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Comparative Analysis of the Dinosaur Record of Pakistan with World Dinosaurs as Diversity and Paleobiogeography Implications

Anees Ahmed Shah[1], Rana Mehroz Fazal[2], Innayat Ullah Malik[3]

1 Department of Zoology, University of Education, D.G Khan Campus. **Corresponding Author:** aneesahmedkazmi@gmail.com & mss24000202@ue.edu.pk

[2,3] Department of Zoology, Ghazi University, D.G Khan.. rfazal@gudgk.edu.pk, iullah@ gudgk.edu.pk

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Abstract

Pakistan dinosaur diversity was once poorly known but this record is now considered a significant part of Gondwanan paleontology. Recent discoveries of fossils especially from Baluchistan have revealed a rich variety of dinosaurs. These include Late Jurassic to Late Cretaceous titanosaurian sauropods. Theropod dinosaurs and track based ichno taxa also found. This study accumulates present data of dinosaur diversity geographic distribution and geological context in Pakistan. It is based on important fossiliferous sites of Pakistan such as the Pab Formation and the Sembar Formation. The most common group in this record is the titanosaurs. They are represented by the genera *Balochisaurus*, *Pakisaurus* & *Sulaimanisaurus*, *Vitakridrinda* & *Vitakrisaurus*. They are also known from theropods which were active hunters of their era. Dinosaur trackways have been reported from at many sites including Mianwali, Zhob and the Potwar Plateau. These findings show that Pakistan is an important region for understanding dinosaur paleoecology and biogeographic links with Gondwana. Further research is needed in Pakistan to improve taxonomy and support the evolutionary interpretations.

Keywords: Pakistan Dinosaur, Titanosauria, Theropoda, Vitakri Formation, Pab Formation, Dinosaur Trackways, Gondwana, Paleontology

Introduction

The history of dinosaurs in Pakistan is much far the formation that found in present day landscapes. In Mesozoic times the area formed part of the northern side of Gondwana land. At that time the landscape was dominated by the large river systems broad also floodplains and coastal areas. These conditions provided a good living environment for many genra of dinosaur. Pakistan remain largely far away from global paleontological study for many decades. This changed in the late twentieth century with systematic field work. Field surveys gradually revealed the existence of important fossil resources in various parts of the country. So now Pakistan has become a progressively important area for the study of dinosaur diversity and evolution in South Asia.

The importance of the dinosaur record in Pakistan is not only limited to the discovery of new species but it is also linked to its paleo history. During the Late Jurassic and Cretaceous the Indian subcontinent including present day Pakistan was part of Gondwana main land. Over time it moved northward and later collided with Eurasia **(**Böhme, M. 2003). This tectonic movement played an important role in shaping the distribution of dinosaur fauna. It is suggested that dinosaurs from Pakistan show evolutionary relationships with those from India, Madagascar and South America (Wilson et al., 2011; Benton, 2015). Because of this connection the study of Pakistani dinosaurs provides useful information about Gondwanan biogeography and patterns of dispersal among ancient land masses (Brett-Surman. et al., 2012)

Early records of dinosaur fossils in Pakistan were limited and mostly based on fragmentary parts. This initial finding provided little detail about the overall diversity of dinosaurs in the region. But situation changed with more systematic fieldwork especially in Balochistan province of Pakistan that has Bugti formation. Such research improved the understanding of the fossil record. Muhammad Sadiq Malkani is senior paleontologist that played key role in dinosaur research. By detailed field surveys and excavation work many dinosaur bearing sites were identified. The most important of these are located in the Vitakri area of Barkhan District. These efforts led to the identification of several new genera and species including titanosaurian sauropods and theropod dinosaurs (Malkani, 2006; 2015a). Geological setting of Pakistan influences the conservation of dinosaur fossils (Carrano.et al., 2002). Most of the discoveries are from the sedimentary rock sequences of the Sulaiman range Basin. The Pab Formation is an important fossiliferous site that has Vitakri formation of Maastrichtian age. These deposits are mainly made up of sandstone mudstone and shale. These were deposited in river and delta. Such conditions also preserved the remains of dinosaurs and also supported their life. Older rocks also contain important evidence of dinosaur fossils (Holtz, T. R. 2012). The Late Jurassic Sembar Formation shows an earlier presence of dinosaurs in this region. It extends the known time range of dinosaurs in Pakistan and suggests that they lived over a long geological interval of time (Malkani, 2006).

One of the most prominent features of Pakistani dinosaurs is the dominance of titanosaurian sauropods (Malkani, M. S. 2021a). These large herbivorous dinosaurs are characterized by long necks and tails. These are represented by several taxa including *Balochisaurus malkani*, *Pakisaurus balochistani*, *Marisaurus jeffi* and *Sulaimanisaurus gingerichi*. The diversity of titanosaurs suggests that they occupied a long range of ecological niches. These were possibly different in feeding strategies also body size and habitat selection. The presence of osteoderm bearing forms such as *Gspsaurus* further indicates defensive adaptations among these herbivores (Malkani, 2015b). Theropod dinosaurs are less common in Pakistani fossil record than the abundant sauropods but still very important for understanding the ecosystem (Hussam.et al., 2011). These carnivorous dinosaurs include as *Vitakridrinda sulaimani* and *Vitakrisaurus saraiki*. Their presence indicates that active predatory groups existed along with herbivorous dinosaurs. These theropods probably were on different trophic levels. Larger species may have been apex predators while smaller forms probably had more specialised feeding strategies and ecological niches (Malkani, M. S. 2014a, 2014b). The coexistence of several theropods and different sauropods shows a rich and organised ecosystem in the Late Cretaceous (Jain, S. L., & Bandyopadhyay, S. 1997, Wilson et al., 2011).

Figure: 1. Bugti formation site, District Dera bugti.

An important aspect of Pakistan dinosaur record is the occurrence of ichnofossils particularly trackways (Karanth, K. P. 2021: Karl et al., 2021, 2024). Unlike skeletal remains trackways preserve direct evidence of behaviour including locomotion group movement and substrate interaction. Ichnotaxa such as Malakhelisaurus mianwali Pashtosaurus zhobi, Samanadrinda surghari and Himalayadrinda potwari have been reported from various localities extending the known distribution of dinosaurs beyond the body fossil localities. Trackways can be particularly useful in environments where skeletal remains are rare providing complementary data for paleoecological reconstructions (Klaus et al., 2016).The geographical distribution of dinosaur fossils in Pakistan is concentrated in Balochistan. The main area is the Vitakri Dome and adjacent areas of the Sulaiman Range (Malkani, M. S. 2023a).The region is the key paleontological zone of the country and most of the known dinosaur taxa have come from the region (Mannion. et al., 2013). The distribution pattern is also extended by other fossil localities. These include the Kirthar Range Mianwali Zhob and the Potwar Plateau. These sites show that dinosaurs were not confined to one environment. Instead, they were spread across a range of environments from coastal plains to inland sedimentary basins. These important discoveries of dinosaurs in Pakistan are still at its infancy.

Many genra are based on just only fragments and broken material making correct classification and phylogenetic analysis much difficult (Shah, A. A. 2026) The lack of advanced analytical techniques and the need for more extensive stratigraphic studies is limitation to understanding of the fossil record (Malkani, M. S. 2015b).Field work good collaboration and modern paleontological techniques will be needed to meet these challenges. In this perspective the present study attempts to rearrange the existing knowledge on diversity and geographic distribution of dinosaurs in Pakistan. It highlights the necessity of combining evidence from both skeletal remains and track ways to build a clear and complete picture of the dinosaur fauna of that area. It also provides a perspective on Pakistan's fossil record within the broader perspective of Gondwanan paleontology (Malkani, M. S. 2022). It also emphasizes the scientific importance of the country dinosaur bearing formations and their contributions to understanding ancient ecosystems. This study shows that the fossil record of Pakistan still holds great promise for future discoveries. More

field works may provide more insights into the evolutionary history and biogeography of dinosaurs in South Asia.

Geological Setting of Dinosaur Era

The dinosaur fossils in Pakistan are mainly associated with sedimentary succession of the **Sulaiman Range Basins.** The most significant formations are given bellow.

1. **Pab Formation. (Maastrichtian, Late Cretaceous)**
2. **Vitakri Member. (fossil rich subdivision of Pab Formation)**
3. **Sembar Formation. (Late Jurassic)**

These formations consist of sandstones mudstones and shales deposited in formations. Such depositional facilitated the preservation of both skeletal remains and trackways. The Vitakri Members in area represents an important fossil bearing site and wide range of dinosaur genres.

Materials and Methods

This study is based on a comprehensive review of published literature including primary descriptions of dinosaur genera from Pakistan. Knowledge obtained from geological surveys and paleontological reports. Taxonomic identifications are evaluated in light of comparative anatomy and stratigraphic occurrence. Both body fossils and ichnofossils are included to provide an overview of dinosaur diversity and distribution.

Dinosaur of Pakistan:

Table: 1. Different genera of dinosaur found in Pakistan

Dinosaur Name	Type / Classification	Key Features / Notes	Location / Formation	Reference (APA)
Balochisaurus malkani	Titanosaurian Sauropod	Robust femurs, broad caudal vertebrae	Vitakri Formation, Balochistan	Malkani, M.S. (2006). *Dinosaurs of Pakistan*. Pakistan Paleontology Journal, 3(2), 45–59.
Pakisaurus balochistani	Titanosaurian Sauropod	Known from caudal vertebrae	Vitakri Formation, Balochistan	Malkani, M.S. (2006).
Marisaurus jeffi	Titanosaurian Sauropod	Distinct, less broad caudal vertebrae	Vitakri Formation, Balochistan	Malkani, M.S. (2006).
Khetranisaurus barkhani	Titanosaurian Sauropod	Fragmentary vertebrae	Vitakri Formation, Balochistan	Malkani, M.S. (2006).
Sulaimanisaurus gingerichi	Titanosaurian Sauropod	Caudal vertebrae; large sauropod	Pab Formation, Balochistan	Malkani, M.S. (2006).
Gspsaurus	Titanosaurian Sauropod	Thick osteodermal armor plates	Vitakri Formation, Balochistan	Fossil Wiki (n.d.). *Gspsaurus*. Retrieved from https://fossil.fandom.com

Nicksaurus razashahi	Titanosaurian Sauropod	Distinct tooth arrangements	Vitakri Formation, Balochistan	Fossil Wiki (n.d.). *Nicksaurus*.
Saraikimasoom vitakriensis	Titanosaurian Sauropod	Short snout; small to medium size	Vitakri Formation, Balochistan	Fossil Wiki (n.d.). *Saraikimasoom*.
Vitakridrinda sulaimani	Abelisaurid Theropod	Carnivorous; femora & vertebrae known	Vitakri Formation, Balochistan	Malkani, M.S. (2006).
Vitakrisaurus saraiki	Noasaurian Theropod	Small theropod; fragmentary bones	Vitakri Formation, Balochistan	SCIRP (2020). *Dinosaur Fossils of Pakistan*. https://www.scirp.org
Brohisaurus kirthari	Sauropod (Late Jurassic)	Fragmentary bones; long-necked herbivore	Sembar Formation, Balochistan	ResearchGate (2023). *Fossil Records of Dinosaurs in Pakistan*.
Samanadrinda surghari	Theropod (Ichnotaxon)	Large carnivorous trackways	Balochistan	SCIRP (2020).
Malakhelisaurus mianwali	Titanosaur (Ichnotaxon)	Sauropod trackways	Mianwali region	SCIRP (2020).
Himalayadrinda potwari	Small Theropod (Ichnotaxon)	Small tridactyl tracks	Potwar Plateau	SCIRP (2020).
Pashtosaurus zhobi	Titanosaur (Ichnotaxon)	Sauropod tracks; locomotion info	Zhob region	SCIRP (2020).
Saraikisaurus minhui	Indeterminate / Possible Pterosaur	Dentary fossil; initially misidentified	Vitakri Formation	Wikipedia (n.d.). *Informally Named Dinosaurs*.

Discussion

The dinosaur record of Pakistan is still low but still provides a clear and comprehensible picture of Late Mesozoic Era along the northern margin of Gondwana plains. Diversity includes the Jurassic *Brohisaurus kirthari.* In the titanosaurian sauropods *Pakisaurus balochistani, Balochisaurus malkani, Marisaurus jeffi, Khetranisaurus barkhani*, *Sulaimanisaurus gingerichi, Gspsaurus pakistani*, *Nicksaurus razashahi* and *Maojandino alami*. The theropod group consist of *Vitakridrinda sulaimani*, *Vitakrisaurus saraiki*, *Samanadrinda surghari* and *Himalayadrinda potwari*. The Dinosaur fauna of Pakistan is also diversified by the pterosaur *Saraikisaurus minhui*. Most of this material is fragmentary and broken but it is sufficient for meaningful explanations. These fossils provide info to palaeoecology and evolutionary trends of dinosaurs in that region.

A prominent piece of the dinosaur fauna of Pakistan is titanosaurian sauropod. Many fossils are recovered belonging to titanosaur taxa in the Vitakri Member of the Pab Formation. It suggests that these herbivores were very abundant and taxonomically diverse. This diversity raises interesting ecological questions. I doubt many large sauropods lived together without some form of niche partitioning from each other. Differences in vertebral structure body proportions and feeding behaviour suggest that these dinosaurs used the available resources in different ways. Some may have fed on the higher vegetation, and others probably browsed in the middle and lower levels. This idea is also supported by small anatomical differences. Balochisaurus has more robust caudal vertebrae than the slenderer ones of Marisaurus. Such variation may reflect functional or ecological differences rather than simple taxonomic variation.

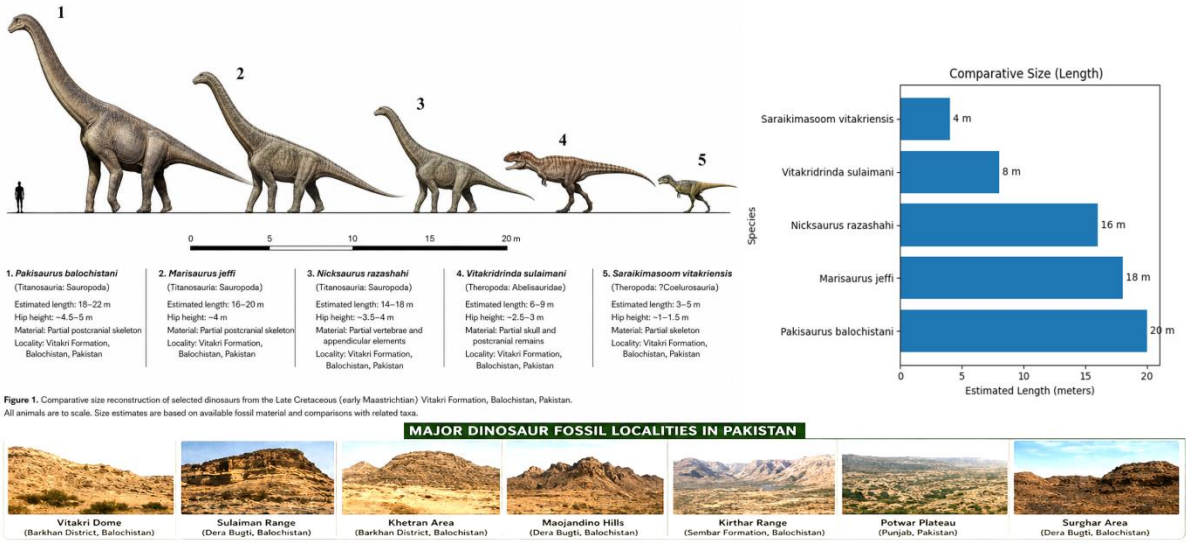

Figure 1. Comparative size reconstruction of selected dinosaurs from the Late Cretaceous (early Maastrichtian) Vitakri Formation, Balochistan, Pakistan. All animals are to scale. Size estimates are based on available fossil material and comparisons with related taxa.

Figure: 2. Comparison of different genra and localities.

The arrival of *Gspsaurus pakistani* adds an important new dimension to the ecosystem of Pakistan. This taxon is understood as a titanosaur with osteoderms. Dermal armour is rare in titanosaurs but has been reported in several lineages from Gondwana. Its presence here could be indicative of a local adaptation, possibly due to predation pressure or environmental stress. Other taxa such as *Nicksaurus razashahi* and *Maojandino alami* are poorly known. It should be noted that many of these taxa are based on broken and limited fossil material. Future discoveries may refine their classification or even lead to taxonomic revisions. The record of *Brohisaurus kirthari* from the Sembar Formation extends the time based record of sauropods in Pakistan. It shows that the dinosaurs already existed there in the area long before the Maastrichtian faunas of Balochistan. The fossil material referred to *Brohisaurus* is fragmentary. Its evolutionary position is undefined but its occurrence is nonetheless important. This suggests that sauropods likely lived in this area during a long geological period. Finding also suggests that earlier dinosaur groups may be undiscovered in Jurassic rock basins of Pakistan.

Theropod dinosaurs are rare in Pakistan's fossil record but important for understanding structure of the ecosystem. *Vitakridrinda sulaimani* is an abelisaurid that was probably a large predator. It compares with other Gondwanan abelisaurids known from India and Madagascar. Its presence indicates the existence of apex predators in this ecosystem. *Vitakrisaurus saraiki* is thought to be a smaller theropod possibly a noasaurid. It may have hunted small animals or eaten scavenged material. The difference in body size suggests an ecological separation between the carnivorous

dinosaurs. Such partitioning would have reduced competition and allowed many theropod species to coexist within the same habitat. *Samanadrinda surghari* and *Himalayadrinda potwari* are two more theropod ichnotaxa that show diversity in Pakistan. These trackways indicate that large and small bipedal predators were present over a much wider area than is suggested by skeletal fossils alone. Trackways preserve evidence of behaviour like bones do. They record movement patterns walking gait and interaction with the ground surface.

Discovery of *Saraikisaurus minhui* adds an important part of knowledge to the paleogeography of Pakistan. Pterosaurs are a important component of Mesozoic vertebrate communities and provide broader ecological structure of that time. Late Cretaceous environments of Pakistan were inhabited by not only large terrestrial dinosaurs but also flying reptiles were found there at that time. These animals may have been aerial predators or scavengers. This additional ecological fauna points out the more complex ecosystem. In which terrestrial and aerial vertebrates coexisted.

Table: 2. Comparison of Pakistani dinosaurs with other countries' genera.

Feature	**Pakistan**	**India**	**South America (Argentina)**	**Madagascar**	**Africa**	**References**
Dominant Sauropods	Titanosaurs (*Pakisaurus, Balochisaurus, Gspsaurus*)	Titanosaurs (*Isisaurus, Jainosaurus*)	Titanosaurs (*Saltasaurus, Argentinosaurus*)	Titanosaurs (*Rapetosaurus*)	Titanosaurs (*Paralititan*)	Malkani (2006, 2019); Wilson et al. (2011); Curry Rogers (2005)
Sauropod Diversity	Moderate–High (fragmentary taxa)	High (better preserved)	Very High (complete skeletons)	Moderate	Moderate	Wilson et al. (2011); Benton (2015)
Theropod Groups	Abelisaurids, Noasaurids	Abelisaurids (*Rajasaurus*)	Abelisaurids, Carcharodontosaurids	Abelisaurids (*Majungasaurus*)	Abelisaurids, Spinosaurids	Carrano et al. (2012); Sereno (1999)
Trackway Evidence	Extensive (Mianwali, Zhob, Potwar)	Present	Abundant	Limited	Moderate	Lockley & Hunt (1995); Malkani (2019)
Osteoderms in Titanosaurs	Present (*Gspsaurus*)	Present	Common	Present	Rare	Curry Rogers (2005); Wilson et al. (2011)
Fossil Preservation	Mostly fragmentary	Moderate	Excellent	Moderate	Variable	Benton (2015); Eberth & Currie (2005)
Geological Age Range	Late Jurassic–Late Cretaceous	Late Cretaceous	Jurassic–Cretaceous	Late Cretaceous	Jurassic–Cretaceous	Kazmi & Jan (1997); Wilson et al. (2011)

Paleoenvironment	Fluvial–deltaic (Pab Formation)	Fluvial–lacustrine	Floodplains	Coastal plains	Coastal/ desert	Shah (2009); Chatterjee & Scotese (2010)
Research Maturity	Developing	Moderate–Advanced	Highly Advanced	Moderate	Moderate	Benton (2015)
Biogeographic Affinity	Gondwanan (India-linked)	Gondwanan	Core Gondwanan	Gondwanan	Gondwanan	Scotese (2001); Chatterjee & Scotese (2010)

It probably hosted high levels of biological productivity and contained a substantial amount of large vertebrate biomass. At the same time periodic sedimentation events were significant for the burial of fossils. Rapid depositional episodes permitted preservation of skeletal remains. Many fossils are disarticulated or fragmentary due to transport and post-burial disturbance. The dinosaur assemblage of Pakistan supports its relationship with Gondwanan faunas. The abundance of abelisaurid and noasaurid theropods and a diverse assemblage of titanosaurs shows a close affinity with faunas known from India Madagascar and South America. The Indian plate was moving northwards during the Late Cretaceous and incorporated the present day territory of Pakistan. This movement provided opportunities for faunal exchange before complete separation of the continents. This suggests that dispersal routes likely promoted the exchange of evolutionary lineages between connected land masses. Possible presence of endemic taxa suggests that some groups evolved locally after partial geographic isolation.

Limitations of the present fossil record in Pakistan must be clearly acknowledged despite these promising interpretations. Many described dinosaur taxa are based on isolated bones especially caudal vertebrae. Such material is often inadequate for reliable taxonomic identification. This has given rise to concerns that species are being over split and that some of the named taxa will be found to be synonyms. So the current taxonomy must be critically reevaluated in the context of new evidences. The Pakistani record needs to be better accepted in leading journals such as Journal of Vertebrate Paleontology. Future work should be focused on more complete and articulated fossils. The significance of the cranial material especially is that it contains the key features for an accurate phylogenetic analysis and for a clearer interpretation of evolution.

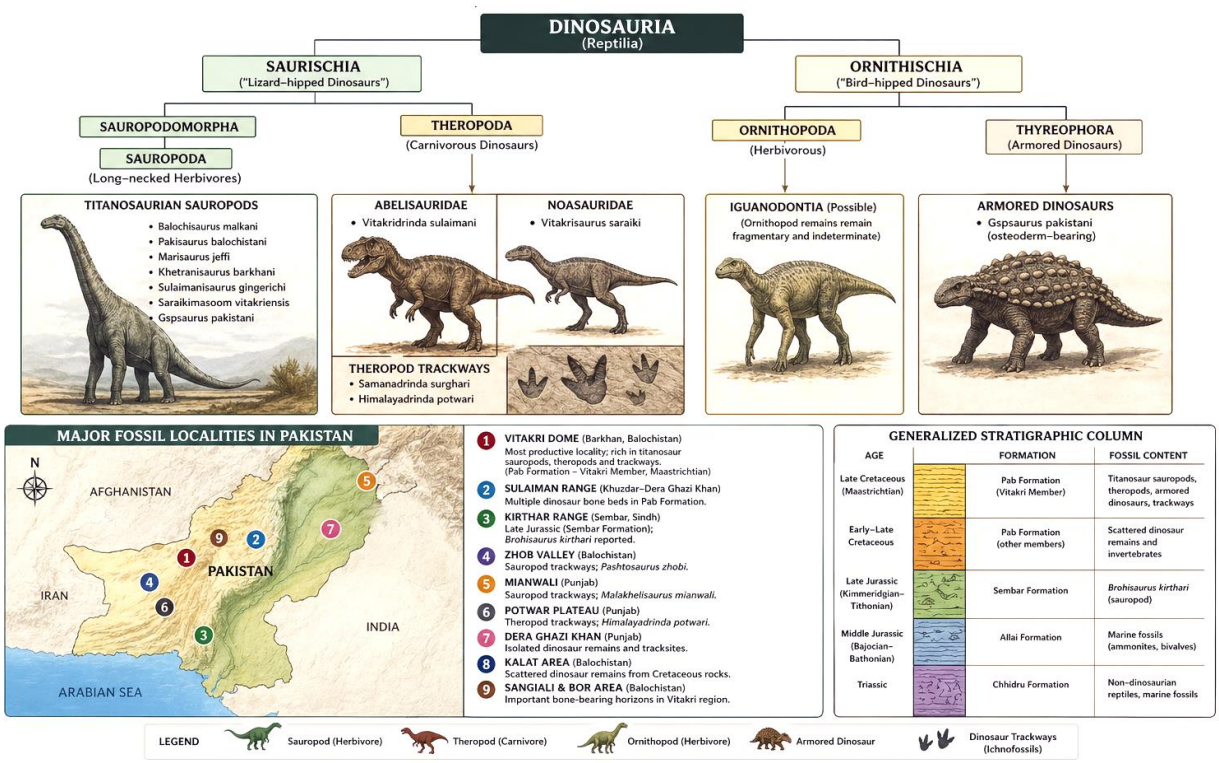

Figure: 3. Classification and typed of different genra of dinosaur found in Pakistan.

The situation has raised concerns that species are being over split. It also opens the possibility that some of the named taxa may be treated as synonyms in the future. The current taxonomy must therefore be carefully re-evaluated in light of new evidence. Future work should focus on more complete and articulated specimens to increase the chances of the Pakistani record being accepted in top tier journals such as the Journal of Vertebrate Palaeontology. Cranial material is of particular importance as it preserves key diagnostic characters required for accurate phylogenetic analyses and an improved understanding of evolutionary relationships. It is due mainly to the pioneering work of Muhammad Sadiq Malkani that these fossils have received their scientific recognition. His work provided the first detailed record of many dinosaur-bearing sites of Pakistan. But the next stage of research demands wider scientific collaboration and a more careful reexamination of existing material. It will also require rigorous application of international standards for fossil description and taxonomic classification.

At the end we say that the dinosaur fauna of Pakistan represents a diverse and dynamic fauna. It also Reflects both the local ecological conditions and wider connections to Gondwanan palaeontology. The diversity of titanosaurs & several theropod lineages also the abundance of trackways suggest a structured ecosystem well defined ecological roles with different trophic levels. This study indicates different dinosaurs living in the same places but in different niches. There are challenges especially around taxonomy and the incompleteness of the data available. But the potential for future discovery is very high. Pakistan has a good chance of becoming a major contributor to global research on dinosaur paleobiogeography. Also need to explore details of Mesozoic ecosystems with more fieldwork and improved analytical methods.

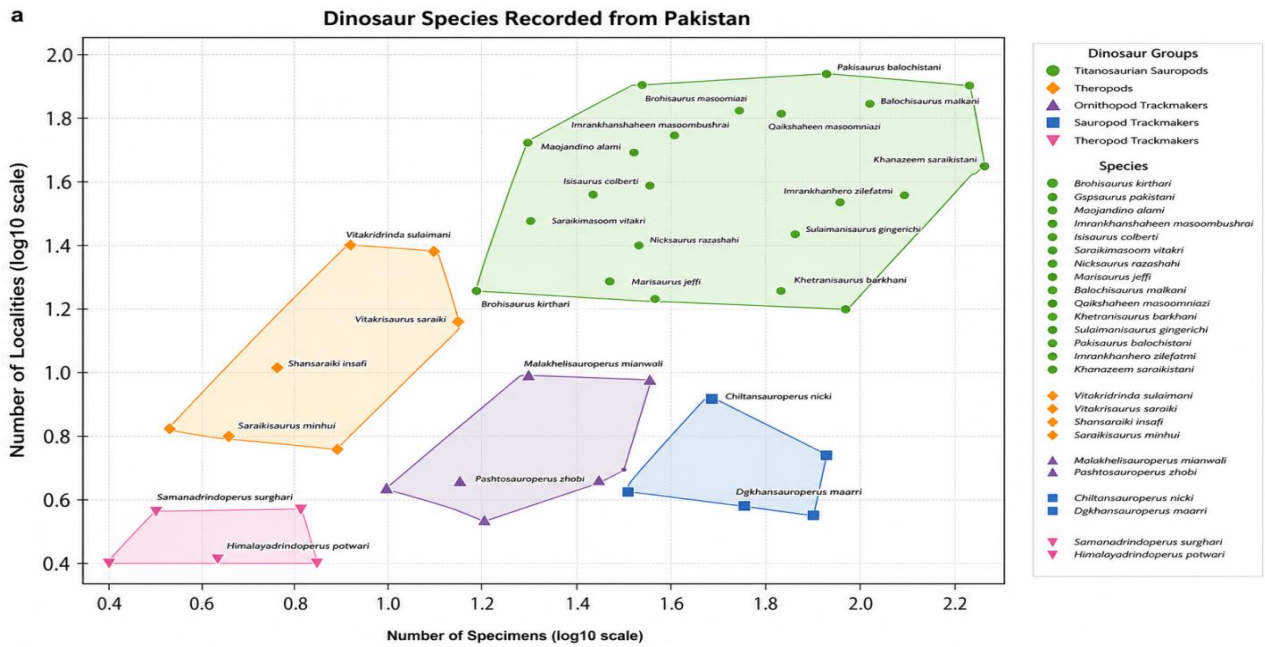

Figure: 4. Plot showing Dino- Diversity.

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