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VARIATION STUDY IN SOME MIOCENE SHARK TEETH FROM BARIPADA BEDS, ORISSA

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ABSTRACT

The phenomenon of heterodonty exhibited by sharks necessitates a thorough study of the limits of the variation shown by teeth for correct identification at species level. This is demonstrated by making a detailed variation study of fossil teeth belonging to *Carcharodon megalodon* Agassiz and *Galeocerdo aduncus* Agassiz.

INTRODUCTION

Teeth have often been used in the identification and classification of sharks and also in stratigraphic correlations but without appreciable success. However, opinions are divided regarding the origin and taxonomic significance of shark teeth. During the course of a micropalaeontological investigation, a fair abundance of fish remains, especially teeth, were found in the Middle Miocene Baripada beds of Orissa, eastern India. The authors were confronted with the problem of their proper taxonomic placement as the fossil teeth were showing considerable range of similarities as well as dissimilarities in their morphologic features. It was, therefore, considered desirable to work out the limits of variation shown by different species present in the fish assemblage. This is possible when rich material is found. In the present case, *Carcharodon megalodon* Agassiz and *Galeocerdo aduncus* Agassiz occur in abundance and, therefore, variation of only these two species was worked out in detail. The present paper deals with this aspect of our study of the fish microfauna from the Baripada beds.

There is no uniformity in the usage of different morphological terms and also the measurements of shark teeth by several authors. Hence, it is necessary to give a concise account of the origin and morphology of shark tooth first and then the study of the range of dental variation exhibitied by the above two species. All the illustrated specimens are deposited in the micropaleontological collection of the Geology Department, Aligarh Muslim University, Aligarh.

ORIGIN AND MORPHOLOGY OF SHARK TOOTH

1. ORIGIN OF SHARK TOOTH

There is no general agreement regarding the origin of teeth in sharks. Some authors believe that they are derived from denticles, while others consider that dermis as well as epidermis participate in their formation.

Generally, workers agree that shark teeth are closely related to denticles. This is an old concept (Tomes, 1923) which exists even to-date and appears to be valid. The denticles of sharks are divisible into three parts, namely, the basal plate or root, the pedicel, and the crown. The outer surface of a denticle is covered by a hard and resistant enamel secreted by epidermal cells, whereas the inner portion is made up of a bonelike substance, the dentine. The hollow part of the denticle corresponds to the pulp cavity of higher vertebrate tooth. The denticles in the mouth cavity are large and arranged in rows along the edges of jaws. The teeth in sharks are produced by a single denticle or by the fusion of two or more denticles (Newman, 1956).

The other view regarding the origin of teeth in sharks is that dermis as well as epidermis are involved in tooth formation. In sharks, teeth are arranged in rows along the edges of jaws together with the infolding of epidermis. A little discrepancy, however, exists regarding the role of epidermis in tooth formation. The earlier workers did not consider that epidermis deposits the outer layer of tooth but recent studies of Santos ans Sasso (1959), Sasso *et al.* (1961), Moss *et al.* (1964), and Applegate (1967) demonstrate that both epidermis and dermis participate in the formation of tooth and

that the enamel is deposited by epidermal cells. The crown of tooth is formed by epidermis in such a manner that it first distinguishes into a tissue made up of ameloblasts which develops a cap around a mesenchymatous papilla formed by the dermis. Gradually, it attains the shape of a crown. Simultaneously, a part of the dermis changes into odontoblasts which forms dentine. This process of tooth formation goes on throughout the entire life span of sharks.

The histology of shark teeth have been discussed by Orvig (1951), James (1954), Kerr (1955), Radinsky (1961), Sasso *et al.* (1961), Moss *et al.* (1964), Patterson (1965), and Applegate (1967) among others. The recent workers recognise the usage of two main hard parts, namely, the enamel and dentine. The enamel is characterised by the absence of canaliculi or dental tubules or cellular processes. It is denser and has less organic material than dentine. The non-mineralised part of tooth is composed of cavities, canals, canaliculi and dental tubules.

2. MORPHOLOGY OF SHARK TOOTH

Bigelow and Schroeder (1948) made a significant contribution to the study of variation in shark teeth. A notable range of variation is generally observed in the shape and size of teeth in sharks. In an individual, the teeth of upper and lower jaws and also those on the anterior and posterior sides exhibit marked variation, thereby showing heterodonty on which tooth terminology and dental formulae are based. Rarely, some sharks (ex. *Rhincodon, Cetorhinus,* etc.) have same shape of teeth without any marked change in their size, thus representing homodonty.

There are several types of heterodont conditions in sharks and this makes it difficult to assign the taxonomic positions to isolated teeth in an assemblage. For a valid identification, it is necessary to fix the proper position of a tooth in a jaw which is not always possible, especially in fossil forms having no living representatives. The shark tooth is divisible into two main parts, namely, crown and root.

A. Crown: It is the part of the tooth which projects from the jaw and is covered by enamel. It can be distinguished from the root by its smoothness, lusture and densely stained surface. It may have different shapes but generally it is triangular, conical, straight or oblique having smooth or serrated margins. These serrations may be fine or coarse or both in a single tooth and they generally decrease in size towards apex. The apex may be acute or blunt and may be straight or deflected anteriorly or posteriorly. The outer surface of the crown is usually flat while the inner one is commonly convex and has fine striations, extending from base towards apex. The enamel extends more on the outer than on the inner surface at the middle of the base of the crown. In some sharks, eg., *Hexanchus, Heptranchias,* etc., the crown is divisible into smaller subdivisions which have been termed as 'crownlets' by Applegate (1965).

The crown may be simple having one cusp only, or near its base, it may have additional cusp or cusps, either in continuation with the main cusp or slightly detached from it and these are termed as secondary cusps (Kato *et al.*, 1967) (=basal cusps or lateral denticles or subsidiary cusps of other workers).

B. Root: In the literature, while the crown has been used consistently, the root has received different names. Peyer (1968) prefers to use "tooth base" or "basal portion of tooth' for the root of shark's tooth on the ground that the term "tooth root" should be applied for the basal part of tooth only in those cases in which it is identical in origin and structure to the mammalian tooth. Root, as commonly understood, conveys the idea of something underground or embedded forming the foundation or basal part of the exposed portion, eg., plant, hair, tooth, etc., but everywhere the boundary between the root and the exposed part is well-defined. The terms "tooth base" or "basal portion of tooth" as used by Peyer (1968) are rather ambiguous because they do not connote or signify a well-defined boundary or outline of this part which is essential in systematic descriptions. The structure of the root in shark's tooth may be different from that of mammalian tooth but in both the cases, it serves the same purpose and is similarly located. In view of the foregoing, there does not appear to be any drawback in calling the basal part of the shark's tooth as root and, therefore, in the present study the term root has been adhered to as against Peyer (1968) and others.

The root is rough in texture, generally large in extension, and is totally made up of osteodentine. Its lower and upper margins may be flat, concave, convex, or wrinkled. The root may be simple, like a basal plate, or bifurcated having grooves or ridges which is a character or advancement. Plate I displays the morphological terminology and different measurements of shark's teeth.

VARIATION IN SHARK TEETH FROM ORISSA

The stratigraphy and fish microfauna from the Baripada beds have been discussed in separate papers by us (Bhalla and Dev, 1984a, 1984b). A fairly large number of shark teeth belonging to *Carcharodon megalodon* Agassiz and *Galeocerdo aduncus* Agassiz were recovered from the exposures of the Baripada beds (Middle Miocene) developed in the cuttings on the left side of river Burhabalang, towards south of Baripada town (21° 56′ 10″ : 86° 43″ 30″). A total of 32 isolated and well-

preserved specimens of *Carcharodon megalodon* and 25 of *Galeocerdo aduncus* were studied for establishing a meaningful range of variation in the teeth of these two species of sharks. The specimens exhibiting morphologic variation in these species are illustrated. (Pl. II, III).

Genus Carcharodon MUELLER AND HENLE, 1838

Carcharodon megalodon AGASSIZ

(Pl. II—1-10)

Diagnosis : Teeth large, broad, moderately thick, compressed, symmetrical to slightly oblique. Crown triangular, smooth; outer surface flat, inner one gently convex with distinct striations running from base towards apex; apex acute to sub-acute, straight to slightly deflected; margins obliquely straight, gently tapering towards apex, rounded at base, serrated, serrations fine, numerous, almost uniform throughout; base broad, smoothly curved. Root moderately bifurcated, broad, low; outer surface nearly flat, inner surface strongly convex with a shallow vertical incision in middle; lateral margins almost straight, parallel; upper margin curve, lower one smoothly curved inwards.

Variation : *Carcharodon megalodon* Agassiz shows variation in the shape of the crown which is symmetrical or slightly oblique and broad or somewhat narrow (Pl. II). The height of the crown varies from 4.66 to 7.33 mm, width from 6.33 to 10.83 mm, and thickness from 1.92 to 2.00 mm. The height of the root varies from 3.66 to 5.50 mm, width form 6.88 to 11.66 mm, and thickness from 2.64 to 3.00 mm.

Remarks : *Carcharodon robustus* described by Davis (1888) was treated by Woodward (1889) as a synonym of *Carcharodon megalodon* Agassiz, 1843. However, White (1926) maintained it as a variety of *C. megalodon* and this was followed by Ghose (1956, 1959) who recorded it from the Baripada beds. *C. megalodon robustus* closely resembles *C. megalodon* and comes well within the range of variation of the parent species. The variation of teeth in shape and size in sharks within a single individual, injects considerable difficulty and confusion in the systematics of shark teeth and erection of the varieties or subspecies, which seems to be unnatural on the basis of teeth alone, would further complicate the situation. To avoid confusion, recognition of *robustus* as a variety of *C. megalodon* does not seem to be justified and it is being treated as a junior synonym of *C. megalodon* (*vide etiam* Woodward, 1889).

Genus Galeocerdo MUELLER AND HENLE, 1837

Galeocerdo aduncus AGASSIZ

(Pl. III—1-6.)

Diagnosis: Teeth broad, compressed, thin, oblique. Crown triangular, compressed, smooth; outer surface almost flat, inner surface convex, with a few fine striations emerging from the base; apex acute, deflected to one side; margins unequal, hunched anteriorly, notched posteriorly, serrations fine except near base, more conspicuous below notch; base gently curved, enamel extends downward on outer than on inner side at middle of base. Root moderately bifurcated, broad, low, thick, extends laterally up to base of crown; outer surface rather flat, inner surface convex, having a shallow, vertical, median incision; lateral margins short, convex, smooth; upper margin more curved on inner side, lower margin farily deep, curved inwards at middle, smooth.

Variation : The teeth of *G. aduncus* exhibit compressed crown having serrated margins and moderately broad root and show a considerable range of variation in the shape and size (Pl. III). The height of the crown varies from 2.55 to 5.55 mm, width from 7.88 to 10.00 mm, and thickness from 1.05 to 1.15 mm. The height of root varies from 2.77 to 4.33 mm, width from 8.88 to 10.77 mm, and thickness from 1.66 to 1.98 mm.

Remarks: The teeth of *G. aduncus* and *G. latidens* are identical and a glance at the literature shows that the two closely allied species of *Galeocerdo*, have been confused and misidentified. This might have occurred due to the fact that Agassiz (1843), who authored these two species, selected anterior teeth as type of *G. aduncus* while middle and lateral teeth as types of *G. latidens*. A few earlier workers tried to distinguish between the teeth of these two species. Emmons (1858) considered that *G. latidens* differs from *G. aduncus* by having low crown, subequal serrations and larger root. Fowler (1911) gave description and illustration to show that the only difference between the two is the broader base and lower crown of *G. latidens*. However, White (1926) opined that the teeth of *G. aduncus* differ from *G. latidens* in having convex anterior and posterior coronal contours and the anterior serrations are very fine and quite different from the coarse denticulations on the posterior side.

From the above review, no clear picture regarding the differences between *G. aduncus* and *G. latidens* emerges. If Fowler is followed, then both the species appear to be synonymous because the broader base and lower crown differentiating *G. latidens* from *G. aduncus* are the features usually exhibited by lateral teeth situated at the corner of the mouth. In our material, only one type of teeth was found which closely resembles *G. aduncus* as described and figured by Fowler (1911). In the absence of teeth showing alliance to *G. latidens*, it is, however, not possible to comment upon the taxonomic validity of these two species.

CONCLUSION

The above study reveals that the shark teeth,

variable as they are within a single species and even in an individual, need careful delineation of their limits of variation. Only then a valid taxonomic placement of shark teeth, especially those occurring in fossil assemblages, is possible.

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EXPLANATION OF PLATES

PLATE I

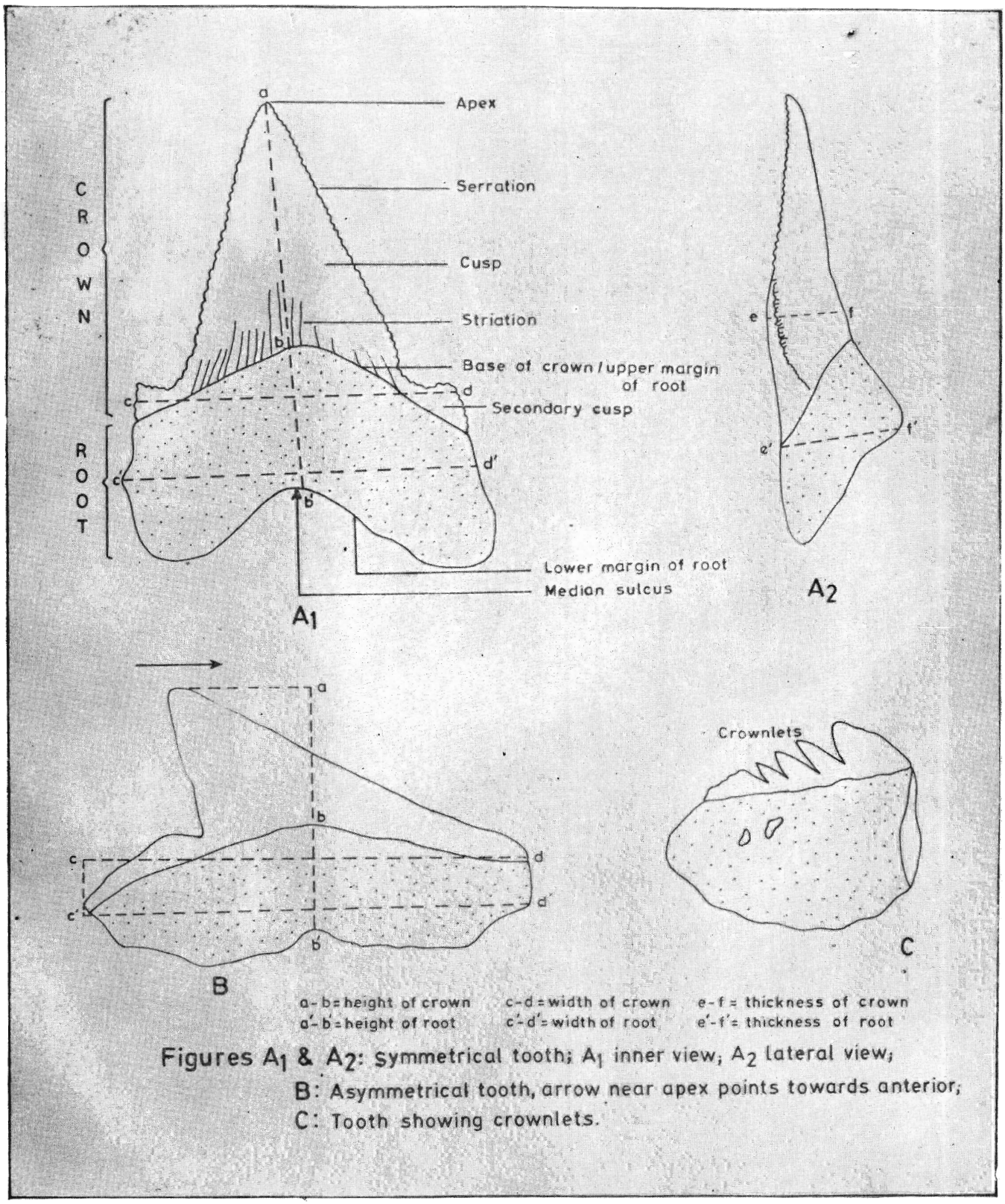
Morphological features of shark teeth.

PLATE II

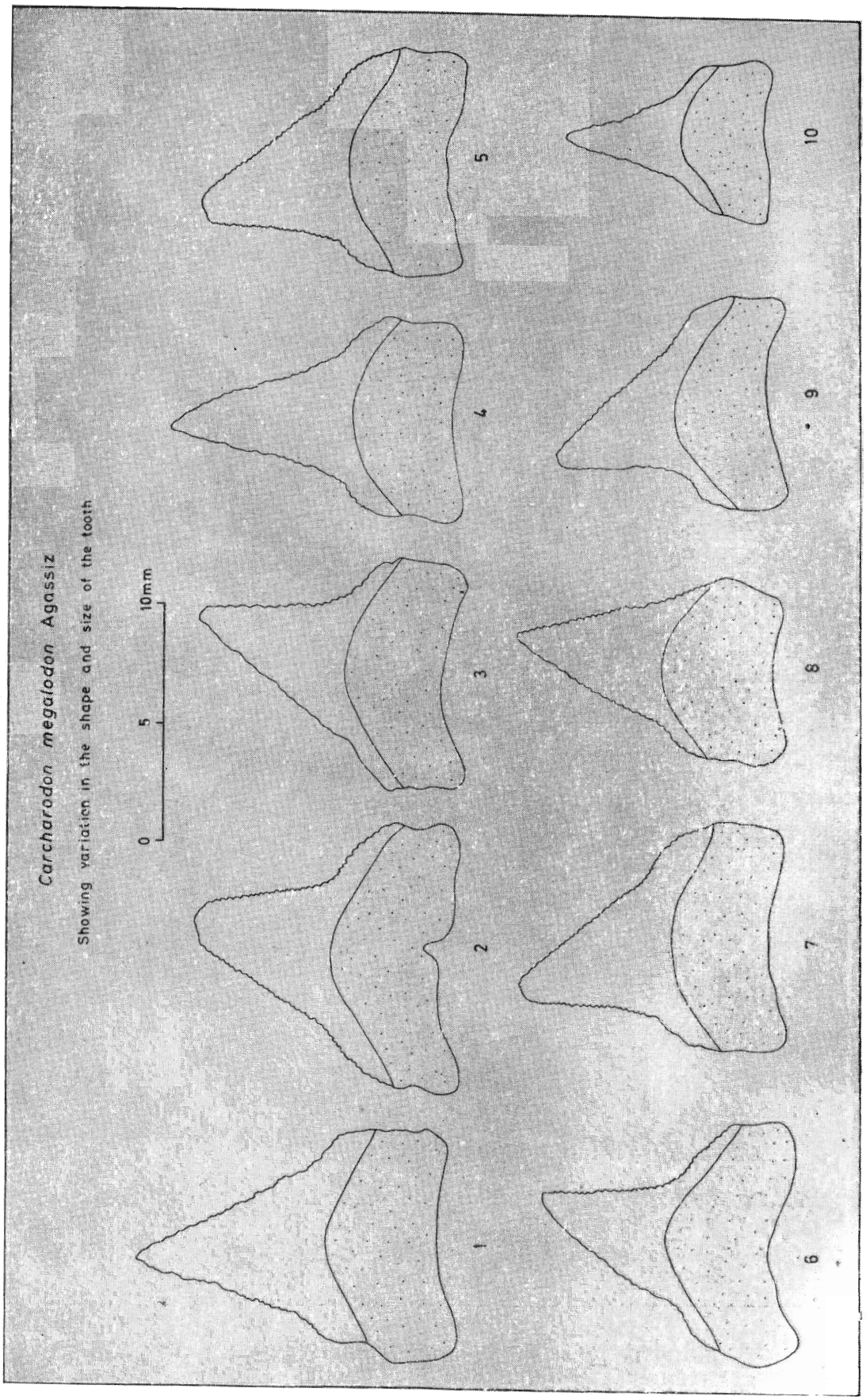
Carcharodon megalodon Agassiz showing variation in the shape and size of the tooth.

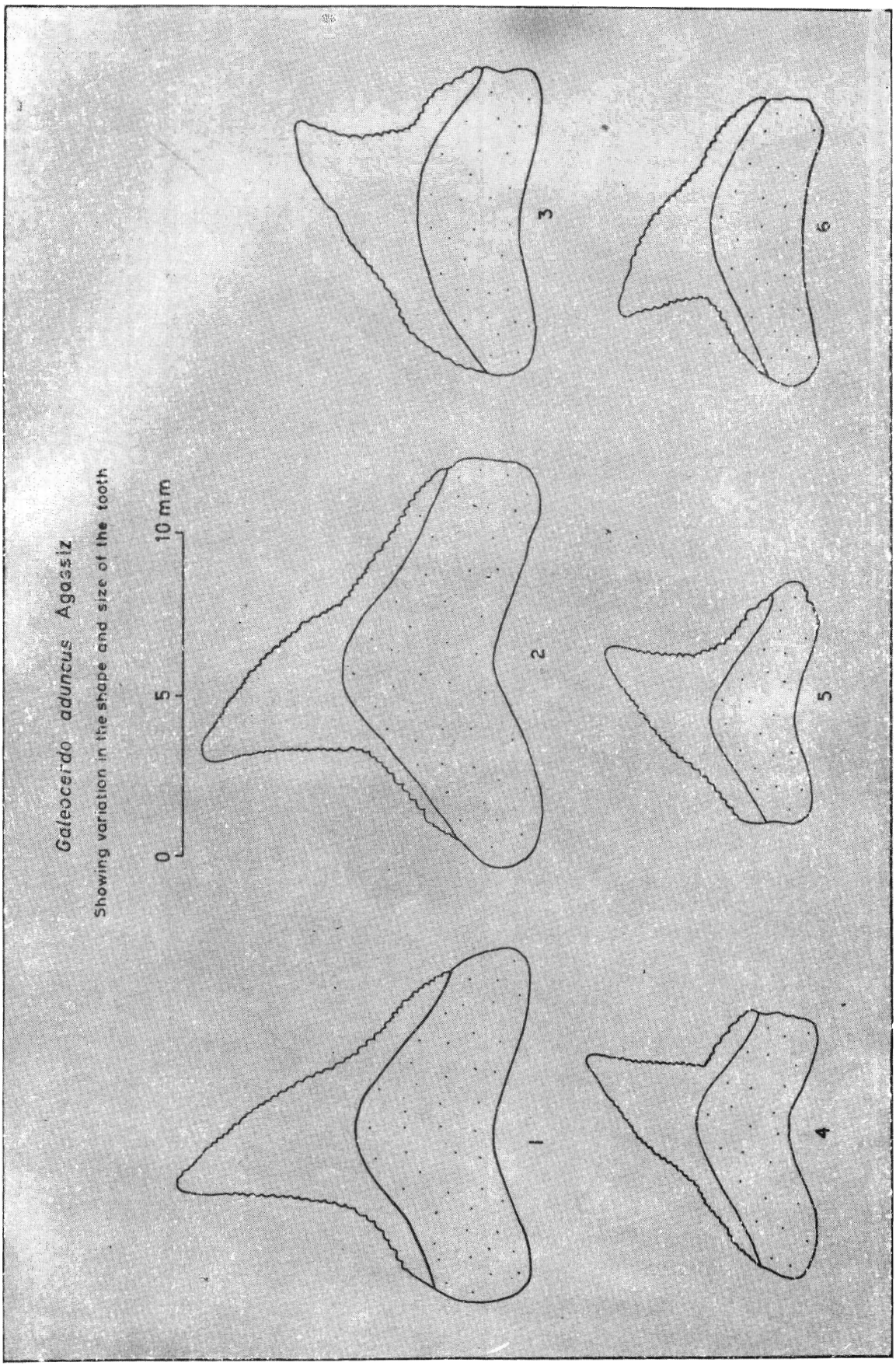
PLATE III

Galeocerdo aduncus Agassiz showing variation in the shape and size of the tooth.



Figures A_1 & A_2: symmetrical tooth; A_1 inner view; A_2 lateral view;
B: Asymmetrical tooth, arrow near apex points towards anterior;
C: Tooth showing crownlets.


Carcharodon megalodon Agassiz
Showing variation in the shape and size of the tooth
0
5
10mm
1
2
3
4
5
6
7
8
9
10


Galeocerdo aduncus Agassiz
Showing variation in the shape and size of the tooth
0
5
10 mm
1
2
3
4
5
6