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Pakistani Titanosauria: are Armoured Dinosaurs?

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ABSTRACT: *Four types of dermal armour bones of Titanosauria are discovered for the first time from the Late Cretaceous Pab Formation of Vitakri and Basti Ghulam Rasul (Zubra), Barkhan district, Balochistan, Pakistan. These dermal armour bones/osteoderms and scutes are different in morphology and are present in the red, maroon and greenish grey shale/clays zone of upper Pab Formation, just below or on the boundary of Mesozoic (Cretaceous) and Cenozoic (Tertiary/Paleocene). The upper Pab Formation seems to be a fresh water deposition in the Sulaiman range deduced from sedimentary structure and it has yielded a large number of archosaurian such as dinosaur and crocodilian fossils discovered during this study.*

The variation of size and shape of dermal armour bones may depend on different positions. However their positions are not clear because these are found fragmentary and are not articulated. The first and second types can be positioned such as above the ribs, on back/tail/limbs etc., due to their light weight. The positions of third and fourth types of armour plate can be positioned on axial column, especially from neck to sacral region like ornithishian. These may occur as single median or double row. In general view these seem to belong to ornithischian, but materials found nearby belong to both Titanosaurids (Pakisaurids) and Saltasaurids. Recently five new genus and species of Titanosauria (Titanosaurids/Pakisaurids, and Saltasaurids) are erected on the basis of morphology of caudal vertebrae, but the assignment of dermal armour bones at species/ genus/ family level is difficult. However, their assignment to Pakistani Titanosauria is confirmed at this level.

INTRODUCTION

Four types of dermal armour bones of Titanosauria are discovered for the first time in Pakistan from the Late Cretaceous Pab Formation of Vitakri region, Barkhan District, Balochistan, Pakistan (Fig. 1). Four types of dermal armour bones of Titanosauria are discovered from Vitakri. These dermal armour bones/osteoderms and scutes are different in morphology and are present in the red, maroon and greenish grey mud/clays/paleosol zone of upper of Pab Formation, just below or on the boundary of Mesozoic (Cretaceous) and Cenozoic (Tertiary/Paleocene). The upper part of Pab Formation seems to be a continental fluviatile fresh water deposition in the central periphery of Sulaiman range due to sedimentary structure and it has yielded a large number of archosaurian such as dinosaur and crocodilian fossils.

The osteoderms are developed as small plates and spines in many Stegosauria and Ankylosauria of Ornithischian dinosaurs (Galton, 1990). The dermal plates have been reconstructed in several different ways, first

as a single median row by Marsh, (1891; 1896) and Ostrom and McIntosh (1966) and as two rows that were either bilaterally paired throughout the entire series (Lull, 1910a&b) or two rows of staggered alternates (Gilmore, 1914; 1915; 1918) favored the alternating arrangement because some of the plates are arranged this way in an almost complete skeleton still embedded in rocks and in addition no two plates have exactly the same shape or size (Galton, 1990).

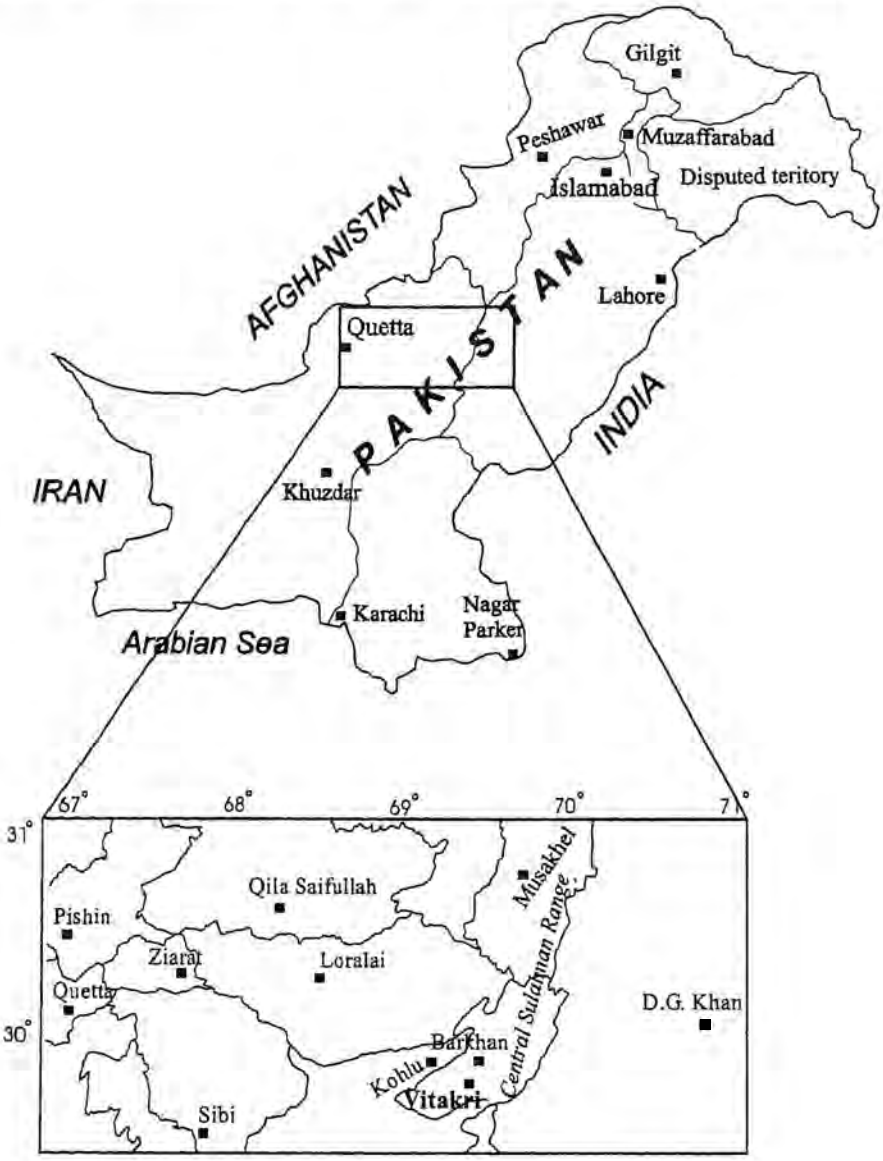

Fig. 1. Index map showing the Vitakri Region, Central Sulaiman Range, Pakistan.

There is mounting evidence that all the titanosaurids possessed dermal armour (McIntosh, 1990). Deperet's (1896) claim that a scute found with titanosaur caudals in Madagascar was ignored until incontrovertible evidence of the association of several types of osteoderms with Argentinian titanosaurids was presented by Bonaparte and Powel (1980) and Powel (1980). Sanz and Buscalioni (1987) reported a third association from the upper Cretaceous of Spain. In Saltasaurus (Bonaparte & Powel, 1980), the osteoderms are of two type; dermal plates 10 to 12 cm in diameter and ossicles 6 to7 mm across. The relatively rare plates whose position is not known with certainty are oval to circular. Their dorsal surfaces are rugose and bear a low but sharp ridge; their ventral surfaces are described as smooth, concave in some with a median ridge in others. The irregularly shaped ossicles, outwardly convex, are tightly packed and apparently covered the dorsal and lateral parts of the body. A third type of ossification typified by the material from Spain and Madagascar and Argentinian material referred by Huen (1929) to a Sauropod nodosaurids *Loricosaurus scutatus* (Powell, 1980) can be differentiated from the nodosaurids according to Sanz and Buscalioni by three characters; the appearance of a well developed cingulum, surface texture made of nodules (without pattern) and the appearance of internal ducts (McIntosh, 1990). Present discovery includes four types of armour plates.

DESCRIPTION OF DERMAL ARMOR BONES OF TITANOSAURS FROM PAKISTAN

The four dermal armour bones/ osteoderms and scutes are different in morphology. The first type of armour bone found from Vitakri region is a simple thin plate. The second type of armour bone (Fig. 2) found from Vitakri is about 9 cm in diameter are made up of nodule/polygon ossicles of irregularly shaped varying diameter ranging from half centimeter to 4 centimeters, separated by internal ducts of 1-3 mm wide. This plate is 1-1.5 centimeters thick and partially preserved. The third variety (Figs. 3, 4, 5) found from Nala Basti (Zubra) is sub circular plate which has slight concavity and rugosities on smooth ventral surface, and rugosities on lateral and dorsal surfaces. Dorsal surface has an asymmetrical low ridge/cone. The ossicles on the ridge area are tightly packed and directing toward the tip of ridge making radial pattern, having centre at tip and remaining dorsal and lateral area has irregularly shaped ossicles and internal ducts. The ridge seems to be directed dorsoposterior. The length and width of ventral sub circular surface are 19 and 16 cm respectively and dorsoventral depth of dorsal ridge from ventral surface to preserved apex is 12 cm. Apex/tip of cone/ridge is not preserved.

The fourth type of dermal plate (Figs. 3, 4, 5) found from Vitakri is an oval shape. Its 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. The third and fourth varieties have resemblance in shape but differ in nature of smooth, concave, convex, circular and oval

ventral surfaces and transverse median concavity belt on dorsal surface. The ventral surface of third type is slightly concave and smooth having corroded rugosities on circular ventral surface. The fourth type shows slight convexity and well developed, irregular rugosities on oval ventral surface, and it bears a transverse median concave belt on dorsal surface.

Fig. 2. Dermal armour bone of Pakistani Titanosauria, nodular plate (scale in centimeters).

Fig. 3. Dermal armour bones of Paksitan Titanosauria, in laterodorsal view (scale in centimeters).

Fig. 4. Dermal armour bones of Pakistani Titanosauria, in ventral view (scale in centimeters).

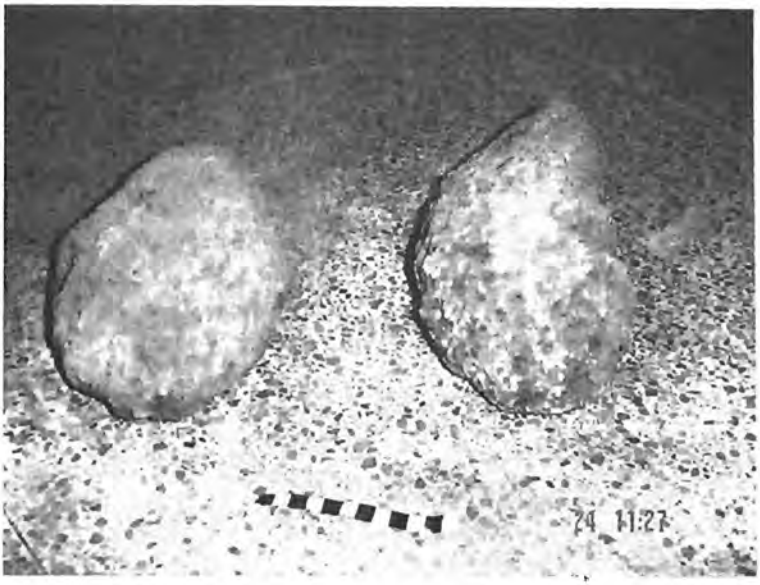

Fig. 5. Dermal armour bones of Pakistani Titanosauria, in dorsal view (scale in centimeters).

The variation of size and shape of dermal armour bones may depend on different positions. However, their positions are not clear because these are found fragmentary and are not articulated. The first and second types can be positioned such as above the ribs, on back/tail/limbs etc. due to their light weight. The positions of third and fourth types of armour plate can be positioned on axial column especially from neck to sacral region

like ornithishian, interpreted due to their heavy weight. In general view these seem to belong to ornithischian but materials found nearby belong to both Titanosaurids (Pakisaurids) and Saltasaurids.

New discoveries from Pakistan including a variety of large vertebrate that indicate five new genus and species of herbivorous Titanosaurian Sauropod (Malkani & Anwar, 2001, Malkani et al., 2001) and one new genus and species of carnivorous Abelisaurid Theropod Dinosaurs and Baurosuchid *Pabwehshi pakistanensis* (Mesoeucrocoreptilia) (Wilson et al., 2001) fossils. But the assignment of armour bones at species/ genus/ family level is difficult. However, their assignment to Pakistani Titanosauria is confirmed at this level.

CONCLUSIONS

The four types of armor bones discovered from Vitakri region are beautifully preserved and provide a wealth of anatomical information. It is confirmed that the armor bones described briefly here found from the upper part of Late Cretaceous Pab Formation of Vitakri region, Balochistan, Pakistan, are referable to Titanosaurian Sauropod dinosaurs, due to nearby findings of cranial, axial and appendicular elements of Titanosauria and correlation with the armor bones already discovered from Argentina (Bonaparte & Powel, 1980; Powel, 1980), Spain and Madagascar (Sanz & Buscalioni, 1987). But assignment below this level is at best uncertain. The placement of armor bones on body parts is uncertain due to fragmentary nature of fossils. It will be confirmed on finding the articulated skeletons. The discovery of different types of armor bones/scutes from Pakistan will provide the facility for comparisons with the already discovered armor bones from the world to deduce the actual taxonomic and paleobiogeographic targets. The excavation at many sites in the Vitakri region is suggested to explore the articulated dinosaurs which will really be useful to science. Present discovery will confirm the statement of McIntosh (1990) that "there is a mounting evidence that all the titanosaurids possessed dermal armor". Thus far, the Late Cretaceous (Maastrichtian) Lameta formation of India has served as the sole source of information on Cretaceous vertebrates of the Indo-Pakistan subcontinent. But new discoveries from Pakistan will act as a milestone for assessing paleobiogeography and phylogeny.

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