Paleontological Journal, Vol. 38, No. 1, 2004, pp. 73–77. Translated from Paleontologicheskii Zhurnal, No. 1, 2004, pp. 68–72.

The First Finds of Armored Dinosaurs in the Upper Cretaceous of Russia (Amur Region)

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Received August 6, 2002

Abstract—Remains of armored dinosaurs (Thyreophora) from the Late Cretaceous, Early Maastrichtian (Udurchukan Formation) deposits of the Kundur locality in the Amur Region, are described. The material includes a single osteodermal scute of extraordinary structure and two cheek teeth. These fossils are tentatively assigned to the family Nodosauridae (Ankylosauria) previously unknown in Asia.

Key words: Armored dinosaurs, Upper Cretaceous, Russia, Amur Region.

INTRODUCTION

A large accumulation of fossil bones was discovered in 1990 in a road cut between the Mutnaya and Udurchukan rivers (southeastern Amur Region, Fig. 1). Vertebrate remains were found in grayish green clays with gravel inclusions, which compose a part of the Udurchukan Formation (Bugdaeva *et al.*, 2001). The bone beds are mixtites by genesis, that is, they were formed as a result of mudstream flows from the heights (Markevich *et al.*, 1994; Bugdaeva *et al.*, 2000). The fossiliferous layers of the new locality named Kundur is dated by palynological data as the Early Maastrichtian (Markevich and Bugdaeva, 1999; Bugdaeva *et al.*, 2001).

To date, the collection from Kundur totals more than a thousand isolated bones, complete skeletons, and their parts. The bulk of the material consists of duck-billed dinosaurs of the families Hadrosauridae and Lambeosauridae. The deposits yielded isolated teeth of carnivorous dinosaurs of the families Tyrannosauridae and Dromaeosauridae and fragmentary remains of turtles (Lindholmemydidae, Trionychidae) and crocodile teeth (*Shamosuchus* sp.) (Bolotsky and Moiseenko, 1988; Moiseenko *et al.*, 1997; Bolotsky and Alifanov, 2001; Danilov *et al.*, 2002).

In 1991, in the Kundur locality, the paleontological team from the Amur Complex Research Institute of the Amur Scientific Center, Far East Division, Russian Academy of Sciences (AEIM) found armored dinosaurs, which had previously been unknown in the Amur Region. The present paper describes these remains and discusses their taxonomic position.

MATERIAL

Materials described in this report include three bones: specimen AEIM, no. 2/1, a tooth with a slightly damaged anterior edge, a worn labial crown surface, and a broken off root (Figs. 2a, 2b); specimen AEIM, no. 2/2, an incomplete tooth, including the basal part of the crown and the root base (Figs. 2c, 2d); and specimen AEIM, no. 2/16, an osteodermal scute (Fig. 3). All bones come from the deposits of the Udurchukan (the lowermost part of the Tsagayan) Formation of the Kundur locality (Arkharinskii District, Amur Region, Russia).

Fig. 1. A map of part of the Amur Region. Designation: ✸ Kundur locality.

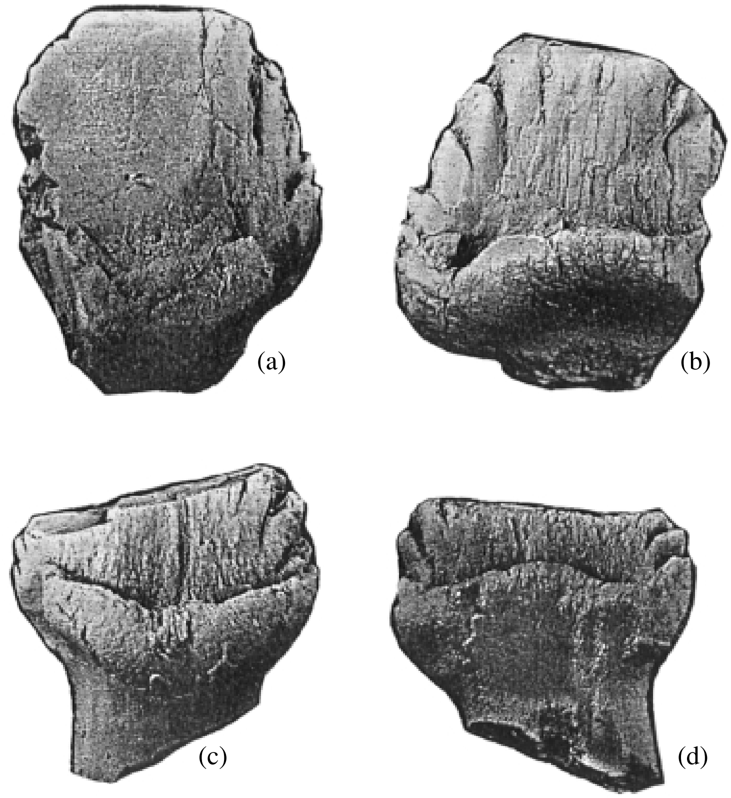

Fig. 2. Ankylosaurian teeth from the Kundur locality, ×4: (a, b) specimen AEIM, no. 2/1: (a) labial and (b) lingual views; (c, d) specimen AEIM, no. 2/2: (c) labial and (d) lingual views; Amur Region, Arkhara District, Kundur locality; Udurchukan Formation, Lower Maastrichtian.

DESCRIPTION

Available teeth are similar in size and structure. The crown is leaf-shaped and compressed labiolingually. Its edges bear denticles separated from each other by shallow grooves terminating before reaching the cingulum. Six denticles are located anterior to the apical cusp, and three or four are located posteriorly to it. The apical cusp is wide, its cutting edge is worn and slightly displaced backwards with reference to the tooth midline. The smallest marginal denticles are close to the base. They are less worn than the others and their apices are pointed. In relation to the axis of the apical cusp, the axis of the anterobasal supplementary denticles is inclined at an angle of about 60°. The cingulum is wide; its apical edge is outlined by a deep groove and the basal edge gradually passes into the base. In the frontal view, the cingulum is asymmetrical; on one side of the crown it is higher than on the other and its maximum expansion is in the central part. Labially, the cingulum is crescent shaped, with its arch facing basally. Lingually, it is sinusoid; the highest point of the wave is at the middle of the tooth. The tooth crown of each specimen is 10 mm long, the labiolingual thickness at the cingulum is 6 mm. The crown height from the cingulum base is 10 mm. The diameter of the preserved part of the root is 6 mm.

The osteoderm is conical, compressed from both sides without keel formation. From the base plane to the top, it is 125 mm high. The osteoderm apex is wide and rounded and shows a cellular surface structure. In the lateral view one edge of this bone looks convex, while the other is straight, its lower part being slightly bent externally. In the anterior or posterior view, one side of the osteoderm is slightly arched externally and the other is curved internally. The bone is thick-walled. The maximum thickness of the wall is 25 mm. There are no foramina in the walls. The vessel grooves running on the osteoderm surface are meandering, branching, more often interrupted than extending from the base to the apex. The projection of the osteoderm base is pear-shaped. Its narrower edge corresponds to the convex edge of the lateral projection. The osteoderm base is 165 mm, and its maximum width is 100 mm. The bone edges are uneven, without thickening. The osteoderm base is dome-shaped. The dome apex is displaced to the middle of the narrow part of the base projection. The osteoderm body is penetrated by a narrow vertical canal passing towards the apex.

DISCUSSION

Some difficulties arise in the identification of isolated dinosaur osteoderms. This is due to the fact that in

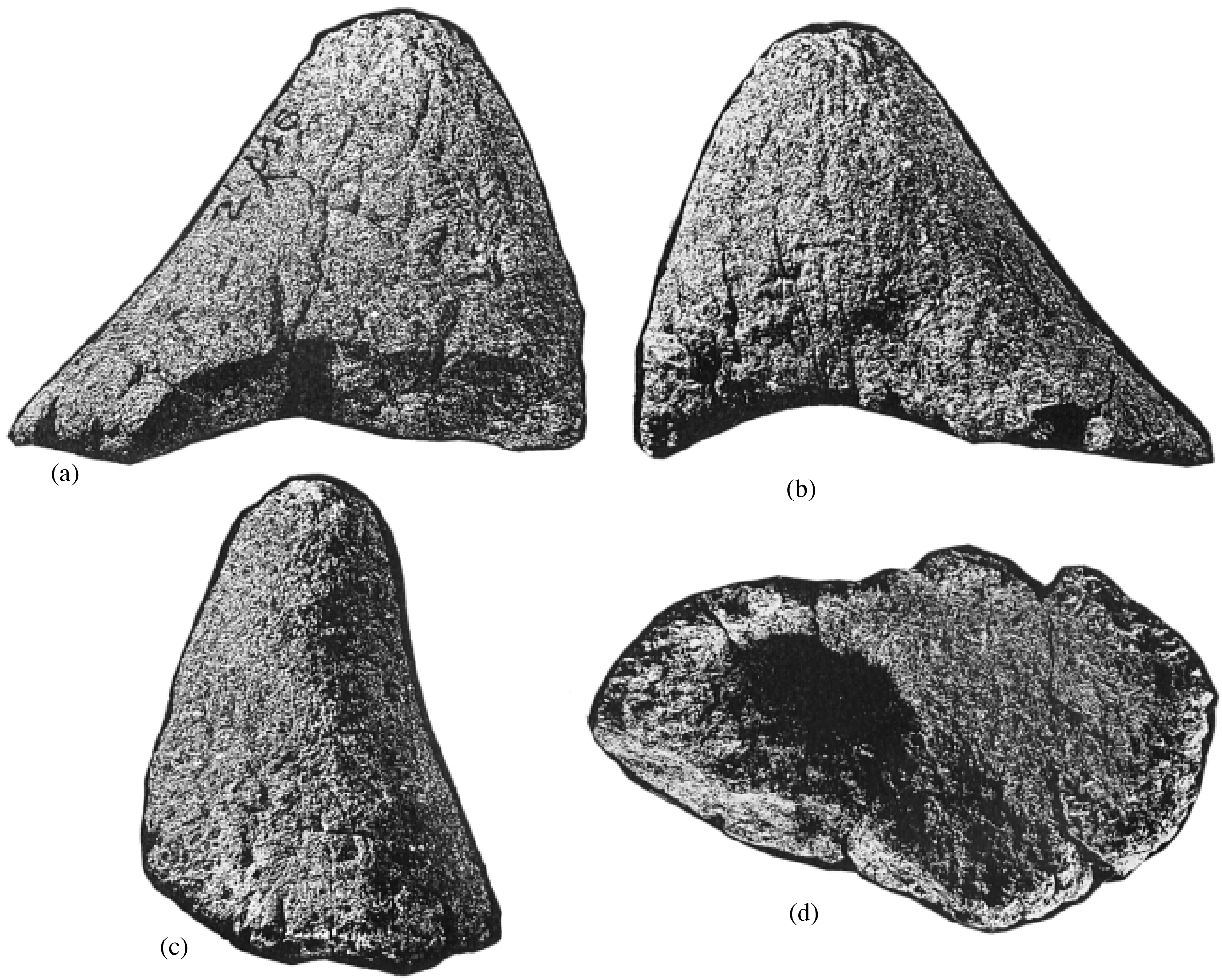

Fig. 3. Dermal scute of Ankylosauria from Kundur, specimen AEIM, no. 2/16, ×0.5: (a, b) lateral, (c) caudal, and (d) ventral views; Amur Region, Arkhara District, Kundur locality; Udurchukan Formation, Lower Maastrichtian.

addition to the Thyreophora (armored dinosaurs in a broad sense), certain other ornithischian groups, such as some sauropods, have osteodermal elements on their trunk (Ford, 2000). Therefore, the assignment of the Kundur osteoderm to the Thyreophora is not certain, although probable. At the same time, the belonging of the teeth described above to thyreophorans is beyond question.

The wandering and interrupted vessel grooves on the osteoderm surface differ from the vessel traces on the surface of stegosaurian spines, whose grooves stretch over the entire extent of the spine, which suggests constant and parallel growth of osteoderms and overlaying horn cover. The oval and concave spine base containing a narrow vertical internal canal disagrees with the nature of stegosaur osteoderms.

The teeth of ankylosaurs and stegosaurs are similar in morphology; however, in ankylosaurs, marginal crown denticles are more pointed (Barrett, 2001), while in stegosaurs the vertical ribbing of lateral crown surfaces is sharper (original data). Both characteristics disagree with the assignment of teeth from Kundur to stegosaurs.

However, the osteoderm and teeth are only tentatively identified because the material includes isolated fragmentary specimens. Therefore, when finding out the taxonomic relationship of teeth and osteoderms, the data on the geological and geographical distribution of the Thyreophora should be taken into account.

Stegosaurs are the most widespread thyreophorans of the Jurassic and Early Cretaceous periods. This group has been found in North America, Africa, Europe, and Asia. The report on Late Cretaceous stegosaurs from India (Yadagiri and Ayyasami, 1979) is based on a fragmentary specimen and can not be considered absolutely veritable (Dong, 1990).

The order Ankylosauria, including the families Nodosauridae and Ankylosauridae, has been discovered on every continent, including Antarctica (Olivero *et al.*, 1987). In Europe, only nodosaurids are known.

All Gondwanian forms also belong to this family. In Asia, only ankylosaurids have been found. Members of both families co-occurred only in North America (Carpenter, 1997).

Nodosaurids persisted from the Middle Jurassic to the terminal Maastrichtian. In the North American west, the last member of this family, *Edmontonia*, was found in the Upper Maastrichtian Lance, Hell Creek, and Laramie formations; however, it only occurred in the lower parts of these formations. Remarkably, the finds mainly consist of skeletal fragments and isolated teeth, and, upsection, they become more scarce. The analysis of localities containing *Edmontonia* made possible a slight extension of the time range of nodosaurids (Carpenter and Breithaupt, 1986), in contrast to the previous opinion, according to which this group survived only until the Campanian.

The time range of ankylosaurids comprises almost the whole Late Cretaceous and includes the terminal Early Cretaceous. The latest Asian ankylosaur, *Tarchia gigantea* (Maleev, 1956), occurs in the deposits of the Nemegt Formation in southern Mongolia and is dated within a wide range, from the Middle Santonian (Alifanov, 2000) to the terminal Maastrichtian (Shuvalov, 1982; Barsbold, 1983). Taking into account the similarity of the Late Cretaceous faunas from North America and Paleoasia, the absence of nodosaurids in the latter continent seems rather puzzling.

The assignment of the thyreophoran remains from Kundur to stegosaurs is less probable not only by virtue of some morphological features, but also by their Late Cretaceous age. Thus, they may be referred to ankylosaurs.

Coombs and Maryańska (1990) traced the following familial distinctions in ankylosaur dental structure. In nodosaurids, the tooth crown is more strongly compressed laterally, the grooves on the flanks are better developed, and the cingulum is always clearly formed and asymmetrical (it is thicker on the labial side of the crown and is sinusoidal on the lingual side). Ankylosaurids more often have a distinct expansion at the crown base rather than a true cingulum. Interestingly, an ankylosaur from Antarctica originally identified as an ankylosaurid (Olivero *et al.*, 1987) was subsequently transferred to nodosaurids on the basis of its dental morphology (Gasparini *et al.*, 1996). The dental morphology of the ankylosaur from Kundur suggests that it could be a nodosaurid. Thus, the large size of the teeth described above and the degree of cingulum expression correspond to the nodosaurid characteristics listed above.

Attempts to make generic diagnoses with the use of dental characteristics were undertaken earlier (Leidy, 1856; Brown, 1908); however, it is not yet possible to perform such identifications with confidence. There might be a sole characteristic in the generic diagnosis worth credibility: the w-shaped cingulum in the teeth of the ankylosaurid *Maleevus disparoserratus* from Mongolia. However, in this form, teeth vary in structural details even within the same tooth row.

The ankylosaurian dermal armor consists of numerous diverse elements, which, while fusing together, may form certain constructions, such as half-rings, shields, and others. The taxonomic significance of osteodermal elements in ankylosaurs has been not quite clear until now. This is because of an insufficient amount of well-preserved articulated armor elements *in situ.* Nevertheless, Coombs and Maryańska (1990) indicated some diagnostic characteristics that distinguish members of the two families. For example, the ventral surface of ankylosaurids' keeled scutes is rather strongly concave, that is, the spines are thin-walled and hollow, while the nodosaurid scute base is flat or only slightly concave even if the keel is high. The surface of nodosaurid scutes and spines is dense, whereas ankylosaurids, show a trend towards augmentation of the amount of pores, in the osteodermal walls of the late forms. For example, the osteoderm walls of the latest Mongolian ankylosaur *Tarchia gigantea* look openwork (Tumanova, 1987). Ankylosaurids don't possess high conical spines, whereas the height of some nodosaurid osteoderms exceeds the diameter of their base by two times. The thick walls of the spine from Kundur, the structure of its base, and its dense surface texture suggest that this osteoderm belongs to a member of the family Nodosauridae.

At the same time, the absence of keel in the Kundur osteoderm combined with its considerable height is an unusual characteristic for dermal ossifications in the known members of both ankylosaurian families. One more distinctive feature of the described spine is the cellular surface structure of its apex, which has not been registed in other ankylosaurian osteoderms. The position of the osteoderm on the animal's body is difficult to determine, although its asymmetric structure excludes its axial localization.

Thus, taking into account the structure of the osteoderm and jaw teeth and their large size, the hypothesis of the relation of the Kundur thyreophoran to nodosaurids looks preferable. This makes the remains from Kundur the first find of a member of the Nodosauridae in Asia.

If it is hypothesized that the thyreophoran from Kundur belongs to ankylosaurids, geographical the range of Asian ankylosaurs would be enlarged eastwards and northwards, and this form from the Amur Region becomes a candidate to be the largest member of the family, since its teeth exceed in size the teeth of the largest known Asian ankylosaurid *Tarchia* (which was more than 7 m long) by approximately one-third.

ACKNOWLEDGMENTS

This work was supported by the Russian Foundation for Basic Research, project nos. 00-15-97754 and 00-04-49348.

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