On the question of the pectoral girdle in *Elasmosaurus* Cope.

(With a plate of drawings.)

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The structure of the pectoral girdle in the Elasmosauri is not yet fully explained.

It is known that among the skeletal remains of *Elasmosaurus* first described by Cope in 1868–71 (*E. platyurus* Cope)[1], the following bones of the pectoral girdle were found: (1) incomplete coracoid and (2) one broad bone, evidently one of a pair, located anterior to the coracoid. According to Cope, this bone is reminiscent of the pubis of certain turtles and measured: 14 inches, 9 lines in length and about 13.5 inches in width. It was joined with the coracoid by means of two processes (outgrowths), a middle one and one at the edge. Between this bone and the coracoid was the oval obturator foramen. Cope thought the bone to be the clavicle or procoracoid. Cope thought that the mesosternum fused with the clavicles and that all three elements formed one solid breastplate. In Cope's opinion, the broad development of the clavicles appeared to be one of the distinguishing characteristics of *Elasmosaurus* as compared with the the remaining Plesiosauri. Cope wrote that in this particular skeleton there was no indication as to how the clavicles were joined with the scapulae.

However, Seeley, examining the structure of the pectoral girdle in various plesiosaurs, had already concluded in 1874 that the bones which Cope thought to be the clavicles or precoracoids of *Elasmosaurus* were actually the scapulae. The clavicles in *Elasmosaurus*, wrote Seeley, were not known; evidently, they also did not have an interclavicle. In this

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[1] *Proceed. Academy of Natur. Scienc. of Philadelphia*, 1868. —March. 24th; July 7th. *Proceed. Boston Soc. Natur. History*, vol. XII, p. 265, 1868–69; *Americ. Naturalist*, vol. III, pp. 84–91, 1870; *Transactions of the Americ. Philosophic. Society*, vol. XIV; *Americ. Journ. Sci*., vol. 50, sec. ser., 1870. *Cpab. Preliminary Report of the Un. Stat. Geol. Survey of Wyoming*, 1872 (On the fossil reptiles and fishes of the Cretaceous rocks of Kansas); *Report of the Un. Stat. Geol. Survey of the Territor*., Washington, 1875 (The Vertebrata of the Cretaceous formations of the West); *Preliminar. Report of the Un. Stat. Geol. Survey of Montana*. Washington 1870 (On the geology and palaeontology of the Cretaceous strata of Kansas).

connection, Seeley thought that *Elasmosaurus* could be united with *Eretmosaurus*, *Colymbosaurus*, and *Muraenosaurus* in a special family, Elasmosauridae, and could be isolated from other Plesiosauria having an interclavicle.[1]

Nevertheless, in 1877 Cope, in describing the skeleton of another elasmosaur, *Elasmosaurus serpentinus*, again pointed out among the bones of the animal's pectoral girdle: (1) remains of a coracoid, 61 cm x 30.5 cm and (2) rather broken up clavicles measuring, according to Cope:

31.1 cm in diameter in cross-section

14.5 cm in diameter at the base

7.0 cm in diameter at the glenoid depression.

Cope presented neither a drawing nor a more detailed description of these bones.[2] In Hulke's 1833 note "The Anniversary address of the President,"[3] a somewhat different view was presented concerning the structure of the pectoral girdle in *Elasmosaurus* Cope, differing from Seeley's view of this question as well as from Cope's view. In Hulke's opinion, the broad paired bone lying anterior to the coracoid in elasmosaurs was neither the clavicle nor the procoracoid as Cope thought; but also it was not the scapula in the sense in which Seeley was inclined to think it. This bone, thought Hulke, was nothing other than the precoracoid, the ventral branch of the scapula. Generally, according to Hulke, in plesiosaurs the scapula was constructed along the same lines as in tortoises [or turtles]. This bone is complex and consists of: (1) a scapula proper and (2) a precoracoid fused with it. In general, there were no clavicles in Sauropterygia; they were replaced by dermal formations. The unpaired middle bone, which in certain plesiosaurs was noted anterior to the pectoral girdle, cannot be considered a homolog of the interclavicles of other Reptilia. This bone in reality corresponds to the omosternum of Amphibia.

Somewhat earlier, Hulke, and Owen as well, expressed himself (1883) in favor of the resemblance in structure of the pectoral girdle in plesiosaurs and turtles.[4] According to Owen, the broad episternum bone in plesiosaurs is located between the anterior ends of the scapulae;

[1] Seeley. Note on some of the generic modifications of the *Plesiosaurus* pectoral arch. *Quart. Journ*., vol. 30, 1874.
[2] *Bullet. Un. Stat. Geolog. and Geograph. Survey*, vol. III, no. 3, art. XIX; *Americ. Naturalist*, vol. XI, 1877.
[3] *Quart. Journ*., vol. 39, 1883.
[4] Owen. On generic characters in the order Sauropterygia. *Quart. Journ*., vol. 39, 1883.

in *Plesiosaurus* it has the form of a wedge placed between the scapulae. The function of the sternum for the most part was borne by the coracoid.[1] Lydekker quickly joined Hulke in his view on the structure of the pectoral girdle in plesiosaurs, and partly in *Elasmosaurus*, but later, however, he hastened to reject Hulke's omosternum.[2,3]

In 1892 Seeley published a critical analysis of the above-mentioned opinions of Hulke.[4] Objecting to Hulke's identifying the shoulder girdle of plesiosaurs with that of turtles, Seeley tried to show that the girdle in plesiosaurs is constructed identically to that in ichthyosaurs, nothosaurs, and pareiasaurs. Hulke's opinion that the so-called scapula in plesiosaurs represents a complex bone in itself and consists of: (1) the scapula proper and (2) the precoracoid fused with the latter, according to Seeley hardly corresponds to reality. In plesiosaurs the precoracoid is not isolated as an independent element; the corresponding cartilage in these forms extends onto the enlargement of the coracoids anterior to the scapulae from the medial side. Regarding the omosternum in plesiosaurs, proposed by Hulke, it is well not to speak of it because plesiosaurs do not have a sternum. Wherever there is a similar unpaired bone, it is the interclavicle. In the shoulder girdle of *Elasmosaurus* Cope, only the scapulae and coracoids are known; clavicles are unknown.[5]

In his reply to Seeley's criticism, Hulke continued to insist[6] that the scapula in plesiosaurs is a complex bone and consists of: (1) a ventral arch (ray)—precoracoid, and (2) a dorsal arch (ray)—scapula proper; both these elements grow together into one bone that is the so-called scapula. A complete correspondence between the three-arched (ray) anterior bone in the shoulder girdle of turtles and the same girdle of plesiosaurs was, in Hulke's opinion, beyond all doubt. Regarding the omosternum, the origin of this bone from the episternum does not necessarily require the presence of a sternum. All the more so in plesiosaurs, where the great development of the abdominal ribs could be accompanied by the presence of a cartilaginous sternum. In certain plesiosaurs it is possible to observe a seam along the middle

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[1] Owen. *l. c*. pp. 134–136

[2] Lydekker. Notes on the Sauropterygia of the Oxford and Kimmeridge clays. *Geol. Magazine*, *new. ser*., Dec. III, vol. V, 1888. On the skeleton of a sauropterygian from the Oxford Clay near Bedford. *Quart. Journ*., 1889.

[3] Lydekker. *Catalogue Foss. Reptilia a. Amphibia British. Museum*, *part. II*, p. 181, 1889.

[4] Seeley. The nature of the shoulder girdle and clavicular arch in Sauropterygia. *Proceed. of the Royal Society of London*, vol. 51, 1892.

[5] Seeley, *l. c*., pp. 119–148

[6] Hulke. On the shoulder girdle in Ichthyosauria and Sauropterygia. *Proceed. Roy. Soc. London*, vol. 52, 1892.

of the omosternum that indicates the formation of this bone out of left and right halves.[1]

Seeley did not fail to object[2] that Hulke's proposed fusion of the scapula and precoracoid into one bone is observed in no other reptile, living or extinct, but the fusion of coracoid with precoracoid is known. In plesiosaurs the precoracoid generally is lacking; in them it has been reduced, compared for example with the Anomodontia in which animals the precoracoid appears to have been ossified, and with the Nothosauria in which it remains cartilaginous. Concerning Hulke's supposed omosternum in plesiosaurs, we may say now that if this bone was formed out of the epicoracoid, we then must note that an epicoracoid is unknown in plesiosaurs. The clavicles in plesiosaurs are of dermal origin; there is one known case of the discovery of fully ossified clavicles in a very young plesiosaur, which could not be the case were they of cartilaginous origin.[3]

Seeley's view was soon supported by Koken, who said[4] that Hulke's supposed fusion of the scapula and precoracoid into one bone in plesiosaurs is unknown in any reptile, and that in plesiosaurs the precoracoid fuses with the coracoid; the latter in this way appears as a complex bone. On the subject of *Elasmosaurus* Cope, Koken thought that if in Liassic plesiosaurs the scapulae are divided toward the sides by the development of the clavicles, in *Elasmosaurus* the scapulae are joined by the ventral ends along the middle and push the clavicles forward or downward. However, in general, the contours of the shoulder girdle remain the same. For example, the omsternum in the Anura is actually formed due to the paired epicoracoids growing together along the middle; but this bone has nothing in common with the sternum.[5]

Of late, Seeley's views on the structure of the shoulder girdle in plesiosaurs, and partly in *Elasmosaurus* Cope, have been developed in the works of Andrews. Having studied a series of young and adult plesiosaurs (*Cryptoclidus oxoniensis* Phil.), this scientist showed[6] that the structure of the shoulder girdle in plesiosaurs changes slightly with the age of the

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[1] Hulke. *l. c*., pp. 233–255.
[2] Seeley. Further observations on the shoulder girdle and clavicular arch in the Ichthyosauria and Sauropterygia. *Proceed. Roy. Soc. London*, Vol. 54, 1893.
[3] Seeley. *l. c*. pp. 149–168.
[4] Koken. Beitrage zur Kenntniss der Gattung *Nothosaurus*. *Zeitschrift. d. deutsch. Geol. Gesellsch*., XLV Bd., 1893.
[5] Koken. *l. c*., pp. 337–377.
[6] Andrews. On the development of the shoulder-girdle of a plesiosaur (*Cryptoclidus oxoniensis* Phill.) from the Oxford Clay. *Ann. Magaz. Natur. Histor*., vol. XV, 1895.

animal. In young forms the anterior parts of the scapulae appear as not fully developed; between them enter the left and right clavicles, of triangular shape. In more fully grown forms the scapulae protrude anteriorly and push the clavicles upward onto the medial side; the joined scapulae take on the function of clavicles. Hence, thought Andrews, there is a very likely possibility of the complete disappearance of clavicles, as is the case with *Elasmosaurus*. There is no basis for considering the ventral part of the scapulae as the precoracoid which has been joined with the scapula. More likely this is a secondary process.[1] According to Andrews,[2] just such an evolution of the shoulder girdle took place in the history of Sauropterygia. In Triassic *Nothosaurus* the shoulder girdle consists of the scapulae, the broadened coracoids, and the more or less full bony arch[3]—which anteriorly forms the transverse vaulted arch that is also joined (by the medial ends) by a small ventral process of the scapulae. The arch consists of (1) the small interclavicle and (2) a pair of elongated clavicles joined together by the medial ends, evenly with the interclavicle. In the majority of Liassic Plesiosauri the ventral process of the scapula is increased in size and widened, and in certain cases approaches the midline junction with the articular process of the opposite scapula. The clavicular arch, which is held from below by the ventral process of the scapulae, changes more or less: the interclavicle becomes larger and spreads out posteriorly toward the coracoid, and the clavicles are greatly reduced. In *Muraenosaurus*, *Cryptoclidus*, and other members of the family Elasmosauridae, the ventral branch of the scapulae attains a still greater development and expanse. The medial ends of the scapulae come together along the midline symphysis and have processes growing out posteriorly up to the juncture with the middle elongated process of the coracoid. As a result of this expansion of the scapulae, the clavicular arch is revealed as lying upon the visceral[4] surface of the scapulae, becomes non-functional, and in adult forms becomes more or less reduced: in some, entirely—in others the clavicles or interclavicles[5] disappear.

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[1] Andrews. *l. c.,* pp. 333–346.
[2] Andrews. *A Descriptive Catalogue of the Marine Reptiles of the Oxford Clay, part. I*, 1910.
[3] [The word "duga" translates literally as "arch," "arc," or "bow". The word "peremychka" translates as "vaulted arch" or "arched wall." Evidently the latter has a vernacular connotation, because it apparently is used to indicate a complex of which the "duga" is a part. D. N. T.]
[4] [The term "visceral" is used throughout the paper to indicate the surface part of a bone oriented innermost with regard to the animal's body. D. N. T.]
[5] Andrews. *Descriptiv. Catalogue etc., part. 1*, p. 77.

In the opinion of Andrews, this evolution took place as a result of adaptation to an aquatic life. If in the majority of land animals the front and hind limbs must bear the whole weight of the body during forward movement of the animal, in aquatic animals the task of the limbs mainly amounts to propelling the body of the animal in the water. In this case, the head of the humerus will press mainly in the forward direction against the wall of the glenoid cavity, whereas in land animals it presses mainly in an upward direction. As a result of this, there arises the necessity in the transverse clavicular cross-piece, which is closely united with the scapulae, for having a sufficient base foundation during the pressure forward and inward from the side of the glenoid cavity. Beginning with Triassic Nothosauridae through Plesiosauridae to the most specialized Elasmosauridae, changes in the pectoral girdle progressed specifically in the direction of increasing the stability of the aforesaid region. The clavicular arch was gradually reduced; in place of it the ventral branch of the scapulae developed and grew in significance.[1]

Such are the theoretical bases and suppositions for these or other presentation of the pectoral girdle of *Elasmosaurus* Cope. It is as if through these [theories] we tried to supplement the lack of direct observations upon the given question. Up until recent times, the only known remains of the shoulder girdle of elasmosaurs are those fragments that Cope pointed out among the skeletal remains of *Elasmosaurus platyurus* and *E. serpentinus*, the identification of which, as we have pointed out, later appeared quite questionable.

Lately, Williston has tried to supplement the factual material on this question. He made a statement[2] about the available remains of the pectoral girdle in several fossils, newly discovered in North America, which Williston referred to the genus *Elasmosaurus* Cope: *E. snowi*, *E.* ?*marschi*[*], *E. nobilis*, and *E. ischiadicus*. Disregarding the fact that identification of the bones of the animal attributed to the genus *Elasmosaurus* Cope, and named by Williston as *E.* ?*marschi*, is still questioned by Williston himself[1], and that generally among the known North American remains referred to the genus *Elasmosaurus* Cope (*E. platyurus* Cope, *E. serpentinus* Cope, *E. orientalis* Cope, *E. intermedius* Cope, *E. snowi*, *E. marschi*, *E. ischiadicus*, *E. sternbergi*, *E. nobilis*), according to Williston, "it is possible—more than

[1] Andrews. *Ibid*.
[2] Williston. N. American plesiosaurs. *Americ. Journ. Sci., 4th ser*., Vol. XXI, 1906.
[*] *sic*: *marshii*

that—it is probable that there is the existence of two or even more different genera."[2] Besides all this, the factual indications adduced by Williston hardly exhaust the given problem.

Thus, among the skeletal remains of *E. snowi*, Williston remarked on the presence of a coracoid "of the real elasmosaur type, with a wide indentation behind," along the middle, and "of both scapulae of the usual type, scapulae that are not very much expanded in the proscapular region."[3] A reconstruction of this girdle presented by Williston[4] comes quite short of corresponding to the one that could be set up from Cope's data on the girdle of the Kansas *Elasmosaurus platyurus*, which appeared as a typical representative of the genus. From this same genus Williston himself, a short time before that, referred the skeletal remains of *E. snowi* to the genus *Cimoliasaurus* (*C. snowi*).[5] The same is to be said about Riggs's reconstruction, cited by Williston as typical for the pectoral girdle of elasmosaurs.[6] In substantial features, this reconstruction does not differ from the one Williston gave for *E. snowi*.[7]

Williston described only the scapula of the shoulder girdle of *E.* (?) *marschi*[8]. He wrote that, "this bone is quite drawn out from the side of the ventral edge and spreads out wide before joining with the opposite scapula, along the mid-line. From the point of symphysis of both scapulae, there extends from behind a narrow elongated process which nevertheless does not reach a junction with the Coracoid, as is the case with *E. platyurus*. Both scapulae diverge widely anteriorly, forming an angular receptacle for the claviculae or interclavicula."

"I think," added Williston, "that the missing bone is the interclavicle, and that the clavicles appear as in *Cryptocleidus*."[9]

Regarding the pectoral girdle of *Elasmosaurus ischiadicus*, Williston said only that among American collections "there exists an almost complete pectoral girdle, it seems, of this

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[1] Williston. *l. c*., p. 223, 229–231.
[2] Williston. *Ibid*., p. 224
[3] Williston. *Ibid*., p. 230.
[4] *American. Journ. Sci., 4th ser*., vol. XXI, p. 230, fig. 4.
[5] Williston. N. Americ. plesiosaurs. *Field Columbian Museum*, vol. II, no. 1, 1903. *cf. Americ. Journ. Sci., 4th ser*., no. 123, 1906.
[6] Williston. *Water Reptiles of the Past and Present*, p. 86, fig. 39. Chicago, 1914.
[7] *Americ. Journ. Sci., 4th ser*., 1906, p. 228, fig. 2.
[8] Williston. N. Americ. plesiosaurs. *Americ. Journ. Sci*, 1906.
[9] Williston. *l. c*., p. 230

very species"[1] which—it is well to say—Williston previously had referred to the genus *Polycotylus*, i.e. to the shortest-necked plesiosaurs.[2] As yet, Williston has given neither a description of the bones nor a drawing.

Finally, from among the bones of the pectoral girdle of *E. nobilis*, Williston designated "the massive fragment of the scapula, showing a broad and firm union along the mid-line with the opposite scapula,"[3] and also "a Coracoid, with a very long and strongly reduced posterior process, expanded from its distal side (its distal width being a little less than twice that of its least width); with its sharp posterior angle not projecting greatly."[1] Williston thus far has not furnished figures and detailed description of these bones.

In 1912, during excavations in the North Don district, (Lysoff homestead, Liska River basin) among skeletal remains that, judging from the well preserved vertebrae, proved to belong to a member of genus *Elasmosaurus* Cope, there were unearthed fragments of the pectoral girdle of the animal, fragments consisting of: (1) piece of the left scapula; (2) interclavicle; and (3) pieces of the left coracoid. Here, we shall give a description of these bones.

SCAPULA

(Plate 1, fig. 2a, b)

The fragments mentioned here are pictured in Plate 1, fig. 2a, b. Fig. 2a shows the largest fragment of the left scapula. The posterior portion of the scapula, or the articular head, has been preserved almost perfectly. The distal branch is depressed dorsally and anteriorly. The ventral branch has been preserved only partially at the base.

In general features, the bone is noticeably concave from the visceral side, and from the ventrolateral side is convex in the manner of a semi-oval.

The posterior portion, or the articular head of the scapula, presents as a short, rather massive bone of a semi-oval triangular contour in cross-section, and slightly convex ventrolaterally. The articular end is raised in relief along the visceral edge. For this reason, the visceral surface of the head appears more concave. The head is thicker (about 3.7 cm) at

[1] *Americ. Journ. Sci., 4th ser*., vol. XXI, no. 123, p. 231
[2] Williston. *Field Columbian Museum*, vol. II, no. 1, 1903.
[3] *Americ. Journ. Sci., 4th ser*., p. 233, 1906.

the lateral edge. On the side of the medial edge, the head tapers off somewhat.

Dimensions of the articular head.

Overall length along a straight line from the posterovisceral edge of the glenoid surface up to the posteroventral corner of the dorsal branch of the scapula—about 9.4 cm.

Cross-sectional diameter of articular head—about 6.8 cm.

Cross-sectional diameter of distal end of head—about 3 to 3.3 cm.

Width of articular end (medial edge is depressed)—about 8 to 9.0 cm. (?)

Only the posterior part of the glenoid surface has been preserved. Evidently, this surface was slightly concave and more or less covered with coarse, warty swellings.[2] The outer contours, apparently, are close to semi-ovate with diameters of 5.7 cm and 6.8 cm along the transverse axes. The area for articulation with the coracoid is beaten down; evidently, it was of almost equilateral triangular shape with a base (from the side of the glenoid surface) of about 6.2 cm, and a height ["length"] of about 5 to 6 cm (?). This area is located at almost right angles relative to the glenoid surface.

The lateral surface of the articular head is decidedly rough and bears traces of muscle attachment. In its upper one-third there are traces of a smooth, circular, comb-type swelling that extends anteriorly into the widely circular keel that separates the ventral branch of the scapula from its dorsal branch. The dorsolateral edge of the head is round and in an arched fashion extends anteriorly into the posteroventral edge of the dorsal branch of the scapula.

The dorsal branch of the scapula is broken off along the anterior edge and is beaten down at the upper suprascapular end. The length [= height] of the protective part is about 12.5 cm; the thickness of the bone at the base is 2.2 cm; about 1.85 cm in the upper half, and about 1.7 cm at the top. From the lateral side, the bone is somewhat concave in the direction of length [= height]; from the visceral side it is ovally convex at the posterior edge, and is somewhat tapered off along the line toward the anterior edge. The posterior edge of the

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[1] *Ibid*., p. 233.

[2] Perhaps, in this case we have an indication of an animal not fully grown. According to Andrews, the glenoid surface, for example in *Muraenosaurus*, "is only slightly concave and nearly smooth in specimens in which ossification seems to be approaching completion, but in younger animals it may be roughened, and was no doubt covered with cartilage." Andrews. *Marin. Reptil., par. I*, p. 110.

dorsal branch was evidently a concave arch in fashion; ventrally, it fuses and rounds off with the lateral edge of the articular head of the scapula.

The ventral branch of the scapula was only partially preserved—in the form of a small part adjacent to the dorsal branch and the articular head of the scapula. It appears as a fragment of a broad bone, slightly concave from the visceral side, and in perfect trough-fashion it fuses with the portions adjoining the dorsal branch and the articular head of the scapula. From the ventral side it is ovally convex. The thickness of the fragment at the boundary with the dorsal branch is about 2.4 cm; the bone tapers off somewhat toward the anterior and medial edges; at the anterodorsal corner the thickness of the fragment is 1.7 cm; at the ventromedial corner it is 1.4 cm. Nearer to the medial edge, the bone is apparently tapered still more.

The fragment of bone pictured in Plate 1, fig. 2b is evidently the symphyseal part of the ventral branch of the left scapula. The bone is beaten down from the sides; the anterior edge is slightly depressed from the left. In general this fragment has the appearance of a short club [pestle], the dorsal end of which is slightly broadened and cut shovel-fashion from the visceral side; the ventral end presents something like a massive handle, semicircular in section, and slightly concave from the left side. From the ventral side the bone is smooth throughout its length, and rounded from the sides.

The above-mentioned shovel-like cut on the widened end of the fragment evidently served as an articular surface for the corresponding wing of the interclavicle and perhaps the clavicle (?). The surface of the cut is slightly concave; from the posterior side the cut is bounded by a low ridge placed diagonally relative to the long axis of the fragment. The anterior edge of the cut extends along the slightly concave line, in general almost parallel to the direction of the elevation behind the cut, at a distance from the latter of 5.1 cm from the left side and 5.6 cm (average) from the right. The thickness of the fragment at the point of the articular cut is: about 4.9 cm on the line of the posterior recession; 3.9 cm at the base of the recession; 2.5 cm at the anterior edge. From the anterior left, the convex surface of the cut sinks somewhat and the fragment tapers off in this direction. From the front and right, the cut is bounded by an almost vertical surface, faintly concave, cutter-fashion, along the circumference; horny callouses are visible that evidently served as attachment for cartilage.

On the surface of the cut there is a small, elongate-oval depression along the long axis of the fragment. The fibers of the bone on the surface of the cut diverge fan-like from the posterior recession which bounds the cut. As has been said, the posterior part of the piece of bone, beyond the line of the articular cut presents the appearance of a sort of handle of a pestle or club, a kind of handle that tapers toward the top. The bone here is semi-oval in cross-section. From the left side it is indented in a semi-arched fashion; and apparently bounded the coracoscapular foramen. From the right side, the bone came in contact with the corresponding part of the right scapula. Unfortunately, the symphyseal surface is battered down. The thickness of the fragment in centimeters is: 4.9 x 5.5 around the articular cut, 4.6 x 4.2 (?) behind the articular cut.

The posterior end of the bone is depressed ventrally. The overall length of the fragment is about 14 cm; the length of the articular surface is about 6.8 cm.

INTERCLAVICLE

(Plate I, fig. la, b, c)

This boat-shaped bone is longitudinally concave from the visceral side and correspondingly keeled from the ventral side. Anteriorly, the keel of the ventral surface is broadly rounded, it tapers posteriorly, becomes sharp and more distinctly outlined. The side wings of the bone, which come down from it [the keel], are slightly concave longitudinally. From behind the bone, these wings form a sharp angle of about 100° with the keel; anteriorly they fuse roundly (on the line of the keel) at an angle of about 120°. From the visceral side, the lateral wings meet on a curve, at an angle of 140 to 150° on the line of the ventral keel.

The longitudinally concave visceral surface of the bone has a noticeable depression in the middle-anterior part; this depression is partially filled with a densely grown piece of torn fibrous bone, evidently a rather thin bone and one that perhaps represents a portion of the broken clavicle. Just such a piece of bone, according to the characteristics of the bone fibers, appeared as having been firmly set on the shelf, and bounding the articular surface of the anterior-symphyseal end of the scapula, described above.[1]

The lateral edges of the bone are broken down. It is possible that it had, in general,

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[1] An analogous case is pointed out by Seeley in *Picrocleidus beloclis* Seeley. "On the left side of the ventral surface (of interclavicula)," wrote Seeley, "its middle part is covered by a thin film of bone, which rests upon the right scapula." *Proc. Royal. Soc.*, vol. 51 (1892), p. 143.

semicircular-triangular contours, with the top on the anterior end of the keel line. The posterior edge of the bone evidently is slightly concave along the middle or almost straight; the adjoining part of the visceral floor of the interclavicle is convexly pushed out toward the side of this border. Laterally and anteriorly, the bone is somewhat stretched toward the edges.

Measurements:

Length of bone (fragment), overall length about 9.2 cm.

Width of bone (fragment), overall about 7.0 cm.

Width of left wing from crest of keel about 6.4 cm.

Width of right wing from crest of keel about 5.5 cm.

Thickness along keel line, posteriorly about 2.8 cm.

Thickness along keel line, anteriorly about 1.0 cm.

Thickness of wings nearer to keel about 1.0 cm.

Thickness of wings nearer to lateral edge about 0.7 cm.

CORACOID

(Plate I, fig. 3a, b, c)

The available fragments of the coracoid are pictured in Plate I, fig. 3a, b, c. They belong to the left coracoid and consist of: (A) fragment of the articular neck of the bone with the glenoid cavity; (B) fragment of the left side; and (C) a piece of the middle-anterior part of the coracoid.

The fragment of the articular neck (fig. 3a) presents the contours of a semi-oval in cross-section that is constricted in the direction of the caudal edge of the neck. While becoming somewhat thinner toward the symphyseal edge of the coracoid, the bone becomes thicker toward the articular end and presents an abruptly projecting edge around the articular cavity. The ventral and partly the caudal edges of this fossa protrude decidedly, and stick out ventrally and laterally.

The features of the articular (glenoid) cavity are seen in fig. 3a, Plate I. In places, the surface of the cavity bears clinging bits of the torn head of the humerus; also there are small oval depressions.

Measurements:

Greatest length of fragment, from the side of the articular cavity, about 6.8 cm.

Cross-section diameter of articular cavity, about 5.5 cm.

Depth of articular cavity, about 1.0 cm.

Anterior thickness of the fragment, about 3.3 cm.

Posterior thickness of the fragment, about 1.0 cm. and less.

The piece of the left side of the coracoid is pictured in Plate 1, fig. 3b and evidently belonged to the anterolateral part of the coracoid. From the ventral side, the bone is convex longitudinally in the manner of an oval comb. From the visceral side it is only slightly concave longitudinally and slopes down anteriorly and posteriorly from the slight transverse swelling. The lateral edge is sharpened and slightly concave. The thickness of the transverse line of the swelling is about 2.8 cm. Length of the fragment about 10.7 cm.

The fragment of the anterior-middle part of the coracoid presents a broad bone that becomes thicker on the anteromedial side, and slightly thinner toward the posterolateral corner (fig. 3c, Plate I), a little bulgingly convex along the from the thickened corner; the visceral surface likewise is convex in the diagonal transverse direction. The bone is broken from all sides, and it is impossible to judge more definitely as to normal features. Thickness of bone, from side of thickened corner, about 4.5 to 5 cm. Thickness of bone, from side of the opposite end that has become thinner, about 2.5 cm.

On the basis of the fragments described, it is difficult to judge the general features of the pectoral girdle of the given animal. The fragments are too broken up, and it is not always possible to orient them with certainty relative to one another.

Nevertheless, there is hardly any doubt that this girdle does not resemble the reconstruction that Cope gave for *Elasmosaurus platyurus*.[1] Disregarding Cope's mistaken interpretation of the scapula, which as we know he mistook for the clavicle or procoracoid, the scapulae of *E. platyurus* were shown by Cope as joining along the straight midline symphysis, and were bounded anteriorly by an almost straight edge (slightly curvedly concave on the symphyseal line). The scapulae of our *Elasmosaurus* undoubtedly diverge

[1] Cope. Synopsis of the extinct Batrachia, Reptilia a. Aves of N. America. *Transact. of the Amer. Philosoph. Society*, Philadelphia, vol. XIV, 1871.

anteriorly along the symphysis; the small boat-shaped interclavicle was wedged between them. Along with this the anteromedial corner of the ventral branch of the scapula was hollow shovel-fashion, and cut from the visceral side for lodging the corresponding wing of the interclavicle, and most likely the clavicle. Evidently there resulted an articulation that more or less approached the corresponding articulation in various members of the Elasmosauridae, as for example in *Muraenosaurus* (*M. leedsi*, etc.), *Tricleidus*, and in part *Picrocleidus* and others.[1] The glenoid cavity took up not only the articular end of the coracoid, as shown by Cope in the case of *Elasmosaurus platyurus*, but the anterior half lay on the articular head of the scapula. The dorsal branch of the scapula was evidently higher [= longer] and narrower than might be supposed according to Cope's drawing for *E. platyurus*.

These same peculiarities distinguish the given girdle from the pectoral girdle of *E. serpentinus* in as far as there are indications about it in Cope.[2]

As compared with the "Iellskim" specimen of *Elasmosaurus snowi* Willst., the pectoral girdle of our elasmosaur evidently has scapulae not as widely separated anteriorly (along the midline symphysis) as that pictured by Williston in the case of *E. snowi*. The medial edge of the ventral branch of the scapula in our elasmosaur had a massive longitudinal process posteriorly that which the coracoscapular foramen, and which evidently was continued along the line toward the anterior edge of the coracoid, which is not observed in *E. snowi*. The same must be stated concerning Riggs's figure, which Williston has used as a representation of a typical girdle in elasmosaurians, and which is really a supplement to Williston's figure of *E. snowi*.[3]

The pectoral girdle of our elasmosaur could much rather approach that of *Elasmosaurus marschi* Williston. The scapulae of this animal pictured by Williston meet by means of the ventral branches along the midline symphysis and from behind produce "the narrow elongated outgrowth;" the latter, however, is not joined with the coracoid.[4] Anteriorly, the scapulae of *E. marschi* leave a wide angular lodgement for the clavicles or

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[1] Compare Andrews. *Descript. Catal. Marine Reptiles, part I*, plate VI, fig. 3; plate VIII, fig. 3; plate VII, fig. 2; pp. 111, 108, 142, 143, 158, 159, etc.
[2] *Bull. U. Stat. Geol. and Geogr. Survey*, v. III, no. 3; 1877. According to Williston, in the near future there should appear a description of this girdle, based on the collections in Field Columb. Museum. See *Americ. Journal of Science, 4th Ser.*, Vol. XXI, p. 228.
[3] See Williston. *Water Reptiles*, p. 86, fig. 39, 1914.
[4] Williston, *Am. J. Sci.*, vol. XXI, 4 ser., p. 230.

interclavicles.[1] However, it is difficult to establish more definitely the features of similarity and difference for the corresponding bones of both animals, because only the scapulae of the pectoral girdle of *E. marschi* are known and those only in schematic description.[2] It is still more difficult at present to judge the likeness and difference of said girdle as compared with the pectoral girdle of *E. ischiadicus* Williston and *E. nobilis* Williston. Pictures and detailed descriptions of the latter are lacking for the present.[3] In the case of *E. nobilis* it is known only that "the massive fragment of the scapula shows a broad firm union along the mid-line with the opposite scapula. The posterior process of the coracoid is very long and decidedly constricted at the end; the posteromedial corner is sharp and projects slightly."[4]

As has been said, the presence of interclavicles, and evidently clavicles, considerably bridges the gap between the pectoral girdle of our elasrnosaur and certain *Muraenosaurus*, *Tricleidus*, *Picrocleidus*, and other representatives of the family Elasmosauridae. Evidently, there is a likeness even in the general features of this girdle when compared with the girdle of the animals mentioned above. But it is difficult to judge how far this similarity extends, as a result of the fragmentary condition of the bones of our elasmosaur. In general, the interclavicle in the latter is likewise boat-shaped, convex, and keel-like from the ventral side, as in *Muraenosaurus leedsi* Seeley.[5]

However, this keel extended as far back as the distance it was located from the ventral branch of the scapula. Was there an interclavicular interscapular foramen as in *M. platyclis* Seeley[6] and *M. durobrivensis* Lydekker,[7] or perhaps the posterior end of the interclavicle was firmly locked with the neighboring scapulae as in *M. leedsi* Seeley,[8] and as Williston generally supposes in the case of *Elasmosaurus* Cope?[9] Unquestionable data for solving these problems are as yet lacking.

In any case, it is correct to suppose that the fragment pictured in Plate I, fig. 2b, is a piece of the anterior-symphyseal end of the ventral branch of the scapula. We can hardly be

[1] Williston, *ibid*. p. 230.
[2] Compare Williston, *1. c*. fig. 4.
[3] See Williston, *ibid*. p. 231–233. Compare Williston, *Field. Col. Mus. Pub., Geol. Ser*., vol. II, p. 72. 1903.
[4] Williston. *Am. J. Sci*. 1906, p. 233.
[5] Compare Andrews. *Descript. Catal. Mar. Rept., part I*, Plate VI, f. 6.
[6] Andrews, *1. c.* Plate IV, fig. 3, p. 134.
[7] Andrews, *ibid*., plate V, fig. 10, p. 109.
[8] Andrews, *ibid*., p. 109, fig. 62.
[9] *Am. Journ. Sci*. 1906, p. 225.

bound to expect in our *Elasmosaurus* so greatly widened [= elongated] scapulae in the ventral branch as in the above-mentioned *Muraenosaurus*.[1] In this connection they are, it seems, nearer to the scapulae of *Pircocleidus*[2] and *Tricleidus*.[3]

The pectoral girdle of our *Elasmosaurus*, as it seems, comes nearest, namely, to the shoulder girdle of *Tricleidus* Andrews (for example *T. seeleyi* Andrews). According to the features of the interclavicle, the position of the clavicles, regarding the general appearance of the scapulae and coracoids, and equally according to the method of articulation of these bones, it seems that the anterior girdle of *Tricleidus* is a great deal like the corresponding girdle of our *Elasmosaurus*.[4] It is possible that the dorsal branch of the scapula in the latter was somewhat longer and more constricted on the dorsal end than that in *Tricleidus*. For the present, the contours of the posterior edge of the coracoid in our elasmosaur are absolutely unknown. But we repeat that the general structure seems to be very close to that structure that indicated for the pectoral girdle of *Tricleidus*.

Thus, in this manner Williston's prognosis, that in the pectoral girdle of at least certain *Elasmosaurus* Cope there most likely existed an interclavicle and clavicles,[5] is substantiated in the skeleton of our elasmosaurs. It is not too early to think about whether in this given case we have the general type of structure of elasmosaurs, or only a case of age peculiarity of an individual, in the sense of Andrews. We recall that Williston also pointed out the probability of the existence of an interclavicle and clavicles in *Elasmosaurus marschi.* Andrews indicates these bones in various representatives of the family Elasmosauridae.

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[1] Compare Andrews, *l. c*. text-fig. 62, 68; plate VI, fig. 3, etc.
[2] Andrews, *ibid*., p. 142–143, plate VII, fig. 2.
[3] Andrews, *ibid*. text-fig. 76.
[4] Compare the detailed description in Andrews, *l. c*., pp. 15, 8–159.
[5] *Am. J. Sci*. 1906, p. 230.