# Dentition of a female megamouth, Megachasma pelagios, collected from Hakata Bay, Japan

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# Dentition of a Female Megamouth, *Megachasma pelagios*, Collected from Hakata Bay, Japan

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*Key words*: dentition, tooth, megamouth, *Megachasma pelagios*

**Abstract** A megamouth shark, *Megachasma pelagios*, was stranded on the beach in Hakata Bay, northern Kyushu, Japan, on the 29th of November in 1994. This is the first female ever examined. Teeth in series of both jaws are described in detail and a histological observation of tooth rows on both jaws was made. There are 42 rows in the right upper jaw, 41 rows in the left upper jaw, 48 rows in the right lower jaw and 49 rows in the left lower jaw. The total number of tooth rows is 83 in the upper jaw and 97 in the lower jaw. The number of the tooth rows of the female is 25 fewer in the upper jaw and 31 fewer in the lower jaw than the male, holotype. There are three rows of functional teeth on each jaw. The difference between the lower and upper teeth is recognized. The lower teeth are larger than the upper teeth. Three or four tooth germs are observed in the jaws. The tooth consists of three hard tissues, an outer enameloid layer, an inner osteodentine, and a basal osseous tissue. The order and pattern of tooth development in the megamouth shark are basically the same as other lamnoid sharks.

A female megamouth, *Megachasma pelagios* Taylor, Compagno & Struhsaker, 1983, was found stranded on the beach in Hakata Bay on the 29th of November, 1994. This is the first female specimen and the seventh record of this species.

The first megamouth shark was a 4.46-meter male collected from about 42 km northeast of Oahu, Hawaii by a research vessel. Taylor et al. (1983) described it as a new species, genus and family. Five other megamouth sharks have been found since then in the Pacific Ocean off California, Western Australia and Japan, and two more young male specimens were found in the Atlantic Ocean (Lavenberg and Seigel, 1985; Berra and Hutchins, 1990, 1991; Nakaya, 1989; Miya et al., 1992; Séret, 1995; Amorim et al., 1995). Four of these specimens, including the holotype are preserved in museums in the United States and Australia, and Brazil (Lavenberg and Seigel, 1985; Berra and Hutchins, 1990, 1991; Amorim et al., 1995).

Teeth of the male megamouth shark were described by Taylor et al. (1983) and Compagno (1990) compared them to fossil teeth found in the Early Miocene of California and also to *Megascyliorhinus* from the Lower Eocene to the Pleistocene. In the present paper, we describe the dentition of both jaws and the structure and development of the teeth of a female megamouth shark.

## Materials and Methods

The specimen was a female collected on the beach at Gannosu in Hakata Bay, Higashi ward

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**Fig. 1.** Mouth of the megamouth shark. Arrows indicate the sites of tooth rows taken from the upper and lower dentitions.

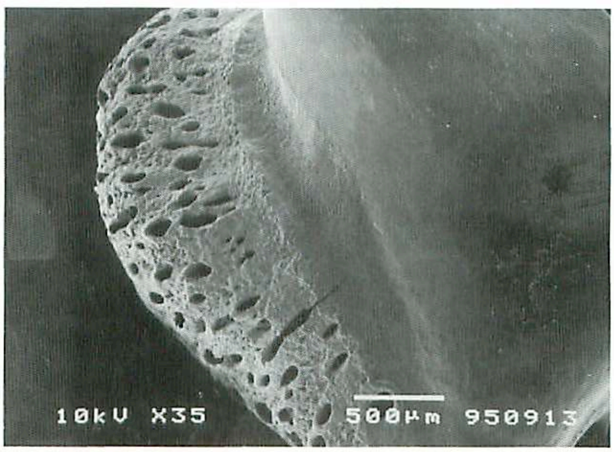


**Fig. 2.** Scanning electron micrograph of the third lower tooth of the female megamouth shark, *Megachasma pelagios*, showing the porous root. Scales is 500 $\mu$m.

in Fukuoka City, northern Kyushu, Japan, on 29 November 1994. The total length was 4710 mm and the body weight was 790 kg. It was preserved in Marine World umino-nakamichi (aquarium). Tooth series were removed from the right upper and lower jaws and the attached tissue were putrefied. The tooth samples were preserved in the same aquarium. Some teeth were examined with a scanning electron microscope (SEM). Drawings were made with a binocular dissecting microscope.

Two tooth rows of the upper and lower jaws were removed (Fig. 1) and fixed in 10% formalin. Decalcification in formic acid was followed by celloidin embedding and serial sectioning. Haematoxylin and eosin and Masson Goldner's staining were done. Tooth terminology is based on Applegate (1965) and Welton and Farish (1993).

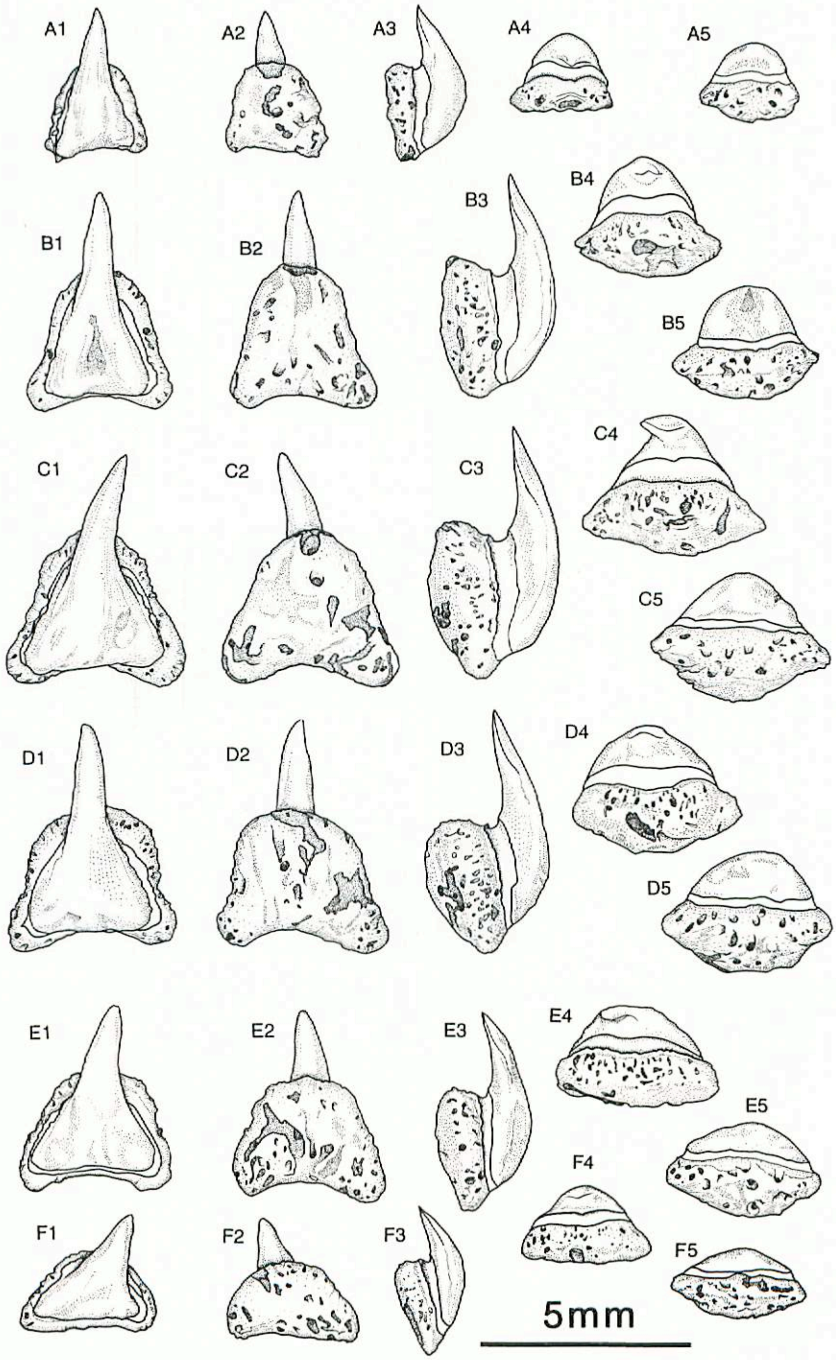


**Fig. 3.** Upper teeth of the female megamouth shark, *Megachasma pelagios*. A, the first tooth; B, the fifth tooth; C, the tenth tooth; D, the fifteenth tooth; E, the twenty-first tooth; F, the thirty-fifth tooth; 1, labial view; 2, basal view; 3, mesial view; 4, apical view; 5, lingual view.

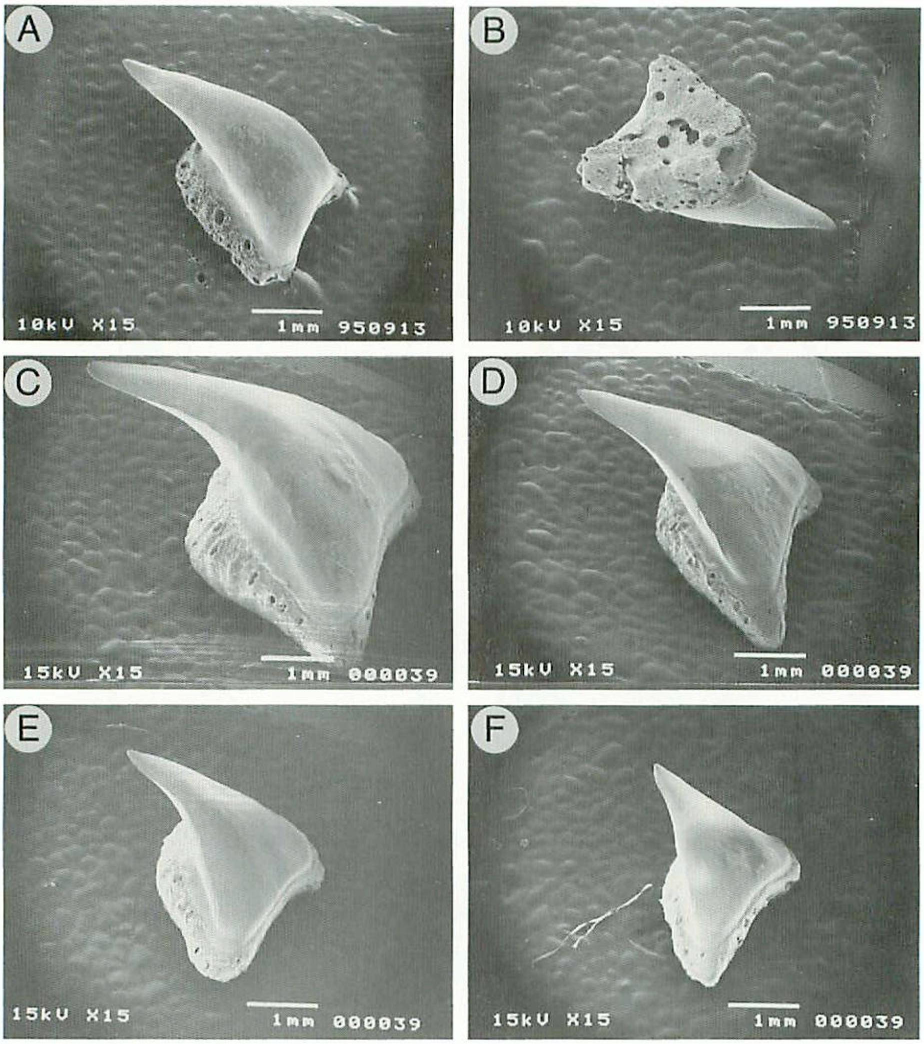


**Fig. 4.** Scanning electron micrographs of the upper teeth of the female megamouth shark, *Megachasma pelagios*. A and B, the first tooth; C, the twentieth tooth; D, the thirtieth tooth; E, the thirty-fourth tooth; F, the thirty-seventh tooth. Scales are 1mm.

## Results

### Description of Teeth

Teeth are very small and numerous. There are 42 rows in the right upper jaw, 41 rows in the left upper jaw, 48 rows in the right lower jaw and 49 rows in the left lower jaw. The total number of tooth rows is 83 in the upper jaw and 97 in the lower jaw. The lower teeth are larger than the upper teeth. The symphyseal toothless space is 18 cm, about four times the orbit diameter in the upper jaw and 8 cm, approximately one and one-half times the orbit diameters in the lower jaw.

The crowns have a strong lingual inclination and the apical parts are almost parallel to the attachment surfaces of the roots in the first and the second teeth of both jaws. The crowns rise slightly in other teeth. The basal parts of the crowns are wide and almost triangular in labial view. The apical parts of the crowns become slender and the cusps are acute with short cutting

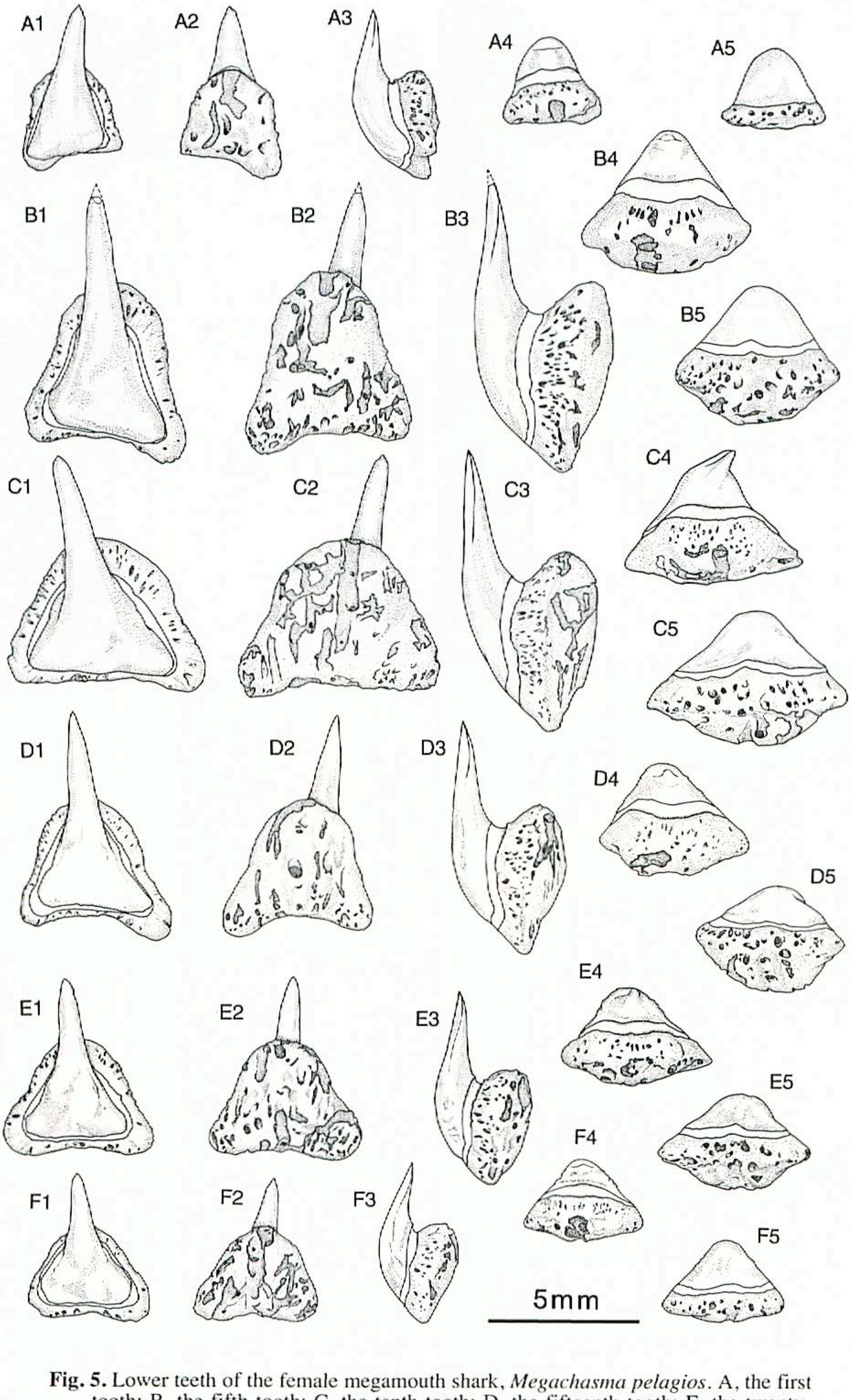


**Fig. 5.** Lower teeth of the female megamouth shark, *Megachasma pelagios*. A, the first tooth; B, the fifth tooth; C, the tenth tooth; D, the fifteenth tooth; E, the twenty-first tooth; F, the thirty-fifth tooth; 1, labial view; 2, basal view; 3, mesial view; 4, apical view; 5, lingual view.

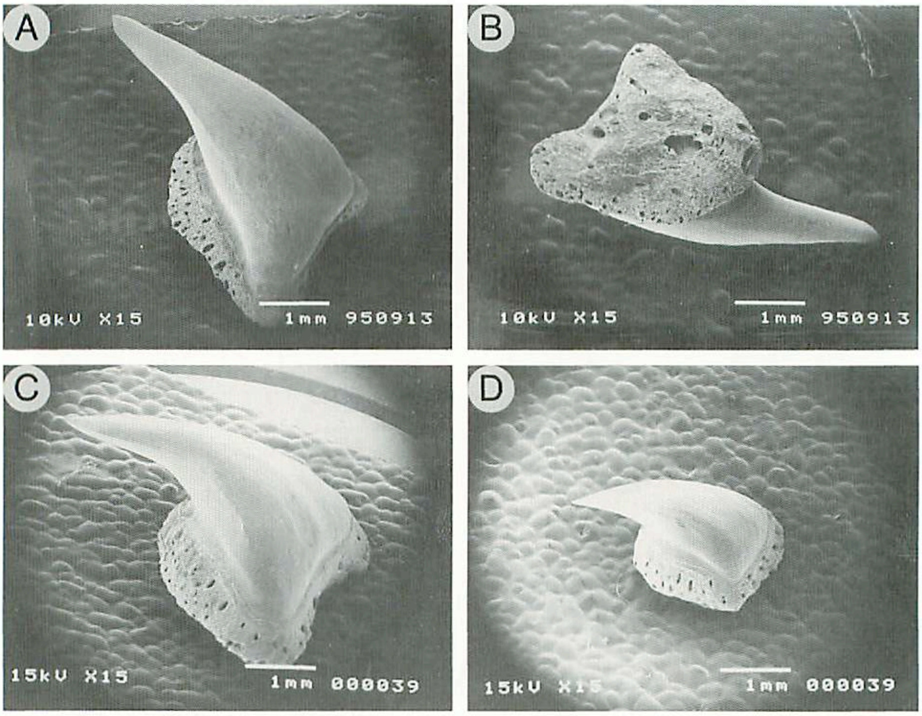


**Fig. 6.** Scanning electron micrographs of the lower teeth of the female megamouth shark, *Megachasma pelagios*. A and B, the first tooth; C, the thirty-seventh tooth; D, the forty-eighth tooth. Scales are 1mm.

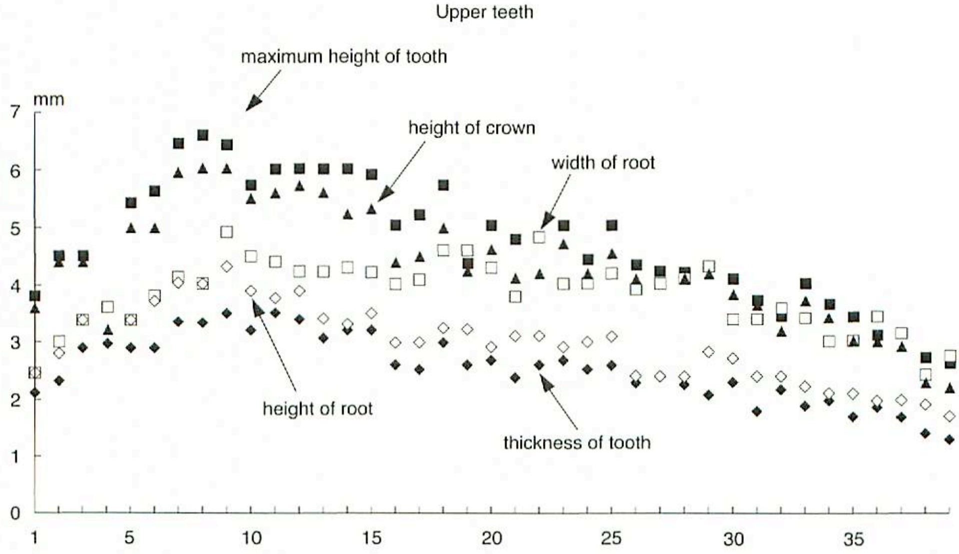


**Fig. 7.** Dimensions of the upper teeth in the right series of the female megamouth shark, *Megachasma pelagios*.

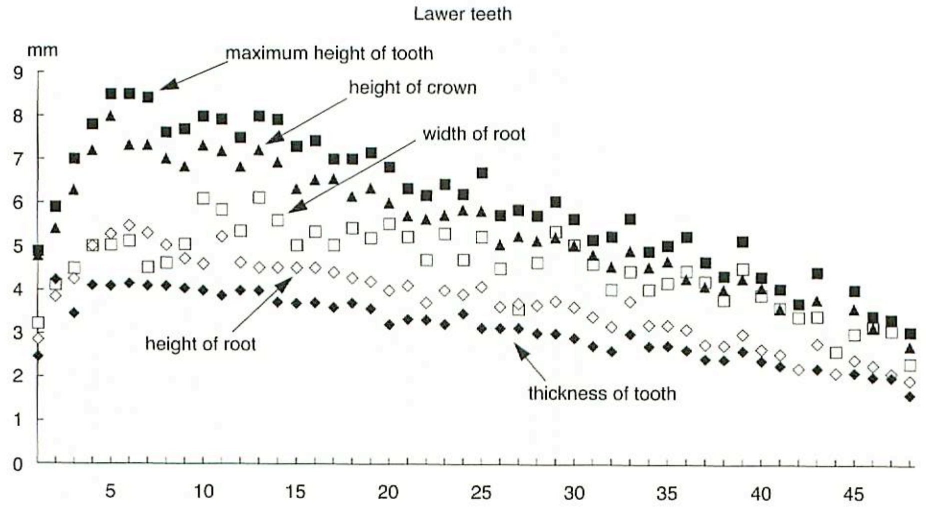


**Fig. 8.** Dimensions of the lower teeth in the right series of the female megamouth shark, *Megachasma pelagios*.

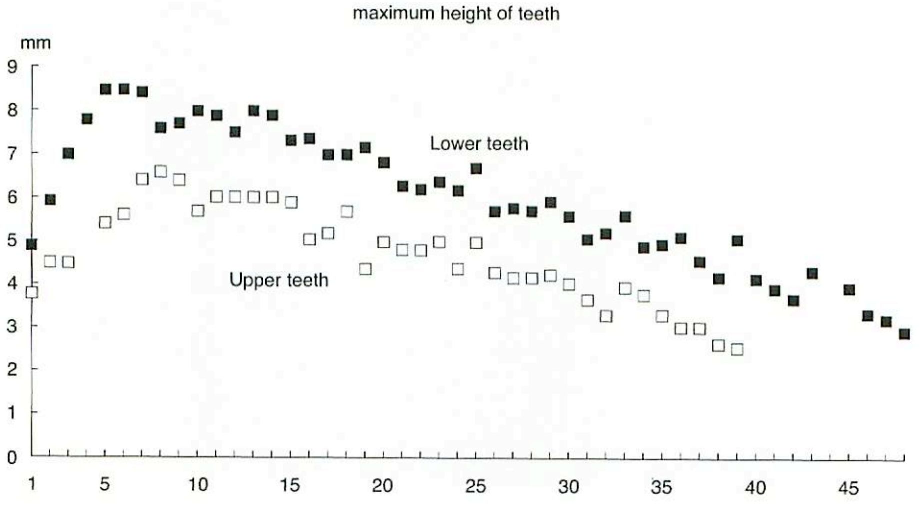


**Fig. 9.** Comparison of the maximum height between lower and upper teeth of the female megamouth shark, *Megachasma pelagios*, in numerical order.

edges on the mesial and distal faces. The cutting edges are about a third to a half of the crown length. The labial and lingual surfaces of the crowns are smooth and convex. The protuberances of the lingual faces are slightly larger than those of the labial faces. There are dental bands ("neck" in Taylor et al., 1983) completely encircling the teeth. The bands of the lingual faces form a shallow groove, but those of the labial faces are flat. The bands are almost the same height, but those of the lingual faces are slightly wider than those of the labial faces.

The roots are porous and the attachment surfaces of the roots are almost triangular in basal view. The teeth are attached to the jaws via tissues from the pores (Fig. 2). There are short distal and mesial root lobes on the labial faces, and an enlarged and expanded lingual protuberance. Each tooth has a large central foramen ("centrolingual foramen" in Taylor et al.,

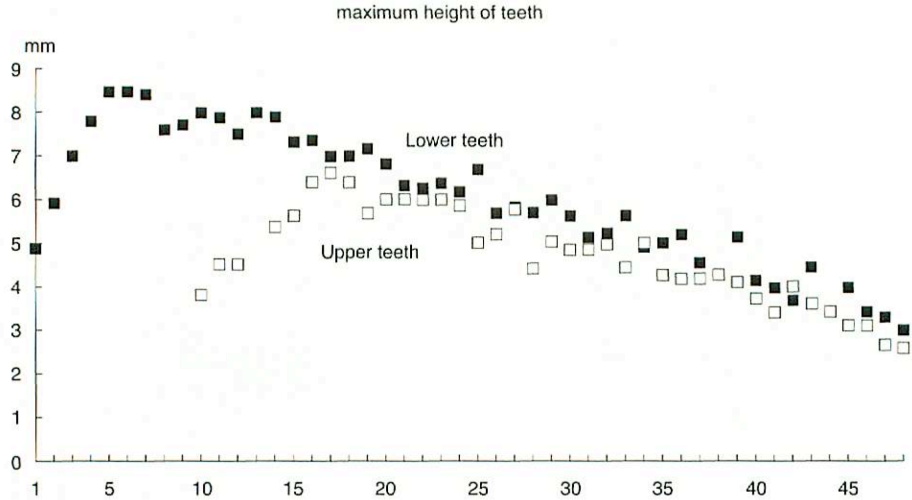


**Fig. 10.** Comparison of the maximum height between lower and upper teeth of the female megamouth shark, *Megachasma pelagios*, in the same position on jaws.

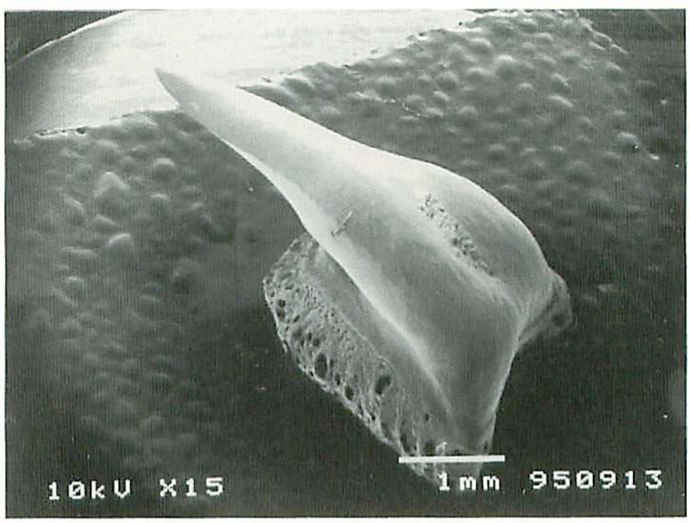


**Fig. 11.** Scanning electron micrograph of the second upper tooth of the female megamouth shark, *Megachasma pelagios*, showing the longitudinal concavity on the labial surface. Scale is 1mm.

1983). In some teeth, the foramen forms a transverse groove on the attachment surface of the root (Figs. 3-6).The tooth series show strong gradient monognathic and moderate dignathic heterodonty. The lower teeth are larger than the upper teeth (Figs. 7-10). The cusps of the lower teeth are more acute and longer than those of the upper teeth (Figs. 3 and 5). The tooth series of both jaws starts with small teeth.

The upper teeth increase in size from row one to row seven. Teeth from the 7th to 15th rows are the largest and are almost the same size. From row 16 the upper teeth begin to decrease gradually in size to the distal end of the series, but the width does not decrease relative to the height. The crowns of the upper teeth have a distal inclination in most teeth and the inclination is largest in the 9th to 12th teeth. But some teeth (e.g., the 7th and 16th) have a mesial curved cusp. A longitudinal concavity is observed in some teeth of the both jaws (e.g., upper teeth

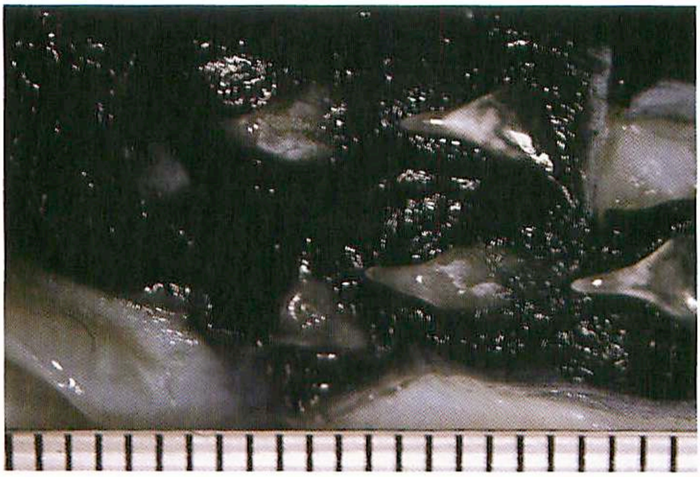

**Fig. 12.** The tooth rows of the upper jaw of the megamouth shark. There are three functional teeth in each tooth row.

from the 2nd to the 6th, and the 18th) (Fig. 3B and 11). The mesial root lobe is not extended in the 1st to 3rd teeth. The other upper teeth have an extended mesial root lobe. The distal lobes of most teeth are larger than the mesial lobes.

The lower teeth increase in size to the 4th row. The 4th to 18th teeth are the largest and are almost the same size. Then teeth begin to gradually decrease in size to the distal end of the series, but the width does not decrease relative to the height. The crowns of most teeth have a distal inclination, but some teeth (e.g., the 4th, 8th, and 13th) have a mesial curved cusp. The mesial root lobe of the first lower tooth is weak and not extended. In the distal teeth of the lower jaw (behind the 10th), the labial root lobes are flat and expanded and the outlines are round in basal view (Figs. 5 and 6).

### Tooth structure

There are three to four functional teeth in each jaw (Figs. 1, 12 and 13). The teeth consists of three hard tissues, an outer enameloid layer, an inner dentine, and a basal osseous tissue (Fig. 14B).

The enameloid consists of an outer layer on the crown of the tooth. The thickness of the enameloid is 80 $\mu$m. The enameloid is composed of highly calcified hard tissue which contains many fibrous structures in its middle and inner layers (Fig. 14C). The inner layer is composed of osteodentine which contains irregularly-shaped pulp cavities as in other lamnoid sharks (Goto, 1978a, 1985; Kakizawa,1984). The pulp cavities of the dentine are composed of fibrous tissues, blood vessels and nerves.

The boundary between the dentine and the basal osseous tissue is not clear. The basal osseous tissue is composed many pulp cavities that are lager than those in the dentine. The basal layer is composed of osseous tissue which has some canals that pass between the pulp cavities in the dentine and the basal osseous tissue and the surrounding tissue of the tooth. The basal osseous tissue contains many collagenous fibers which connect the root of the tooth to the dense fibrous tissue of the lamina propia mucosae (Fig. 14D).

### Tooth development

There are three or four tooth germs in the jaw, however the earlier tooth germs cannot be observed because the fixation of the tissues is poor and the tooth lamina is almost lost.

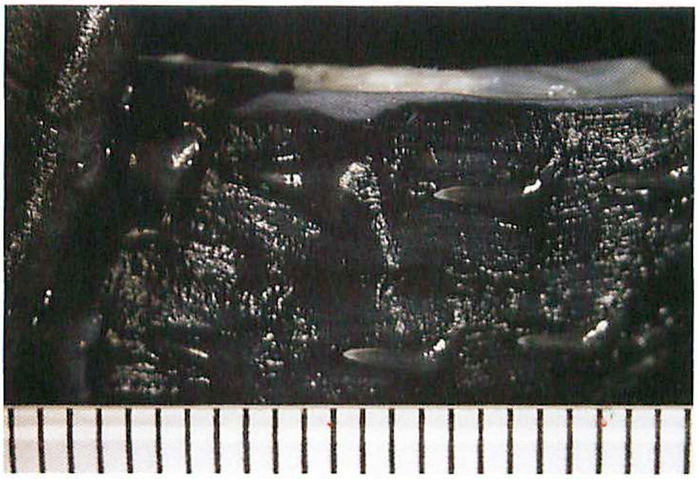

**Fig. 13.** The tooth rows of the lower jaw. There are three functional teeth in each tooth row.

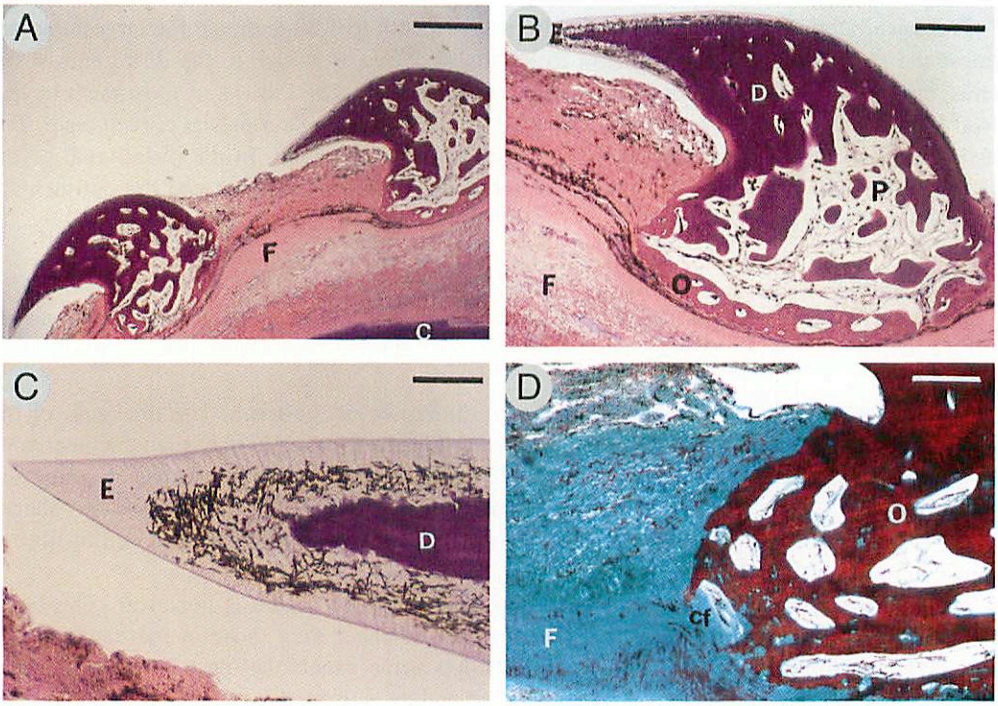


**Fig. 14.** Histological observation of the teeth of the female megamouth, *Megachasma pelagios*.
A, Two functional teeth of the lower jaw. H-E stain. Scale is 1mm. B, The most lingual functional tooth of the lower jaw. H-E stain. Scale is 500 $\mu$m. C, An enlargement of the tip of the cusp. H-E stain. Scales is 100 $\mu$m. D, An enlargement of the basal osseous tissue. Masson Goldner's stain. Scale is 250 $\mu$m. C= jaw cartilage; cf= collagenous fibers which connect the basal osseous tissue and surrounding fibrous tissue; D= osteodentine; E= enameloid; F= fibrous tissue layer; O= basal osseous tissue; P=dental pulp.

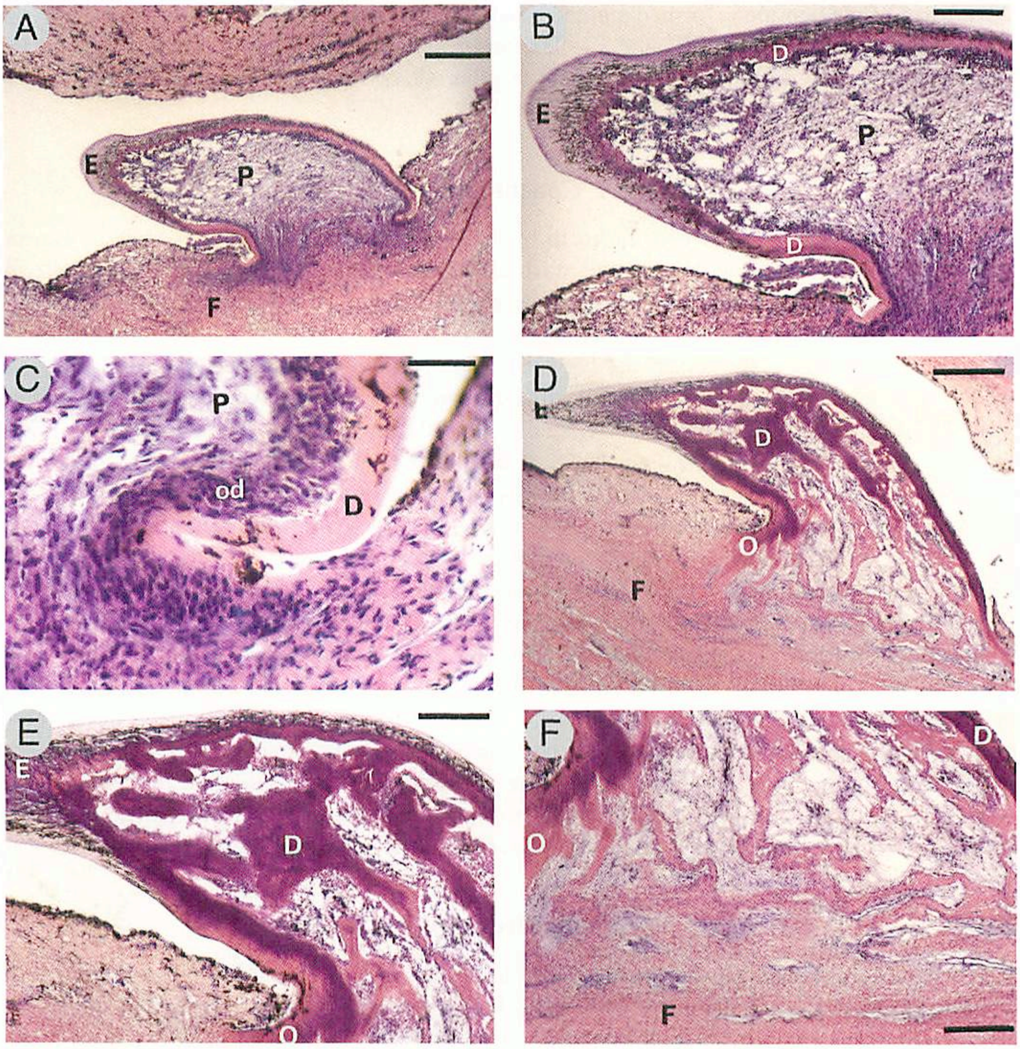


**Fig. 15.** Histological observation of tooth germs from the first female megamouth *Megachasma pelagios*.
A, A tooth germ in the stage of calcification from the tooth rows of the upper jaw. H-E stain. Scale is 500 μm. B, The dental papilla of the tooth germ in the stage of calcification. H-E stain. Scales is 250 μm. C, The basal part of the dental papilla of the tooth germ in the stage of calcification. H-E stain. Scale is 100 μ m. D, A tooth germ in the stage of dentine formation. H-E stain. Scale is 500 μm. E, An enlargement of the tooth germ in the stage of dentine formation. H-E stain. Scale is 250 μm. F, An enlargement of the basal part of the tooth germ in the stage of dentine formation. H-E stain. Scale is 250 μm. D= osteodentine in formation; E= enameloid; F= fibrous tissue layer; O= basal osseous tissue in formation; od= odontoblasts; P= dental papilla.

A tooth germ in the stage of calcification was observed in the upper jaw (Fig. 15A). The enameloid matrix is already formed and the dentine is just beginning to form in the crown of the tooth germ (Fig. 15B). Fibrous structures are formed in the middle and inner layers of the enameloid. The dentine of the crown is only a thin layer, but in the dental band the dentine layer is thicker than that of the crown. The dental papilla is composed of fibrous tissue which contain many mesenchymal cells and fibers. The basal osseous tissue is not formed, and in the basal part of the dentine there are a lot of odontoblasts on the surface of the dentine (Fig. 15C).

A tooth germ during the stage of dentine formation was observed in the lower jaw (Fig.

15D). Most of the dentine is formed and the basal osseous tissue is just beginning to form in the basal fibrous tissues (Figs. 15E and F). The order and pattern of tooth development in the megamouth shark is similar to that reported in other sharks (e.g. Goto and Hashimoto, 1977; Goto, 1978b; Kakizawa, 1989).

## Conclusions

Taylor et al. (1983) described the teeth of the holotype, an adult male, 4460 cm in total length. The dentition was described with illustrations of a lower lateral tooth from approximately midway along the lower left series and a figure of a sagittal section of a lower tooth from the same area.

In the present study, the difference between the upper and the lower teeth was recognized. The first five upper teeth are considerably smaller than the first five lower teeth (Figs. 8 and 9). The more distal upper teeth are slightly smaller than the lower teeth. The cusps of the lower teeth are more acute and longer than those of the upper teeth (Figs. 2 and 4). The difference between the upper and lower teeth of this species has not been described previously.

The number of tooth rows in the female is fewer than those in the male. The female has 42 tooth rows in the right upper jaw, 41 rows in the left upper jaw, 48 rows in the right lower jaw and 49 rows in the left lower jaw. Therefore the total number of tooth rows is 83 in the upper jaw and 97 in the lower jaw. But the male holotype has 52 tooth rows in the right upper jaw, 56 rows in the left upper jaw, 69 rows in the right lower jaw and 59 rows in the left lower jaw. Therefore the total number of tooth rows is 108 in the upper jaw and 128 in the lower jaw. Therefore, although the female specimen is 25 cm larger than the male, the number of the tooth rows in the female is 25 fewer in the upper jaw and 31 fewer in the lower jaw than in the male.

The number of tooth rows is 100 or more in *Cetorhinus maximus* and 300 or more in *Rhincodon typus* (Bigelow and Schroeder, 1948). Sexual dimorphism of dentition and the difference between the upper and lower teeth have not been described in either species.

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