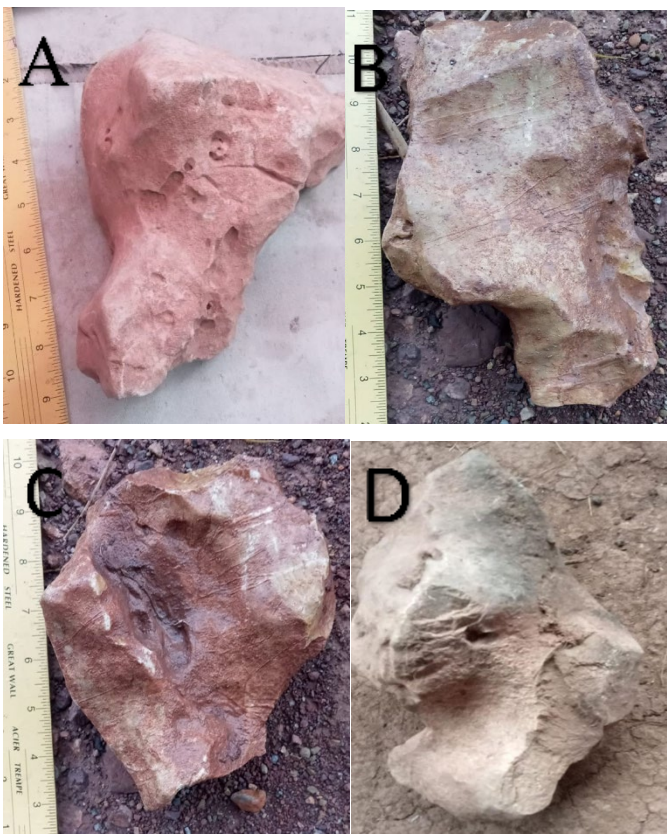


Figure 6: Holotypic materials of *Safisaur niazensis*, A. Laterally expanded distal limbs of bifid neural spines of posterior dorsal vertebra; B. diapophysis of possible posterior cervical/anterior dorsal; C. sub-circular distal neural spine limb of anterior cervical vertebra; D. Chevron. (Scale is in cm).

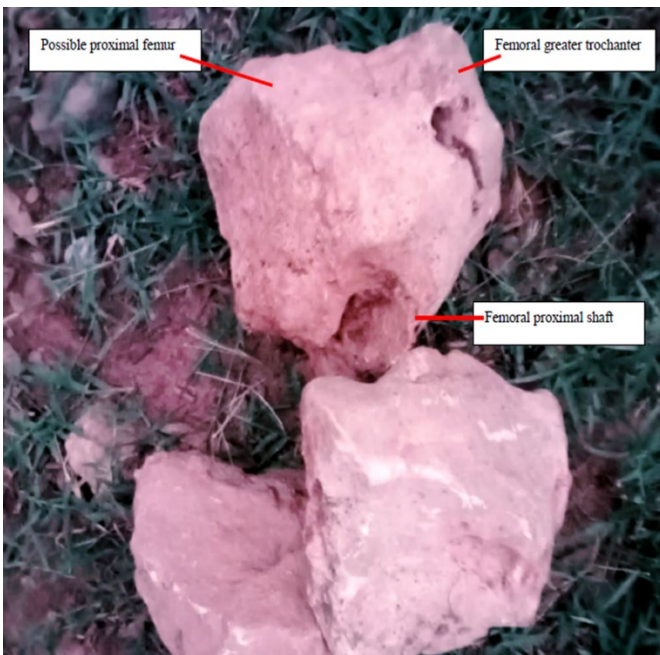


Figure 7: *Safisaur niazensis* (proximal femur).

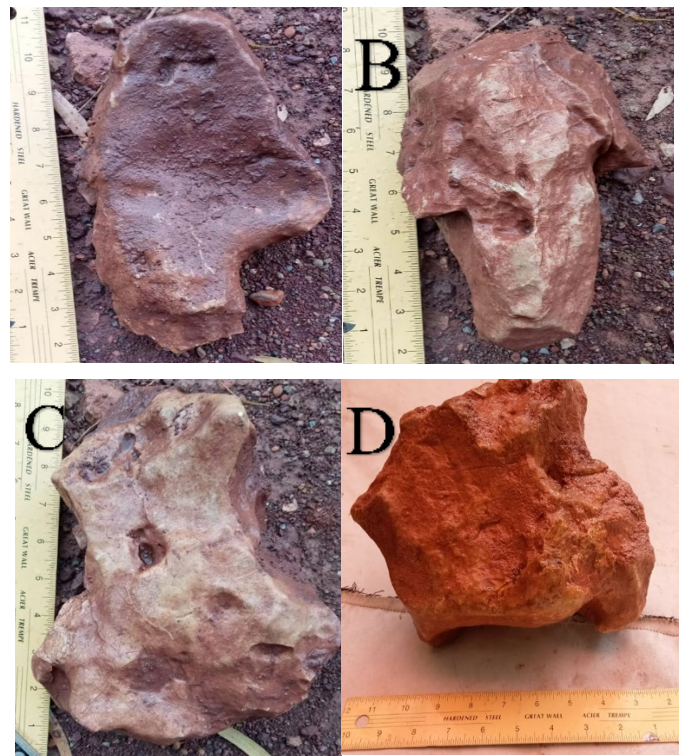


Figure 8: *Safisaur niazensis*, new genus and new species, holotypic materials (KUST-DM-NM-1/2025), A. Distal thoracic rib; B. Distal neural spine limb (not expanded) of bifid spines of posterior cervical/anterior dorsal vertebra; C. Metatarsal I; D. A cervical vertebra of Diplodocidae (Scale is in cm).

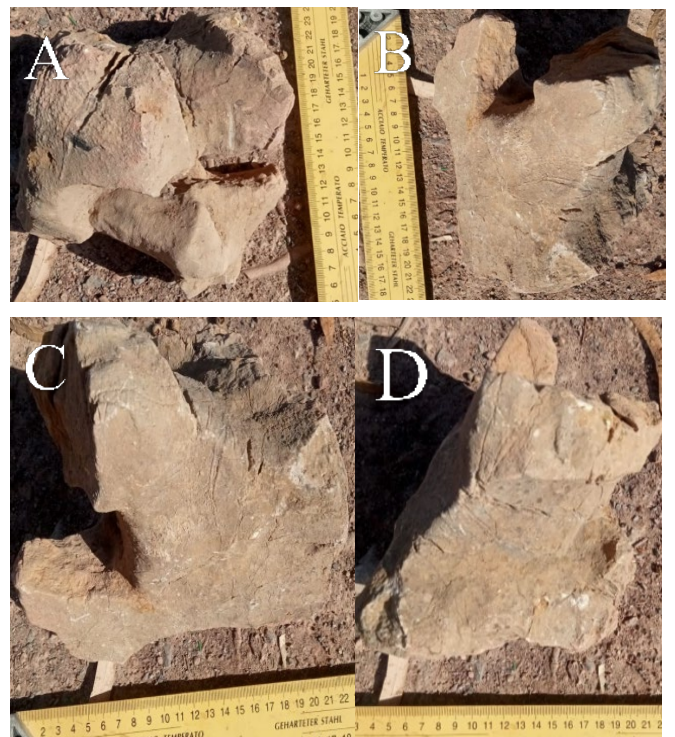


Figure 9: *Safisaur niazensis*, new genus and new species, holotypic materials (KUST-DM-NM-1/2025), A. a Centrum; B and C. A partial neural arch having the bifurcated typical neural spine; D. A possible fossil of *Safisaur niazensis* (Scale is in cm).

A

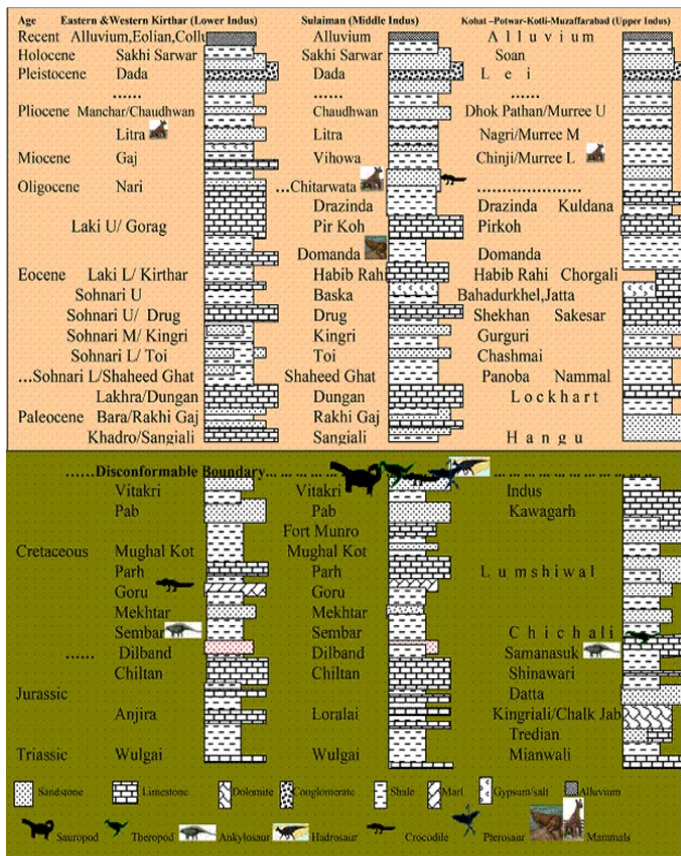


Figure 10: Revised Stratigraphic Correlation chart (with major vertebrates) of North/Upper Indus (Kohat-Potwar-Kotli-Muzaffarabad) Basins, Middle Indus (Sulaiman) Basin, and South/Lower Indus (Eastern and Western Kirthar) Basin of Pakistan (Malkani and Mahmood, 2016, 2017; Malkani, 2025; Malkani et al., 2025).

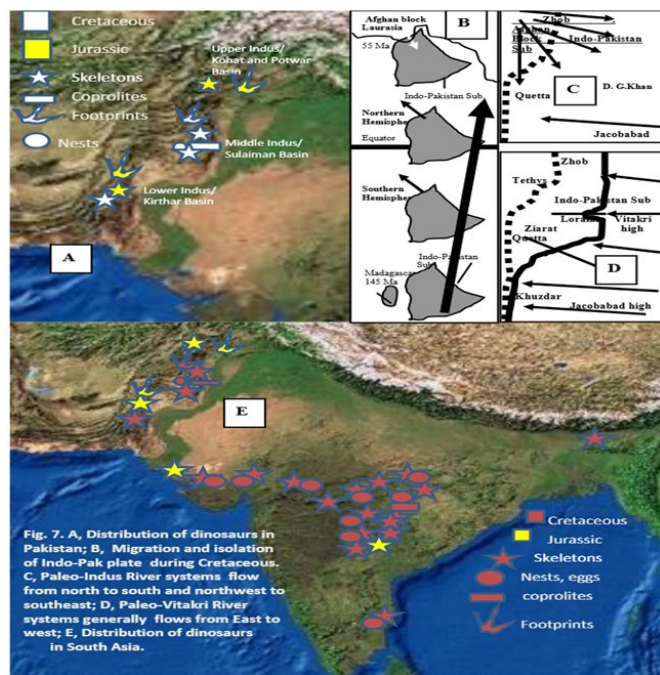


Figure 11: A, Distribution of dinosaurs in Pakistan; B, Migration, and isolation of the Indo-Pak plate during the Cretaceous. C, Paleo-Indus River systems flow from north to south and northwest to southeast; D, Paleo-Vitakri River systems generally flow from East to west; E, Distribution of dinosaurs in South Asia (Figures updated after: Sahni, 2001; Malkani, 2015, 2025c).

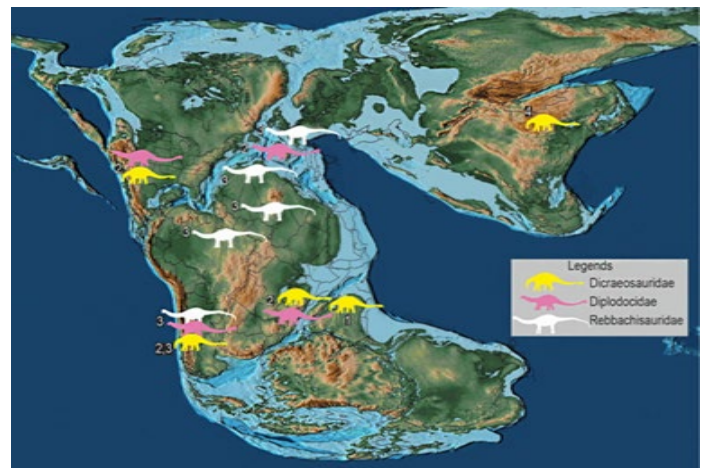


Figure 12: Paleogeographic distribution of diplodocoids with taxa of different ages plotted together in a simplified Middle Jurassic (170 Ma) map to show their spatio-temporal distribution across Pangea. Silhouettes indicate the type of diplodocoid and fossil occurrences. Numbers adjoining saurpods silhouettes indicate age of the fossils as follows: 1—Middle Jurassic (early-middle Bathonian); 2—Late Jurassic; 3—Cretaceous; 4—Middle Jurassic (Callovian). Palaeogeographic map after Scotese, 2016, and sourced from <https://www.earthbyte.org/paleomap-paleoatlas-for-plates/> Source of information on saurpods distribution from the Paleobiology database (<https://www.paleobiology.org/>) and Ren et al. 2023 (Bajpai et al., 2023).

4. DISCUSSIONS

The bifurcation of the neural spine is an unusual feature found in the cervical and dorsal vertebrae of some neosauropods (Hatcher, 1901). Bifurcated neural spines are a phylogenetically distinctive trait of Diplodocoidea (Woodruff and Fowler, 2012). The shallow bifurcation of the neural arch in *Safisaur* also aids in assigning it within Diplodocidae, as a deep bifurcation is observed in Dicraeosauridae. *Safisaur niazensis*'s bifurcated neural spines are shallow, similar to those of other diplodocids. *S. niazensis* (Figures 4-8) closely resembles MOR 592 diplodocid based on features such as the sub-circular and expanded distal ends of each limb of the bifid neural spine in the anterior cervical region the close proximity of two elongated limbs with a short, thin medial cavity in the bifid neural spine of posterior cervical vertebrae (Woodruff and Fowler, 2012); two elongated, non-expanded distal parts of each limb in the bifid neural spine of the anterior dorsal region (Woodruff and Fowler, 2012); shape of the diapophysis process in the cervical vertebra (Woodruff and Fowler, 2012); and especially, the laterally expanded, two elongated limbs of the bifid neural spine in the posterior dorsal region (Figure 8 of (Woodruff and Fowler, 2012; (Woodruff and Fowler, 2012). *Safisaur* has broad centra (Figure 8) whereas MOR 592 diplodocid has slightly taller centra (Woodruff and Fowler, 2012; Malkani, 2025c). Most of the cervical and dorsal features of *S. niazensis* closely resemble MOR 592 (a species of Diplodocus, diplodocid from the Late Jurassic Morrison Formation of North America), primarily differing from *Amargasaurus* and *Dicraeosaurus*. The robust metatarsal I of *Safisaur niazensis* (row 4, p5 of Figure 8 closely resembles that of *Suuwassea emilieae* (Harris and Dodson, 2004; Woodruff and Fowler, 2012; Malkani, 2025c). *Suuwassea emilieae* was also classified as a diplodocid thus, the link for *Safisaur* also points toward a diplodocid classification (Harris, 2006). *Safisaur* exhibits more extensive internal pneumaticity and complex pneumatic structures—especially in neural arches—similar to those of diplodocids, while dicraeosaurids generally lack pneumaticization in dorsal and caudal vertebrae, though some internal chambers (reduced pneumaticity) are present at the base of the neural spine or in certain cervical vertebrae. Therefore, *Safisaur* is considered a diplodocid. Diplodocids are not known from India (Sahni, 2001). Previously, a claim of the first diplodocid from Asia was based on a caudal vertebra which was later reinterpreted as titanosauriform (Whitlock et al., 2011; Upchurch and Mannion, 2009). If this interpretation is correct, then *Safisaur* extends the distribution and the middle Jurassic time range of Diplodocids, aiding in understanding their evolution and dispersal. *Safisaur* is the first diplodocid dinosaur discovered in Pakistan and also the first from the Indo-Pakistan subcontinent and Asia. As the oldest diplodocid found in Pakistan, *Safisaur* provides valuable insights into the radiation and dispersal of this group globally.

Diplodocoids, which were previously recognized outside of North America, were discovered in the Tendaguru Formation of Tanzania who identified two sauropods, one of which was *Gigantosaurus africanus* by

(Janensch, 1914). The taxonomic history of "*Gigantosaurus*" is very complex, but the outcome is that the species described by Janensch is currently known as *Tornieria africana* and identified as a diplodocine (Remes, 2006). The second one was named *Dicraeosaurus hansemanni*, the first representative of the diplodocoid family Dicraeosauridae. The clade Dicraeosauridae was first coined and is defined as all taxa more closely related to *Dicraeosaurus* than *Diplodocus* (Sereno, 1998; Huene, 1927). The first described genus was *Dicraeosaurus* of which there are two recognized species, *D. hansemanni* and *D. sattleri*, both from the Upper Jurassic period from the "Tendaguru Formation" of Tanzania (Janensch, 1914). Both of these species were differentiated in the robustness of their bones of limbs and geological age. *D. hansemanni* is represented by an almost complete specimen, with all areas of the skeleton preserved, excluding the lower forelimbs and some parts of the skull, while *D. sattleri* material consists of fragmentary bone remains, tail vertebrae, and some of the upper limb bones. *Dicraeosaurus* was the only genus included within Dicraeosauridae for 90 years, until the 1991 description of *Amargasaurus cazaui* from the Early Cretaceous of Argentina. Since then, a further 8 species have been recovered as dicraeosaurids (Salgado and Bonaparte, 1991). The holotype of *Dicraeosaurus hansemanni* is made up largely of a single articulated individual from quarry m within the Tendaguru area (Janensch, 1914). Isolated remains of *D. hansemanni* have been found in numerous quarries across the Middle Dinosaur Member of the Tendaguru Formation, with all skull material having been found in a single quarry. The holotype of *D. sattleri* consists of material Lingwulong shenqi from the Middle Jurassic of Lingwu, China, and is known from the materials of multiple individuals and referred material, and includes the basicrania, teeth, and all post-cranial regions (Xu et al., 2018). It has consistently been recovered as a basal member of Dicraeosauridae (Xu et al., 2018; Bajpai et al., 2023).

Pilmatueia faundezi from the Lower Cretaceous Mulichino Formation of Argentina was first described based on a posterior dorsal vertebra and dorsal neural arch, a partial cervical vertebra, and two mid-caudal vertebrae. It was recovered in a derived position within Dicraeosauridae as the sister taxon to *Amargasaurus* (Coria et al., 2019). Subsequent studies identified *Pilmatueia* as belonging to a sister group of the clade including *Dicraeosaurus*, *Amargasaurus*, and *Brachytrachelopan* (Bajpai et al., 2023). The study described three articulated cervical vertebrae, seven dorsal vertebrae, a caudal vertebra, and a scapula belonging to *Pilmatueia* and scored the taxon in matrices from both and Whitlock and Wilson Mantilla (2020; Windholz et al., 2022; Tschopp and Mateus, 2017). From the matrix, *Pilmatueia* formed a polytomy with *Amargatitanis* and *Bajadasaurus*, with *Amargasaurus*, *Brachytrachelopan*, and *Dicraeosaurus* as successive branches (Tschopp and Mateus, 2017). The analysis matrix resolved *Pilmatueia* in a group with *Suuwasseea* and *Amargatitanis*, as the sister group to the clade containing *Amargasaurus*, *Brachytrachelopan*, and *Dicraeosaurus*. *Bajadasaurus pronuspinax* from the Lower Cretaceous Bajada Colorada Formation in Argentina, includes a partially complete skull, proatlases, atlantal neuropophyses, axis, and a mid-cervical vertebra from a single individual (Whitlock and Mantilla (2020; Gallina et al., 2019; Garderes et al., 2023). This Research identified the species as a sister taxon to a group containing *Pilmatueia* and an unresolved grouping of *Dicraeosaurus*, *Amargasaurus*, and *Brachytrachelopan* (Gallina et al., 2019). Later analyses placed *Bajadasaurus* in various positions basal to the group of *Amargasaurus*, *Brachytrachelopan*, and *Dicraeosaurus* (Whitlock and Mantilla, 2020; Windholz et al., 2022; Bajpai et al., 2023). The most recently described dicraeosaurid, *Tharosaurus indicus* (Bajpai et al., 2023), from the Middle Jurassic Fort Member of the Jaisalmer Formation in India—the first from the subcontinent—is known from partial mid/posterior cervical vertebrae, a partial dorsal neural arch, dorsal neural spines, dorsal ribs, and partial caudal vertebrae. It was recovered as a sister taxon of a clade containing *Pilmatueia*, *Amargatitanis*, *Brachytrachelopan*, *Dicraeosaurus*, and *Amargasaurus* (Bajpai et al., 2023). Its inclusion so far in only a single analysis and the fragmentary state of the specimen mean that more evidence is necessary to confirm its position within Dicraeosauridae.

The earliest clear diplodocoid sauropod remains include the dicraeosaurid Lingwulong from the Middle Jurassic of China along with the subcontinental diplodocoid *Tharosaurus indicus* from the Middle Jurassic of India (Bajpai et al., 2023; Xu et al., 2018). The fragmentary nature of *Tharosaurus indicus* raises doubts about its dicraeosaurid affinities and the origins of Diplodocoidea (Van der Linden et al., 2025). Other remains from the Callovian (latest Middle Jurassic) of western Eurasia may also be ambiguous diplodocoids (Averianov and Zverkov, 2020). Fragmentary limb fossils from the Bathonian-Callovian of Mexico have been attributed to Flagellicaudata (Rivera-Sylva and Espinosa-Rubiarrena, 2020). An isolated tooth from the Bathonian of Madagascar has also been suggested as a possible diplodocoid but identifying isolated teeth can be problematic (Bindellini and Dal Sasso, 2021). The Upper Jurassic Morrison Formation

(Kimmeridgian-Tithonian) in North America is particularly rich in species, including diplodocids like *Amphicoelias*, *Apatosaurus*, *Barosaurus*, *Brontosaurus*, *Diplodocus*, *Galeamopus*, and *Supersaurus* (Jensen, 1985; Cope, 1877b; Marsh, 1877; Marsh, 1890; Marsh, 1879; Tschopp et al., 2015; Marsh, 1878; Tschopp and Mateus, 2015; Tschopp et al., 2017). It also includes dicraeosaurids such as *Dyslocosaurus*, *Smithanosaurus* and *Suuwasseea* as well as the putatively basal diplodocoid *Haplocanthosaurus* the possible rebbachisaurid *Maraapunisaurus* and flagellicaudatan *Kaatedocus* (Tschopp and Mateus, 2013, 2017; Tschopp et al., 2015; Whitlock and Mantilla, 2020; Tschopp et al., 2015; Marsh, 1889; Whitlock and Mantilla, 2020; Harris and Dodson, 2004; Whitlock, 2011a; Whitlock, 2011; Woodruff and Foster, 2014). The Late Jurassic record of Portugal includes the diplodocid *Dinheirosaurus* (Bonaparte and Mateus, 1999; Mannion et al., 2012, Tschopp et al., 2015, Mannion et al., 2019, and Whitlock and Mantilla, 2020). Some diplodocoid fossils from the Late Jurassic are also known from Spain and Georgia (Mannion et al., 2012).

The dicraeosaurid record is much richer, however, boasting the Early Cretaceous taxa *Amargasaurus*, *Amargatitanis*, *Bajadasaurus*, and *Pilmatueia*, comprising roughly one-third of known dicraeosaurid diversity (Salgado and Bonaparte, 1991; Gallina, 2016; Whitlock and Mantilla, 2020; Gallina et al., 2019; Coria et al., 2018). Rebbachisaurids primarily flourished in South America during this time, including two taxa from Brazil, the Aptian-Albian-aged *Amazonsaurus* and the *Cenomanian Itapeuasaurus* (Lindoso et al., 2019; Carvalho et al., 2003).

The cranial remains of *Dicraeosaurus hansemanni*, from the Tendaguru beds (Upper Jurassic) of Tanzania, and those of *Amargasaurus cazaui*, from the Lower Cretaceous La Amarga Formation of Argentina, suggest that dicraeosaurids were adapted for low to mid-level browsing (Schwarz et al., 2015; Janensch, 1914; Salgado and Bonaparte, 1991). This corresponds with their general small to medium body size, as exemplary body size estimates reach between 9 m in *Amargasaurus* and 12 m in *Dicraeosaurus*, as well as the comparatively small necks and more robust morphology in contrast to diplodocids (Gallina, 2022; Schwarz et al., 2015). As a study proposed that dicraeosaurids favored more forested ecosystems, rather than savannah-type ecosystems (Whitlock, 2011). A thoroughly studied dicraeosaurid regarding feeding strategies is *D. hansemanni* (Whitlock, 2011b; Schwarz et al., 2015). *D. hansemanni* is considered to be a mid-level browser, which is supported by the results of carbon isotope analysis by (Tütken, 2011). Researchers suggested that *D. hansemanni* fed specifically on lower mid-level foliage and speculated on the possible use of the tongue for feeding (Van der Linden et al., 2025; Schwarz et al., 2015).

The clade Dicraeosauridae is represented by nine taxa dating from the Middle Jurassic to the Early Cretaceous. The tree topology shows a late-diverging clade with mostly South American dicraeosaurids (*Pilmatueia*, *Amargatitanis*, *Brachytrachelopan*, and *Amargasaurus*) along with the African *Dicraeosaurus*, supporting a Gondwanan origin for this group (Bajpai et al., 2023). However, assigning immature specimens to specific taxa is challenging and some studies have questioned the validity of certain taxa (Tschopp et al., 2015; Woodruff, 2019). The lack of skeletal maturity and complete osteological development can result in missing key features (apomorphies), making clear taxonomic assignment difficult and sometimes leading to different phylogenetic placements (Tschopp et al., 2015). Similarly, the increasing skeletal pneumaticity and vertebral complexity occur through ontogenetic stages (Tschopp and Mateus, 2017; Woodruff et al., 2017). Evolutionary changes driven by heterochrony in developmental events appear to play a significant role in sauropod growth. These changes may also be related to shifts in ecological niches, with size influenced by available food resources (Woodruff et al., 2018). The scarcity of Middle Jurassic dinosaur fossils worldwide makes the sauropod material uncovered in the subcontinent especially important for understanding sauropod development. These specimens represent the osteological southeastern record of sauropods. The holotype and other related materials from the same horizon offer promising opportunities for future collection and study in the upper Indus Basins, contributing valuable data for interpreting the biogeography, diversity, and evolutionary patterns of the group.

5. CONCLUSION

Safisaur niazensis (KUST-DM-NM-1/2025) is the first recorded dinosaur from the Khyber Pakhtunkhwa Province of Pakistan and the first dicraeosaurid diplodocoidean sauropod discovered in the country. It is the second dicraeosaurid diplodocoidean sauropod found in the Indo-Pak subcontinent. The first dicraeosaurid diplodocoid from this region is *Tharosaurus indicus*, from the Jaisalmer Formation in the Thar Desert, Rajasthan, India, while the second is *Safisaur niazensis* from Kohat, Pakistan. The specimens collected are poorly preserved and fragmentary; they originate from the same horizon and were obtained through digging. Some fossils exhibit many recognizable bone features, whereas others are

less complete with fewer identifiable features. Diplodocoidea is a well-studied group of successful sauropods, but many questions remain regarding inter- and intraspecific variation, ontogeny, and the discovery of new taxa. Our goal is to shed light on the origin and paleontology of this diplodocoid sauropod, as well as its ecology and evolution. This report details recently discovered paleontological sites, a new titanosaur, and updates on findings, including the first dinosaur identified from Khyber Pakhtunkhwa Province, Pakistan, and the first diplodocid dinosaur from Indo-Pakistan and Asia. More geological and paleontological exploration is necessary to recover additional bones from the dumped materials and host bed rocks, and to resolve the stratigraphic position and age of *Safisaur niazensis*. Further research on the paleo-bio-geography and paleo-phylogenetics of these Pakistani dinosaur fossils should be conducted soon to clarify their precise evolutionary relationships.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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