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Contributions to the study of the comparative morphology of teeth and other relevant ichthyodorulites in living supraspecific taxa of Chondrichthyan fishes

Editor: M. STEHMANN

Part B: Batomorphii 4: Order Torpediniformes - Family Narcinidae – Subfamily Narcininae – Genera: *Benthobatis*, *Diplobatis*, *Discopyge* and *Narcine*, Subfamily Narkinae – Genera: *Bengalichthys*, *Crassinarke*, *Heteronarce*, *Narke*, *Temera*, and *Typhlonarke*, Family Torpedinidae – Subfamily Torpedininae – Genus: *Torpedo* – Subgenus: *T.(Tetronarke)* and *T. (Torpedo)* and Subfamily Hypninae – Genus: *Hypnos*.

by J. HERMAN, M. HOVESTADT-EULER, D.C. HOVESTADT & M. STEHMANN

Abstract

Part B of this series, the Batomorphii is continued with the description and illustration of the tooth morphology (SEM-photographs) with additional information about the tooth vascularisation of the order Torpediniformes. Differential diagnosis and a classification of the torpediniform taxa from the odontological point of view are also presented. It closes the entire series on sharks, rays and skates and holocephalans after 16 years. The authors and editor are planning to enhance the contents of the series with the publication of additional short notices including their personal reflections on the systematics of the whole group concerned.

Key words: Elasmobranchii – Batomorphii – Torpediniformes Odontology.

Résumé

Ce fascicule complète la partie B de cette série par la description et l'illustration (clichés MEB) de la morphologie dentaire des Torpediniformes. Diagnose différentielle, description de leur vascularisation dentaire et conclusions générales concernant les Torpediniformes y sont formulées. Il clôture cette étude initiée il y a quelques 16 ans. Les auteurs et leur éditeur auront à coeur de compléter cet ensemble par la publication de quelques notes additionnelles incluant leurs réflexions personnelles concernant la systématique du groupe concerné.

Mots-clés: Elasmobranchii – Batomorphii – Torpediniformes – Odontologie.

Kurzfassung

Mit der Beschreibung und Illustrierung durch REM-Photos der Zahnmorphologie der Ordnung Torpediniformes und additioneller Information der Zahnvascularisation wird Teil B dieser Serie (die Batomorphii) fortgesetzt. Auf Basis odontologischer Merkmale werden ferner eine zusammenfassende Differentialdiagnose und eine Bewertung der Klassifikation präsentiert. Nach 16 Jahren wird dieser Serie über Haie, Rochen, und Holocephalen abgeschlossen. Die Autoren und der Editor überlegen den Inhalt dieser Serie mit u.a. ihren persönlichen Ansichten der Systematik Rezenten Chondrichtyern vom Standpunkt der Odontologie.

Schlüsselwörter: Elasmobranchii – Batomorphii – Torpediniformes – Odontologie.

Part B: Batomorphii - Order: Torpediniformes

Introduction

Part B of this series, the Batomorphii, is continued with representatives of all supraspecific taxa of the Torpediniformes. The classification of Nelson (1994) is adapted, with eleven genera *Benthobatis*, *Crassinarke*, *Diplobatis*, *Discopyge*, *Heteronarce*, *Hypnos*, *Narcine*, *Narke*, *Temera*, *Torpedo* and *Typhlonarke*. *Bengalichthys* was not mentioned in this classification, however, its tooth morphology is here additionally described, illustrated and compared. Nelson (1994) divided

the Torpediniformes into two families: the Torpedinidae and Narcinidae. He subdivided further the Torpedinidae into the subfamilies Torpedininae, with the genus *Torpedo*, and Hypninae, with the genus *Hypnos*. Gill (1862) subdivided the genus *Torpedo* into two subgenera: *T.(Torpedo)* and *T.(Tetronarke)*. The tooth morphology of representatives of both subgenera will be described, illustrated and compared, additionally. Nelson (1994) also subdivided the Narcinidae into the two subfamilies: Narcininae, with the genera *Benthobatis*, *Diplobatis*, *Discopyge* and *Narcine*, and Narkinae, with the genera *Crassinarke*, *Heteronarce*, *Narke*, *Temera* and *Typhlonarke*.

The nominal species listed of each genus or subgenus are after MOULD (1999).

Cappetta (1988, along with the description and illustration of a new fossil torpediniform taxon based on tooth morphology, also described and illustrated the tooth morphology of most of the extant genera. The taxa are here redescribed and illustrated by SEM-photographs according to the standard of this series, with additional information about the tooth vascularization.

A differential diagnosis and conclusions on the classification of the torpediniformes are given from the odontological point of view. However, being aware of dealing with one complex of characters only, the odontological results will be presented here only, and we leave it to following revising authors to incorporate also odontological points of view in a full systematic review with eventual possible taxonomic and nomenclatorial changes. The complete bibliographical reference for each genus, subgenus and species here described will be given in the descriptive section, respectively, and not be repeated under literature references.

Along with every description of the tooth morphology, the vascularization of the teeth will be described and illustrated.

Material

The following 61 species of 17 genera and 2 subgenera were examined for this study:

Bengalichthys impennis

Coll. Herman ♂ 160 mm TL

Benthobatis moresbyi

Coll. Herman ♂ 215 mm TL

Crassinarke dormitor

UMTF 20718 ♂ 190 mm TL

Diplobatis ommata

Coll. Herman ♀ 250 mm TL

MNHN uncat. ♀ 150 mm TL

Discopyge tschudii

ISH 883-1979 ♂ 357 mm TL

Coll. Herman ♂ 400 mm TL

ISH 1632-1966 ♀ 165 mm TL

ISH 1632-1966 ♀ 307 mm TL

Heteronarce garmani

ISH 225-1975 ♀ 219 mm TL

Heteronarce mollis

ISH 254-1975 ♂ 196 mm TL

Hypnos monopterygium

Coll. Hartman ♀ 265 mm TL

Hypnos subnigrum

Coll. Herman ♂ 140 mm TL

Coll. Herman ♀ 270 mm TL

Narcine brasiliensis

ISH 1856-1968 ♂ 249 mm TL

ISH 1856-1968 ♀ 540 mm TL

Narke dipterygia

Coll. Herman ♀ 160 mm TL

ISH 8-1961 ♀ 163 mm TL

Temera hardwicki

Coll. Herman ♂ 105 mm TL

Torpedo (Tetronarke) sp.

Coll. Herman ♂ 253 mm TL

Coll. Herman ♂ 310 mm TL

Coll. Herman ♂ 315 mm TL

Coll. Herman ♂ 340 mm TL

Coll. Herman ♂ ? mm TL

Coll. Herman ♀ 328 mm TL

Coll. Herman ♀ 340 mm TL

Coll. Herman ♀ ? mm TL

Torpedo (Tetronarke) nobiliana

Coll. Hovestadt ♀ 620 mm TL

Coll. Hovestadt ♀ 800 mm TL

Coll. Hovestadt ♀ 890 mm TL

Coll. Hovestadt ♀ 1050 mm TL

Coll. Herman ♀ ? mm TL

Torpedo (Torpedo) torpedo

Coll. Herman ♂ 350 mm TL

Coll. Herman ♂ 350 mm TL

Coll. Herman ♂ 380 mm TL

Coll. Herman ♂ 380 mm TL

Coll. Herman ♂ 385 mm TL

Coll. Herman ♂ 405 mm TL

Coll. Herman ♂ 410 mm TL

Coll. Herman ♀ 345 mm TL

Coll. Herman ♀ 360 mm TL

Torpedo (Torpedo) marmorata

Coll. Hovestadt ♂ 150 mm TL

Coll. Hovestadt ♂ 160 mm TL

Coll. Hovestadt ♂ 160 mm TL

Coll. Hovestadt ♂ 190 mm TL

Coll. Herman	♂	385 mm TL
Coll. Hovestadt	♀	120 mm TL
Coll. Hovestadt	♀	185 mm TL
Coll. Hovestadt	♀	250 mm TL
Coll. Hovestadt	♀	260 mm TL
Coll. Hovestadt	♀	290 mm TL
Coll. Herman	♀	350 mm TL
Coll. Hovestadt	♀	360 mm TL
Coll. Hovestadt	♀	370 mm TL
Coll. Herman	♀	430 mm TL
Coll. Hovestadt	♀	450 mm TL
Coll. Hovestadt	♀	450 mm TL
Coll. Hovestadt	♀	500 mm TL
Coll. Hovestadt	♀	500 mm TL
Coll. Hovestadt	♀	620 mm TL

Typhlonarke aysoni

Coll. Herman ♂ 200 mm TL

Additionally, the illustrations of CAPPETTA (1988) were used.

Description of the odontological characters

Family: Narcinidae
Subfamily: Narcinae

The Narcininae comprise the genera *Benthobatis*, *Diplobatis*, *Discopyge* and *Narcine*.

Genus: *Benthobatis* ALCOCK, 1898

Natural history notes from H.M. Indian marine survey ship "Investigator", Commander T.H. Heming, R.N., commanding. Series II, 25. Annals and Magazine of Natural History (ser.7) 2 (8): 136-156.

The genus comprises three named species: *B. Kreffti* (recently described by Rincon, Stehmann & Vooren, 2001), *B. marcida* and the type species *B. moresbyi*. A fourth, yet undescribed species from Taiwanese waters was mentioned by Carvalho (1999).

Benthobatis moresbyi ALCOCK, 1898
(Plates: 1 and 2)

Benthobatis moresbyi ALCOCK, 1898 Natural history notes from H.M. Indian marine survey ship "Investigator", Commander T.H. Heming, R.N., commanding. Series II, 25. Annals and Magazine of Natural History (ser.7) 2 (8): 136-156.

HETERODONTY

The dentition is gradient monognathic heterodont with lateral and posterior teeth becoming generally smaller and the cusp slightly more inclining toward the commissure. Lacking female and juvenile specimens sexual and ontogenetic heterodonty cannot not be evaluated.

VASCULARIZATION

The teeth show the holaulacorhizid root type with an elongated, well developed pulp cavity, from which the vascular tubes of the circumpulpar dentine radiate into crown and root. Osteodentine and inner lateral foramina are absent. (See textfigure 1).



Textfigure 1.
Benthobatis tooth histological cross section

MALES AND FEMALES

The crown is divided by sharp mesial and distal cutting edges into an inner and outer face. The outer face shows an arched, rounded crown base, largely overhanging the root. Both, mesial and distal cutting edges are of about equal size and arched similarly, each joining seamlessly with the crown base. In about the middle of the crown both cutting edges turn upward to form a narrow cusp, being half as high as the length of a cutting edge. The cusp becomes only slightly and gradually lower in lateral and posterior teeth. The outer surface is slightly concave. Generally, the smooth inner face is concave, but the mid-section is convex. Inner and outer ornamentation are absent.

The basal surface of the crown shows a rather, broad, slightly rounded crown rim at the outer margins, with inner and outer parts joining in blunt mesial and distal angles. The crown-root junction lies in a relatively deep depression in the center of the crown's basal surface.

The high, narrow holaulacorhizid root is more or less oval in cross-section, slightly oblique toward the rear of the tooth, and slightly diverges at the root base. The root base presents a well-developed, deep and narrow median groove, with a relatively large aperture in the outer central base of the groove. Root coating is present at about one third of the upper part, all around the root. Inner and outer foramina are absent.

Genus: *Diplobatis* BIGELOW & SCHROEDER, 1948

New genera and species of batoid fishes. Journal of Marine Research 7: 543-566.

This genus comprises the species *D. colombiensis*, *D. guamachensis*, *D. pictus* and the type species *D. ommata*.

Diplobatis ommata (JORDAN & BOLLMAN, 1890)
(Plates: 3 and 4)

Discopyge ommata JORDAN & BOLLMAN, 1890 Description of new species of fishes collected at the Galapagos Islands

and along the coast of the United States (1887-1888). In: Scientific results of explorations by the U.S. Fish commission steamer Albatros. *Proceedings of the United States national Museum* 12 (770): 149-183 (1889) 1890.

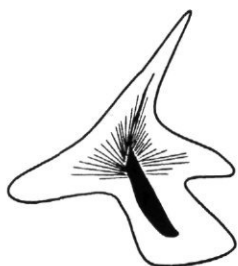
HETERODONTY

The dentition is gradient monognathic heterodont with lateral and posterior teeth becoming lower and the cusp tip slightly inclined toward the commissure.

Sexual heterodonty is absent. Lacking juvenile material ontogenetic heterodonty cannot not be evaluated.

VASCULARIZATION

The teeth show the holaulacorhizid root type with an elongated, well developed pulp cavity, from which the vascular tubes of the circumpulpar dentine radiate into crown and root. Osteodentine and inner lateral foramina are absent. (See textfigure 2)



Textfigure 2.
Diplobatis tooth histological cross section

MALES AND FEMALES

The crown is divided by sharp mesial and distal cutting edges into an inner and outer face. The outer face shows an arched, convex crown base, more or less overhanging the root. Both, mesial and distal cutting edges are of about equal size and blade-like, each joining the crown base in a blunt angle. In about the middle part of the crown both cutting edges turn upward, after lowering as a blunt notch, to form a narrow, elongated cusp, about as high as the length of a cutting edge. The cusp becomes only slightly and gradually lower and more oblique distally in lateral and posterior teeth. The outer surface is slightly concave. Generally, the smooth inner face is concave, but the mid-section is convex. Inner and outer ornamentation are absent.

The basal surface of the crown shows a rather, broad, slightly rounded crown rim at the outer margins, with inner and outer parts joining in blunt mesial and distal angles. The crown-root junction lies in a relatively deep depression in the centre of the crown's basal surface.

The narrow holaulacorhizid root is more or less oval in cross-section, slightly oblique toward the rear of the tooth, and diverges at the root base. The root base presents a well-developed, moderately broad, shallow median groove, with a relatively large aperture in the outer central base of the groove. Root coating is present at about one third of the upper part, all around the root. Inner and outer foramina are absent.

Genus: *Discopyge* HECKEL, 1846

Ichthyologie. In: Tschudi 1846 Untersuchungen über die Fauna Peruana. *Scheitlin & Zollikofer, St.Gallen*. 1844-1846 in 12 parts Fauna Peru.

The genus is monotypic with the type species *D. tschudii*.

Discopyge tschudii HECKEL, 1846

(Plates: 5 to 9)

Torpedo tschudii HENKEL, 1846 Ichthyologie. In: Tschudi 1846 Untersuchungen über die Fauna Peruana. *Scheitlin & Zollikofer, St.Gallen*. 1844-1846 in 12 parts Fauna Peru.

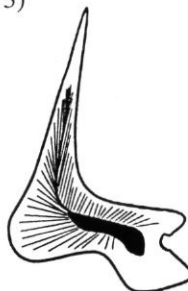
HETERODONTY

The dentition is gradient monognathic heterodont with lateral and posterior teeth becoming lower and the cusp slightly inclined toward the commissure.

Sexual heterodonty is absent. Ontogenetic heterodonty is presented by less developed, lower cutting edges and cusp in juveniles.

VASCULARIZATION

The teeth show the holaulacorhizid root type with an elongated, well developed pulp cavity, from which the vascular tubes of the circumpulpar dentine radiate into crown and root. Osteodentine and inner lateral foramina are absent. (See textfigure 3)



Textfigure 3.
Discopyge tooth histological cross section

MALES AND FEMALES

The crown is divided by sharp mesial and distal cutting edges into an inner and outer face. The outer face shows an arched, convex crown base, more or less overhanging the root. Both, mesial and distal cutting edges are of about equal size and blade-like, each joining the crown base in a blunt angle. In about the middle part of the crown both cutting edges turn upward, after lowering as a blunt notch, to form a narrow, elongated cusp being about as high as the length of a cutting edge. The cusp being only slightly and gradually lower in lateral and posterior teeth. The outer surface is slightly concave. Generally, the smooth inner face is concave, but the mid-section is convex. Inner and outer ornamentation are absent.

The basal surface of the crown shows a rather, broad, slightly rounded crown rim at the outer margins, with inner and outer parts joining in blunt mesial and distal angles. The crown-root junction lies in a relatively deep depression in the centre of the crown's basal surface.

The high, narrow holaulacorhizid root is more or less oval in cross-section, slightly oblique toward the rear of the tooth, and diverges at the root base. The root base presents a well-developed, moderately broad, shallow median groove, with a relatively large aperture in the outer central base of the groove. Root coating is present at about one third of the upper part, all around the root. Inner and outer foramina are absent.

Genus: *Narcine* HENLE, 1834

Über "Narcine", eine neue Gattung elektrischer Rochen nebst einer Synopsis der elektrischer Rochen. Berlin: 1-44. The genus comprises the species *N. bicolor*, *N. brasiliensis*, *N. brevilaniata*, *N. brunnea*, *N. entemedor*, *N. firma*, *N. indica*, *N. lingula*, *N. maculata* (type species), *N. nigra*, *N. prodorsalis*, *N. rierai*, *N. tasmaniensis*, *N. timlei*, *N. vermiculatus* and *N. westralensis*. Lacking tooth material of the type species *N. brasiliensis* was used instead for description and illustration.

Narcine brasiliensis (OLFERS, 1831)
(Plates: 10 and 11)

Torpedo brasiliensis OLFERS, 1831 Die Gattung Torpedo in ihren naturhistorischen und antiquarischen Beziehungen erläutert. Berlin: 1-35.

HETERODONTY

The dentition is gradient monognathic heterodont with lateral and posterior teeth becoming lower and the cusp slightly inclined toward the commissure.

Sexual heterodonty is absent. Ontogenetic heterodonty is presented by less developed, lower cutting edges and cusp in juveniles.

VASCULARIZATION

The teeth show the holaulacorhizid root type with an elongated, well developed pulp cavity, from which the vascular tubes of the circumpulpar dentine radiate into crown and root. Osteodentine and inner lateral foramina are absent. (See textfigure 4)



Textfigure 4.
Narcine tooth histological cross section

MALES AND FEMALES

The crown is divided by sharp mesial and distal cutting edges into an inner and outer face. The outer face shows an arched, rounded crown base, overhanging the root. Both, mesial and distal cutting edges are of about equal size and similarly

arched, each joining seamlessly with the crown base. At about one third of the crown both cutting edges turn upward to form a cusp being half as high as the length of a cutting edge. The cusp becomes lower gradually and more oblique in lateral and posterior teeth. The outer surface is slightly concave. Generally, the smooth inner face is concave, but the mid-section is convex. Inner and outer ornamentation are absent.

The basal surface of the crown shows a rather, broad, slightly rounded crown rim at the outer margins, with inner and outer parts joining in blunt mesial and distal angles. The crown-root junction lies in a relatively deep depression in the centre of the crown's basal surface.

The high, narrow holaulacorhizid root is more or less oval in cross-section, slightly oblique toward the rear of the tooth, and slightly diverges at the root base. The root base presents a well-developed, deep and narrow median groove, with a relatively large aperture in the outer central base of the groove. Root coating is present at about one third of the upper part, all around the root.

Subfamily: Narkinae

The Narkidae comprise the genera *Crassinarke*, *Heteronarce*, *Narke*, *Temera* and *Typhlonarke*.

Genus: *Crassinarke* TAKAGI, 1951

Sur la nouvelle raie torpille, *Crassinarke dormitor*, gen. et sp. nov., appartenant à la sous-famille Narkinée. *Journal of the Tokyo University of Fisheries* 38 (1): 27-34.

This genus is monotypic with the type species *C. dormitor*.

Crassinarke dormitor TAKAGI, 1951

(Textplate 1; no SEM illustration of isolated teeth because the roots are too badly preserved)

Crassinarke dormitor TAKAGI, 1951 Sur la nouvelle raie torpille, *Crassinarke dormitor*, gen. et sp. nov., appartenant à la sous-famille Narkinée. *Journal of the Tokyo University of Fisheries* 38 (1): 27-34.

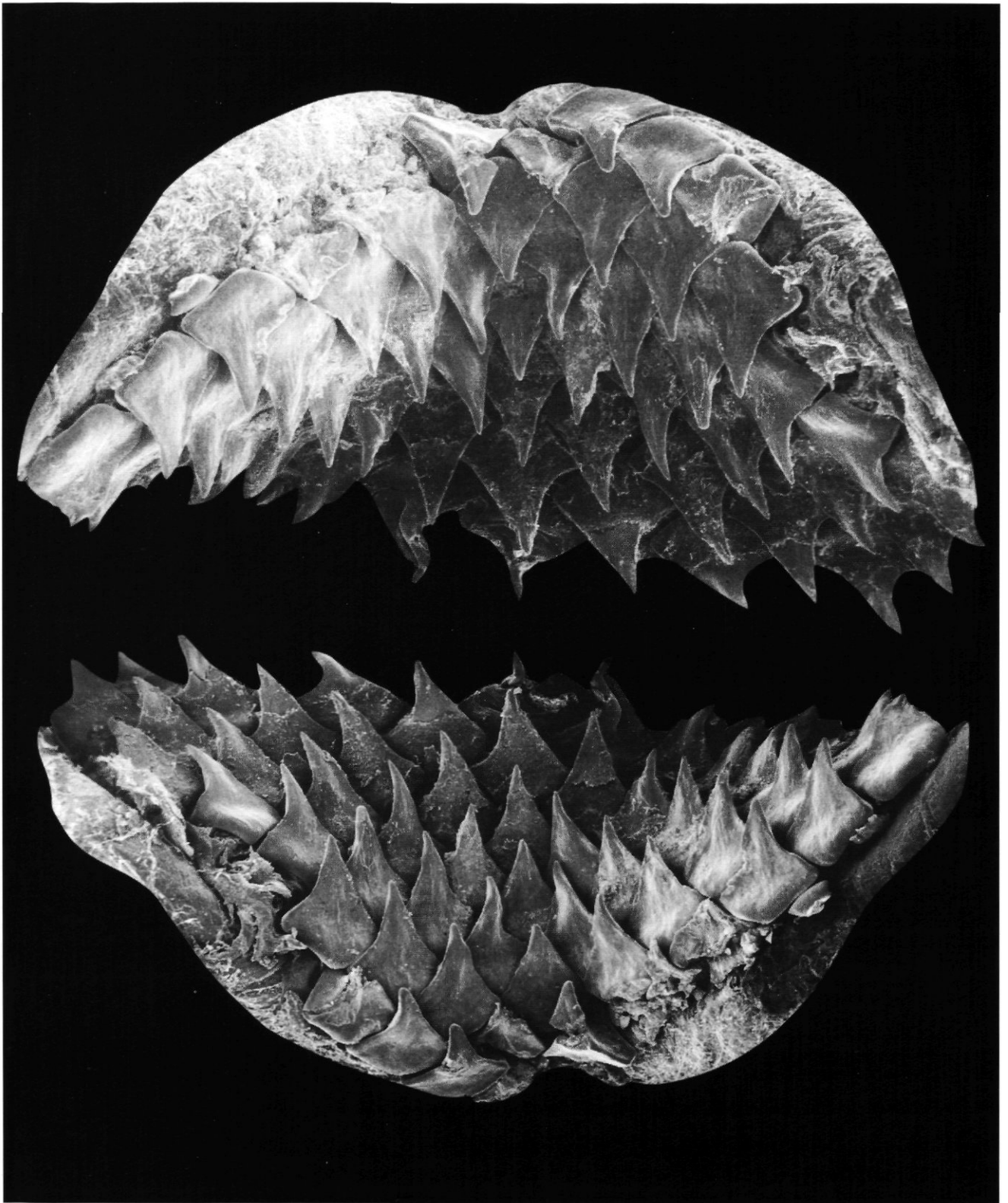
HETERODONTY

The dentition is gradient monognathic heterodont with lateral and posterior teeth becoming lower and the cusp slightly inclined toward the commissure.

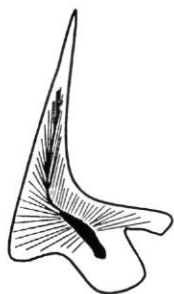
Lacking a female and juvenile specimen sexual nor ontogenetic heterodonty could not be evaluated.

VASCULARIZATION

The teeth show the holaulacorhizid root type with an elongated, well developed pulp cavity, from which the vascular tubes of the circumpulpar dentine radiate into crown and root. Osteodentine and inner lateral foramina are absent. (See textfigure 5)



Textplate 1. *Crassinarke dormitor* TAKAGI, 1951. Upper and lower dentitions of a male 19cm t.l., off Japan. Enlargement circa 20.



Textfigure 5.
Crassinarke tooth histological
cross section

MALES AND FEMALES

The crown is divided by sharp mesial and distal cutting edges into an inner and outer face. The outer face shows a crown base that forms a blunt angle in the center, and overhangs the root. Both, mesial and distal cutting edges are of about equal size and curve upward to form a well-developed cusp; each joins the crown-base in a blunt angle. Lateral and posterior teeth become gradually lower and asymmetrical. The outer surface is slightly concave. Generally, the smooth inner face is concave, but the mid-section is convex. Inner and outer ornamentation are absent.

The basal surface of the crown shows a rather, broad, slightly rounded crown rim at the outer margins, with inner and outer parts joining in blunt mesial and distal angles. The crown-root junction lies in a relatively deep depression in the centre of the crown's basal surface.

The narrow holaulacorhizid root is more or less oval in cross-section, slightly oblique toward the rear of the tooth, and slightly diverges at the root base. The root base presents a well-developed, deep and narrow median groove, with a relatively large aperture in the outer central base of the groove. Root coating is present at about one third of the upper part, all around the root. Inner and outer foramina are absent.

Genus: *Heteronarce* REGAN, 1921

New fishes from deep water off the coast of Natal. *Annals and Magazine of Natural History*, Series 9, 7 (41): 412-420. The genus comprises the species *H. bentuviai*, *H. garmani* (type species), *H. mollis* and *H. prabhui*.

Heteronarce garmani REGAN, 1921 (Plate: 12; see also plate: 13)

Heteronarce garmani REGAN 1921 New fishes from deep water off the coast of Natal. *Annals and Magazine of Natural History*, Series 9, 7 (41): 412-420.

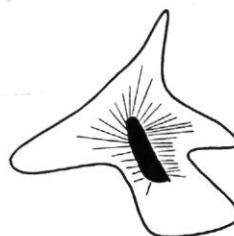
HETERODONTY

The dentition is gradient monognathic heterodont with lateral and posterior teeth becoming lower and the cusp slightly inclining toward the commissure.

Only a male specimen was at hand for this study, but female teeth were illustrated by CAPPETTA (1988), so that absence of sexual heterodonty could not be confirmed. Lacking juvenile material ontogenetic heterodonty could not be evaluated.

VASCULARIZATION

The teeth show holaulacorhizid root type with an elongated, well developed pulp cavity, from which the vascular tubes of the circumpulpar dentine radiate into crown and root. Osteodentine and inner lateral foramina are absent. (See textfigure 6)



Textfigure 6.
Heteronarce tooth histological
cross section

MALES AND FEMALES

The crown is divided by sharp mesial and distal cutting edges into an inner and outer face. The outer face shows a slightly arched, rounded crown base, overhanging the root. Both, mesial and distal cutting edges are about equal size and similarly arched, and continuously with the crown base. At about one third of the crown both cutting edges turn upward to form a cusp, half as high as the length of a cutting edge, that lowers gradually in lateral and posterior teeth. The outer surface is slightly concave. Generally, the smooth inner face is concave, but the mid-section is convex. Inner and outer ornamentation are absent.

The basal surface of the crown shows a rather, broad, slightly rounded crown rim at the outer margins, with inner and outer parts joining in blunt mesial and distal angles. The crown-root junction lies in a relatively deep depression in the centre of the crown's basal surface.

The moderately high, narrow holaulacorhizid root is more or less oval in cross-section, slightly oblique toward the rear of the tooth, and diverges at the root base. The root base presents a well-developed, deep and narrow median groove, with an aperture in the outer central base of the groove. Root coating is present at about one third of the upper part, all around the root.

Part of the dentition of a male of *Heteronarce mollis* is also illustrated on plate 13.

Genus: *Narke* KAUP, 1826

Beiträge zu Amphibiologie und Ichthyologie. Isis 19 (1): 87-90.

The genus comprises the type species *N. capensis* and *N. dipterygia* and *N. japonica*. Lacking tooth material of the type species *N. dipterygia* was used instead for description and illustration.

Narke dipterygia (BLOCH & SCHNEIDER, 1801) (Plate: 14)

Torpedo dipterygia BLOCH & SCHNEIDER 1801 M.E. BLOCHII Systema Ichthyologiae iconibus ex illustratum. Post

obitum auctoris opus inchoatum absolvit, correxit, interpolavit Jo. Gottlieb Scheider, Saxo. Berolini. Sumtibus Austoris Impressum et Bibliopolio Sanderiano Commissum. *Systema Ichthyologiae*: 1-584, 110 pls.

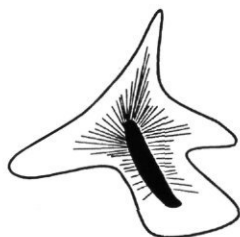
HETERODONTY

The dentition is gradient monognathic heterodont with lateral and posterior teeth becoming lower and the cusp slightly inclining toward the commissure.

Only a female specimen was at hand for this study, but male teeth were illustrated by CAPPETTA (1988), so that the absence of sexual heterodonty could not be confirmed. Ontogenetic heterodonty is presented by less developed, lower cusps in juveniles.

VASCULARIZATION

The teeth show the holaulacorhizid root type with an elongated, well developed pulp cavity, from which the vascular tubes of the circumpulpar dentine radiate into crown and root. Osteodentine and inner lateral foramina are absent. (See textfigure 7)



Textfigure 7.
Narke tooth histological cross section

MALES AND FEMALES

The crown is divided by sharp mesial and distal cutting edges into an inner and outer face. The outer face shows an arched, rounded crown base with an apron-like bulge, overhanging the root. Both, mesial and distal cutting edges are somewhat irregularly straight, more or less of equal size; each joins the crown base in a blunt angle, and both merge in an apex, giving the outer face a triangular appearance, that slightly lowers gradually in lateral and posterior teeth. The outer surface is slightly concave. Generally, the smooth inner face is concave, but the mid-section is convex. Inner and outer ornamentation are absent.

The basal surface of the crown shows a rather, broad, slightly rounded crown rim at the outer margins, with inner and outer parts joining in blunt mesial and distal angles. The crown-root junction lies in a relatively deep depression in the centre of the crown's basal surface.

The moderately high, narrow holaulacorhizid root is more or less oval in cross-section, slightly oblique toward the rear of the tooth, and diverges at the root base. The root base presents a well-developed, deep median groove, with an aperture in the outer central base of the groove. Root coating is present at about one third of the upper part, all around the root.

Genus: *Temera* GRAY, 1836

Description of twelve new genera of fish, discovered by General Hardwicke in India, the greater part in the British Museum. *Zoological Miscellany* 1: 4-9.

The genus is monotypic with the type species *T. hardwicki*.

Temera hardwicki GRAY, 1836

(Plate : 15)

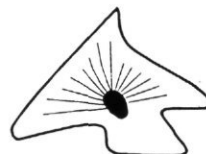
Temera hardwicki GRAY, 1836 Description of twelve new genera of fish, discovered by General Hardwicke in India, the greater part in the British Museum. *Zoological Miscellany* 1: 4-9.

HETERODONTY

The dentition is gradient monognathic heterodont, with lateral and posterior teeth lowering toward the commissure. Lacking material of juveniles and full-grown females, ontogenetic or sexual heterodonty could not be determined. However, the low crown with a transverse keel instead of a cusp indicates absence of sexual heterodonty.

VASCULARIZATION

The teeth show an adapted, holaulacorhizid root type with a relatively small pulp cavity. The vascular tubes of the circumpulpar dentine radiate into crown and root. Osteodentine and inner lateral foramina are absent. (See textfigure 8)



Textfigure 8.
Temera tooth histological cross section

MALES AND FEMALES

In occlusal view, the crown is mesio-distally broad and exhibits an inward bent, relatively high transverse keel, which is often flattened by abrasion, and lowers gradually in lateral and posterior teeth. It divides the crown into an inner and outer part. The outer and inner margins of the crown are more or less equally arched, and both margins join in sharp mesial and distal angles. The smooth inner face is concave with a weak bulging of the upper central part. The outer face's upper part is concave, changing into an apron-like lower part, that is strongly convex and sometimes presenting a central depression. Inner and outer ornamentation are absent. The basal surface of the crown shows a broad, slightly convex crown rim at the outer margin, gradually narrowing to half its width at the inner part. The crown-root junction lies in a shallow depression in the centre of the crown's basal surface.

The high, narrow holaulacorhizid root is more or less oval in cross-section, slightly oblique toward the rear of the tooth, and diverges at the root base. The root base presents a well-

developed, median groove, with an aperture in the outer central base of the groove. Root coating is present at about one third of the upper part, all around the root.

Genus: *Typhlonarke* WAITE, 1909

Scientific results of the New Zealand government trawling expedition 1907. Records of the Canterbury Museum 1: 41-156.

The genus comprises the type species *T. aysoni* and *T. tarakea*.

Typhlonarke aysoni (HAMILTON, 1902)
(Plates: 17 and 18)

Astrape aysoni HAMILTON, 1902 Notice of an electric ray new to the fauna of New Zealand, belonging to the genus *Astrape*. *Transactions and Proceedings of the New Zealand Institute* 34: 224-226

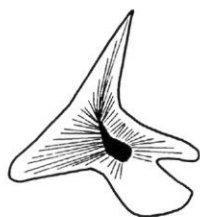
HETERODONTY

The dentition is gradient monognathic heterodont with lateral and posterior teeth becoming lower and the cusp slightly inclined toward the commissure.

Only a male specimen was at hand for this study, but a female was illustrated by CAPPETTA (1988), so that absence of sexual heterodonty is confirmed. Lacking juvenile material ontogenetic heterodonty could not be examined.

VASCULARIZATION

The teeth show the holaulacorhizid root type with an elongated, well developed pulp cavity, from which the vascular tubes of the circumpulpar dentine radiate into crown and root. Osteodentine and inner lateral foramina are absent. (See textfigure 9)



Textfigure 9.
Typhlonarke tooth histological cross section

MALES AND FEMALES

The crown is divided by sharp mesial and distal cutting edges into an inner and outer face. The outer face shows an arched, rounded crown base with an apron-like bulging, overhanging the root. Both, mesial and distal cutting edges are of about equal size and blade-like, each joining with the crown base in a blunt angle. At about one third of the crown both cutting edges turn upward to form a cusp, half as or equally as high as the length of a cutting edge and lowering gradually in lateral and posterior teeth. The outer surface is slightly concave.

Generally, the smooth inner face is concave, but the mid-section is slightly convex. Inner and outer ornamentation is absent.

The basal surface of the crown shows a rather, broad, slightly rounded crown rim at the outer margins, with inner and outer parts joining in blunt mesial and distal angles. The crown-root junction lies in a relatively deep depression in the center of the crown's basal surface.

The generally small, narrow holaulacorhizid root is more or less oval in cross-section, slightly oblique toward the rear of the tooth, and diverges at the root base. The root base presents a well-developed, narrow median groove, with an aperture in the outer central base of the groove. Root coating is present at about one third of the upper part, all around the root.

Family: Torpedinidae

Subfamily: Hypninae

Genus: *Hypnos* DUMERIL, 1852

Monographie de la famille des Torpéidiens, ou poissons plagiostomes électriques, comprenant la description d'un genre nouveau, de trois espèces nouvelles, et de deux espèces nommées dans le Musée de Paris, mais non encore décrites. *Rev. Magazine de Zoologie (ser.2)* 4: 176-189.

The genus comprises the type species: *H. monopterygium* and *H. subnigrum*.

Hypnos monopterygium SHAW & NODDER, 1794
(Plates: 19 and 20)

Lophius monopterygium SHAW & NODDER, 1794 Naturalist's Miscellany, or colored figures of natural objects drawn and described from nature. *Naturalist's Miscellany, London*: unnumbered pages.

HETERODONTY

The dentition is gradient monognathic heterodont with lateral and posterior teeth becoming lower and the cusp slightly inclined toward the commissure.

Sexual and ontogenetic heterodonty are absent.

VASCULARIZATION

The teeth show the holaulacorhizid root type with an elongated, well developed pulp cavity, from which the vascular tubes of the circumpulpar dentine radiate into crown and root. Osteodentine and inner lateral foramina are absent. (See textfigure 10)

MALES AND FEMALES

The tri-cuspid crown is structured by sharp mesial and distal cutting edges at each side of the cusps dividing the crown into an inner and outer face. The outer face shows an almost straight to slightly arched crown base, overhanging the root. The extremely elongated cusps are constricted at their base, and the central one can be more than seven times as high as



Textfigure 10.
Hypnos tooth histological cross section

its base width, the mesial and distal cusps can be up to five times as high as their base width. The latter ones slightly curve away from the central cusp. The three cusps are positioned next to each other, in occlusal view, the central one stands slightly backwards and is slightly more bent inward. The teeth only diminish in their general size and the three cusps only slightly become more oblique distally in lateral and posterior teeth. The outer surface is slightly concave. Generally, the inner face of the cusps is strongly convex and from the cusps, the inner face protrudes almost horizontally inward to a central basal depression at the inner margin. Inner and outer ornamentation is absent.

The basal surface of the crown has a rather, broad, slightly rounded crown rim at the outer margins, and is more or less quadrangular with blunt mesial and distal angles. The crown-root junction lies in a relatively narrow depression in the centre of the basal crown's surface.

The low, broad holaulacorhizid root is slightly oblique toward the rear of the tooth, and diverges at the root base. The root base presents a well-developed, deep and very broad median groove, with an aperture in the outer central base of the groove and sometimes one or several scattered smaller apertures. Root coating is present at about one third of the upper part, all around the root.

Subfamily: Torpedininae
Genus: *Torpedo* HOUTTUYN, 1764

Natuurlyke historie of uitvoerige beschryving der dieren, planten en mineraalen, volgens het samenstel van den Heer Linnaeus. Met nauwkeurige afbeeldingen. 3 vols. in 37 parts. Natuurlyke historie, Amsterdam 1761-1785

The genus was subdivided by Gill (1862) into the two subgenera *T. (Torpedo)* and *T. (Tetronarke)*. The former comprises the species *T. andersoni*, *T. alexandriensis*, *T. bauchotae*, *T. fuscomaculata*, *T. marmorata*, *T. mackayana*, *T. panthera*, *T. sinuspersici*, *T. panthera*, *T. torpedo* (type species), and another new species from the Gulf of Aden (CARVALHO, M., Stehmann, M.F.W., MANILO, L.G. in press. *T. (Tetronarke)* comprises the species *T. californica*, *T. fairchildi*, *T. microdiscus*, *T. nobiliana* (type species), *T. puelcha*, *T. semipelagica*, *T. tokionis* and *T. tremens*.

Subgenus: *Torpedo (Tetronarke)* GILL, 1862

Analytical synopsis of the Order of Squali and revision of the nomenclature of the genera: Squalorum generum Novorum

Descriptioes Diagnostices. Annals of the Lyceum of Natural History of New York 7 (32): 367-413.

Torpedo (Tetronarke) nobiliana BONAPARTE, 1835
(Plates: 21 and 22)

Torpedo nobiliana BONAPARTE 1835 Iconografia della fauna italiana per le quattro classi degli animali vertebrati. III Pesci. - Roma Iconografia 3 (12-14): 1-824.

HETERODONTY

The dentition is gradient monognathic heterodont with lateral and posterior teeth becoming lower and the cusp inclined toward the commissure.

Sexual and ontogenetic heterodonty are absent.

VASCULARIZATION

The teeth show the holaulacorhizid root type with an elongated, well developed pulp cavity, from which the vascular tubes of the circumpulpar dentine radiate into crown and root. Osteodentine and inner lateral foramina are absent. (See textfigure 11)



Textfigure 11.
Tetronarke tooth histological cross section

MALES AND FEMALES

The crown is divided by sharp mesial and distal cutting edges into an inner and outer face. The outer face shows an upward arched, rounded crown base, overhanging the root. Both, mesial and distal cutting edges are of about equal size, each joining seamlessly with the crown base. They curve abruptly upward to form a broad-based, elongated cusp and joint apex, more than ones as high as the length of each cutting edge. The cusp becomes lower gradually in lateral and posterior teeth. The outer surface is slightly concave, with a basal central depression, giving the impression of mesial and distal basal lobes. Generally, the smooth inner face is concave, but the mid-section is convex, the mesial and distal lower lobe-like parts protruding inwardly. Inner and outer ornamentation are absent.

The basal surface of the crown has a rather, broad, slightly rounded crown rim at the outer margins, and is more or less quadrangular with blunt mesial and distal angles. The crown-root junction lies in a relatively narrow depression in the centre of the basal crown's surface.

The low, broad holaulacorhizid root is slightly oblique toward the rear of the tooth, and diverges at the root base. The root base presents a well-developed, deep and very broad median groove, with an aperture in the outer central base of

the groove and sometimes one or several scattered smaller apertures. Root coating is present at about one third of the upper part, all around the root.

Subgenus: *Torpedo (Torpedo)* HOUTTUYN, 1764

Natuurlyke historie of uitvoerige beschryving der dieren, planten en mineraalen, volgens het samenstel van den Heer Linnaeus. Met nauwkeurige afbeeldingen. 3 vols. in 37 parts. Natuurlyke historie, Amsterdam 1761-1785

Torpedo (Torpedo) torpedo LINNAEUS, 1758
(Plates: 23 to 26)

Raia torpedo LINNAEUS, 1758 Systema naturae per regna tria naturae, secundum classes, ordinus, genera, species, cum characteribus, differentiis, synonymis, locis. Tomus I Editio decima, reformata. *Holmiae*: 1-824.

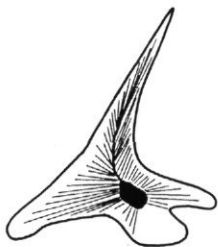
HETERODONTY

The dentition is gradient monognathic heterodont with lateral and posterior teeth becoming lower and the cusp inclined toward the commissure.

Sexual and ontogenetic heterodonty are absent.

VASCULARIZATION

The teeth show the holaulacorhizid root type with an elongated, well developed pulp cavity, from which the vascular tubes of the circumpulpar dentine radiate into crown and root. Osteodentine and inner lateral foramina are absent. (See textfigure 12)



Textfigure 12.
Torpedo tooth histological cross section

MALES AND FEMALES

The crown is divided by sharp mesial and distal cutting edges into an inner and outer face. The outer face shows a rounded, upward arched crown base, overhanging the root. Both, mesial and distal cutting edges are of about equal size and continuous with the crown base. They curve from abruptly upward to form a broad-based, elongated cusp and joint apex being twice or more as high as the length of each cutting edge. The cusp becomes lower gradually in lateral and posterior teeth. The outer surface is slightly concave, with a basal central depression, which gives the impression of mesial and distal basal lobes. Generally, the smooth inner face is concave, but the mid-section is convex, with the mesial and distal lower lobe-like parts protruding inward. Inner and outer ornamentation are absent.

The basal surface of the crown has a rather, broad, slightly rounded crown rim at the outer margins, and is more or less quadrangular with blunt mesial and distal angles. The crown-root junction lies in a relatively narrow depression in the centre of the basal crown's surface.

The low, broad holaulacorhizid root is slightly oblique toward the rear of the tooth, and diverges at the root base. The root base presents a well-developed, deep and very broad median groove, with an aperture in the outer central base of the groove and sometimes one or several scattered smaller apertures. Root coating is present at about one third of the upper part, all around the root.

Family: not defined

Genus: *Bengalichthys* ANNANDALE, 1909

Report on the fishes taken by the Bengal fisheries steamer Golden Crown Part 1, Batoidei. *Memoirs of the Indian Museum* 2 (1): 1-60.

The genus is monotypic with the type species *B. impennis*.

Bengalichthys impennis ANNANDALE, 1909
(Plate: 16)

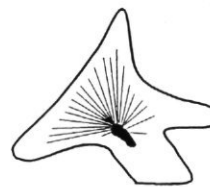
Bengalichthys impennis ANNANDALE, 1909 Report on the fishes taken by the Bengal fisheries steamer Golden Crown Part 1, Batoidei. *Memoirs of the Indian Museum* 2 (1): 1-60.

HETERODONTY

The dentition is gradient monognathic heterodont, with lateral and posterior teeth lowering toward the commissure. Lacking material of juveniles and full-grown females, ontogenetic and sexual heterodonty could not be determined.

VASCULARIZATION

The teeth show an adapted, holaulacorhizid root type with a relatively small pulp cavity. The vascular tubes of the circumpulpar dentine radiate into crown and root. Osteodentine and inner lateral foramina are absent. (See textfigure 13)



Textfigure 13.
Bengalichthys tooth histological cross section

MALES AND FEMALES

The crown is divided by sharp mesial and distal cutting edges into an inner and outer face. The outer face shows an arched, rounded crown base overhanging the root. Both, mesial and distal cutting edges are straight, more or less of equal size, and joining the crown base in an angle. Both cutting edges join in an apex, giving the outer face a triangular appearance,

which lowers gradually in lateral and posterior teeth. The outer surface is slightly concave. Generally, also the smooth inner face is concave. Inner and outer ornamentation are absent.

The basal surface of the crown shows a rather, broad, slightly rounded crown rim at the outer margins, with inner and outer parts joining in mesial and distal angles. The crown-root junction lies in a relatively deep depression in the centre of the basal crown's surface.

The moderately high, narrow holaulacorhizid root is more or less oval in cross-section, slightly oblique toward the rear of the tooth, and diverges at the root base. The root base presents a well-developed median groove, with a large aperture in the outer central base of the groove. Root coating is present at about one third of the upper part, all around the root.

Differential diagnosis

The most significant tooth morphology characters are summarized in table 1. Generally for Torpediniformes, the most characteristic part is the outer face of the crown, particularly the absence or presence of a cusp, its shape and the shape of the mesial and distal cutting edges. Further, the type of root is significant: a narrow and high or moderately high or low and broad root. *Hypnos*, *T.(Tetronarke)* and *T.(Torpedo)* share a low and broad root. The tricuspid crown is typical for *Hypnos*. There are minor odontological differences between *T.(Tetronarke)* and *T.(Torpedo)* only, which may only be interspecific variation.

Among the remaining taxa with a high to moderately high, narrow root, only *Temera* possesses a transverse keel. *Bengalichthys*, *Crassinarke* and *Narke* share a more or less triangularly shaped crown. The cutting edges of *Bengalicht-*

hys are straight, those of *Crassinarke* slightly curved upward and those of *Narke* irregularly, more or less undulated. *Benthobatis*, *Diplobatis*, *Discopyge*, *Heteronarce*, *Narcine* and *Typhlonarke* all possess a central cusp, which is more or less resulting from the shape of the mesial and distal cutting edges. With the exception of *Benthobatis* and *Heteronarce*, with upward curving cutting edges, cutting edges of the remaining taxa are more or less blade-like. The cusp of *Benthobatis* is narrow, whereas that of *Heteronarce* is broader and more massive. The cutting edges of *Benthobatis* are irregularly shaped, but smooth in *Heteronarce*. The mesial and distal blades of *Diplobatis*, *Discopyge* and *Narcine* join the cusp base in a notch. Those of *Typhlonarke* are continuous with the cusp base. The notches of *Diplobatis* are shallow and the cusp is low, whereas in *Discopyge* and *Narcine*, the notches are deeper and the cusp is high to moderately high. Generally, the cusps of *Discopyge* are lower than those of *Narcine*. However, the tooth morphology differences between *Diplobatis*, *Discopyge* and *Narcine* are minor and may vary within these taxa.

Conclusions

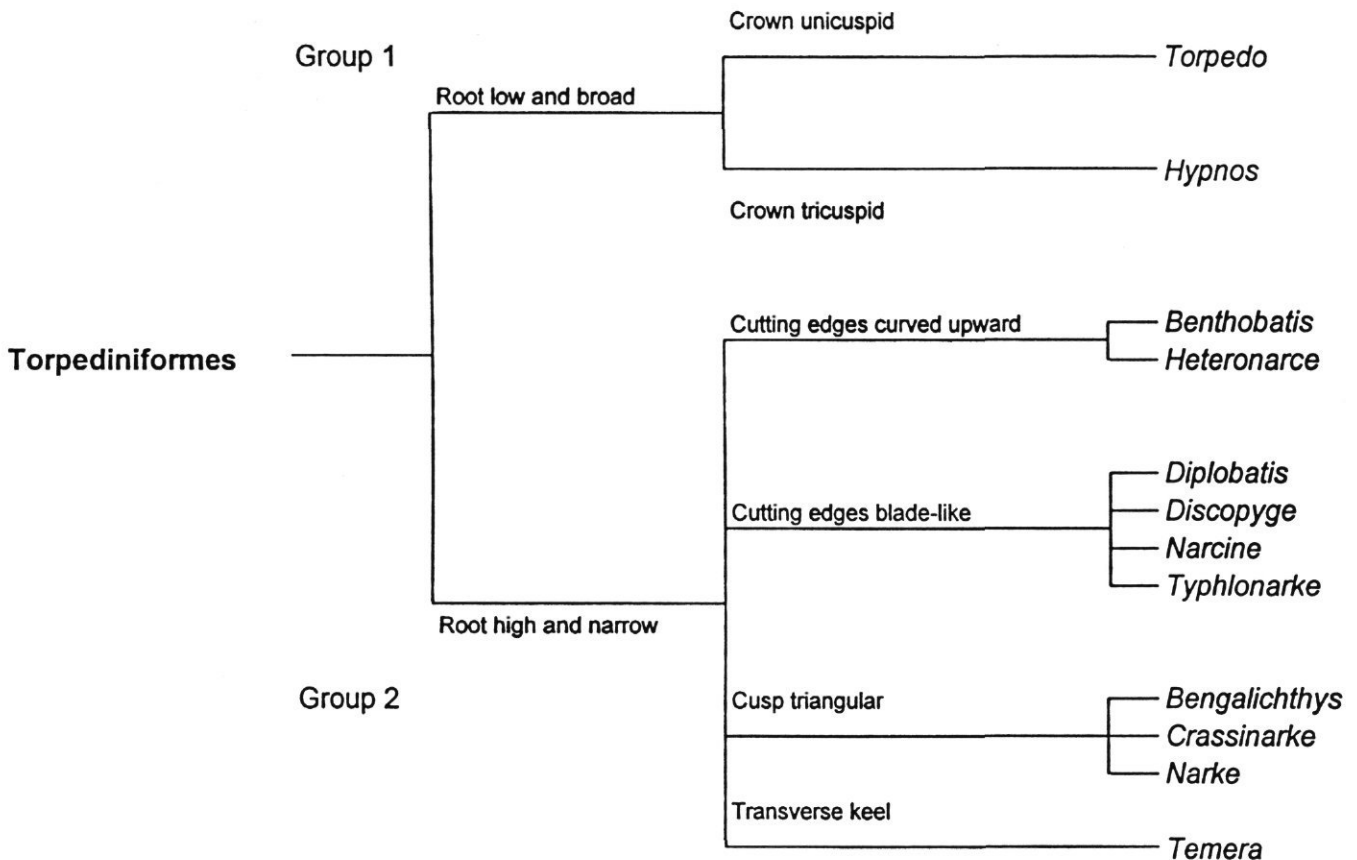
From the odontological point of view the Torpediniformes can be divided into two major groups by their typical root type. *Hypnos*, *T.(Tetronarke)* and *T.(Torpedo)* have a low broad root. All remaining taxa possess a narrow and high or moderately high root.

Group 1

Hypnos and *Torpedo* are considered as separate evolutionary developments. The odontological differences between *T.(Tetronarke)* and *T.(Torpedo)* are minimal and do not support retaining two separate subgenera.

Table 1. General morphologically significant characters

Species	Crown	Root
<i>Bengalichthys</i>	Cusp triangular Cutting edges straight	Moderately high and narrow
<i>Benthobatis</i>	Cusp narrow and moderately high Cutting edges curved upward	Moderately high and narrow
<i>Diplobatis</i>	Cusp narrow and moderately high Cutting edges blade-like	Moderately high and narrow
<i>Discopyge</i>	Cusp narrow and high Cutting edges blade-like	Moderately high and narrow
<i>Crassinarke</i>	Cusp triangularly Cutting edges slightly curved upward	Moderately high and narrow
<i>Heteronarce</i>	Cusp relatively broad Cutting edges curving upward	Moderately high and narrow
<i>Narcine</i>	Cusp narrow and high Cutting edges blade-like	Moderately high and narrow
<i>Narke</i>	Cusp triangular Cutting edges straight	Moderately high and narrow
<i>Temera</i>	Transversal keel high	Low and narrow
<i>Typhlonarke</i>	Cusp relatively broad Cutting edges blade-like, curving upward	Low and narrow
<i>Hypnos</i>	Tricuspid	Low and broad
<i>Torpedo (Tetronarke)</i>	Cups high Cutting edges blade-like, curving upward	Low and broad
<i>Torpedo (Torpedo)</i>	Cups high Cutting edges blade-like, curving upward	Low and broad



Group 2

This group is subdivided into three separate evolutionary lines:

Subgroup 1 *Temera* with a transverse keel and more or less dasyatid appearance.

Subgroup 2 *Bengalichthys*, *Crassinarke* and *Narke* with their more or less triangularly shaped crown.

Subgroup 3 *Benthobatis*, *Diplobatis*, *Discopyge*, *Heteronarce*, *Narcine* and *Typhlonarke* with their particular cusp and mesial and distal cutting edges.

Within this subgroup *Benthobatis* and *Heteronarce* are different by the shape of mesial and distal cutting edges, as well as *Diplobatis*, *Discopyge*, *Narcine* and *Typhlonarke* are characterized by the shape of mesial and distal blades and cusp.

Probably due to the small size of the torpediniform micro-teeth, there are only few fossil records known. However, their tooth morphology shows similarity with the dasyatids, which particularly is documented in *Temera*. Not only the transversal keel, but the whole tooth morphology has similarity with dasyatids, and the Torpediniformes may well have derived from the Dasyatidae.

The lack of sexual heteronty appears to be a more advanced stage of development.

The vascularization of the teeth of all torpediniform taxa is principally the same. The orthodont type, lacking osteodentine in the root, is also an indication of an advanced development.

Acknowledgements

The authors thank Prof. Dr. H. Wilkens, Zoologisches Institut und Zoologisches Museum der Universität Hamburg (ZMH), Dr. H. Ishihara, Museum of the Tokyo University of Fisheries (MTUF), Mr. B. Seret, Antenne XXX, Musée National d'Histoire Naturelle, Paris (NMHN), Dr. D. Nolf, Institut Royal des Sciences naturelles de Belgique, Brussels (IRSNB) and Mr. C. Hartman, Ryan's Falls (Australia) for permission to examine specimens at their disposal. The SEM-photographs were taken by J. Cillis, Institut Royal des Sciences naturelles de Belgique, Brussels.

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General glossary

(applying to all previous issues of this series)

Concerning the jaw

Anterior

Tooth position close to junction of left and right jaw halves.

Commissural

Tooth position near the end of jaw.

Dignathic

Heterodont by having different tooth morphology in upper and lower jaws.

File

Tooth row from symphysis toward end of jaw.

Heterodonty

Different tooth morphology within a tooth file. There are two types of heterodonty: dignathic and monognathic.

Homodonty

Uniform tooth morphology within a tooth file

Lateral

Tooth positions half way along the jaw.

Longitudinal

Symphysial/commissural direction of a tooth file.

Monognathic

Heterodonty within one jaw only. (this can appear as gradient or disjunct)

Parasymphysial

First anterior tooth row, if a symphysial tooth row is absent.

Posterior

Tooth positions toward the angle of jaws.

Pseudosymphysial

One of the parasymphysial tooth rows placed in the position of the symphysial tooth row (symmetry).

Row

Tooth row from inner face to outer face of jaw.

Symphysial

Teeth at junction of both halves of a jaw.

Transverse

Outer/inner direction of a row.

Concerning the tooth

An-, Hemi-, Hol- and Polyaulacorhizid

Concerning their vascularization, E.Casier(1947) recognized and described four phylogenetically significant root types within the orthodont histotypes of elasmobranch teeth.

Anaulacorhizid

Vascularization through scattered foramina of equal size on both outer and inner faces, (e.g. Hexanchidae).

Hemiaulacorhizid

Vascularization through a median groove and 1 or 2 lateral foramina on inner face, (like in Squatinidae and Orectolobidae)

Holaulacorhizid

Vascularization through many small foramina concentrated in a median groove running from outer to inner face, (e.g. Rajidae)

Polyaulacorhizid

Vascularization through many small foramina concentrated in several grooves running parallel from outer to inner face, (e.g. Myliobatidae)

Apron

Expansion of the central part of the outer crown base.

Basal

Bottom face concerned.

Inner central ridge

Convex protrusion at the upper midsection of the inner crown face.

Costules

Short, vertical ridges sometimes present on inner and/or outer crown base.

Crown

Enamelled tooth part.

Distal

Tooth edge or part toward angle of jaws.

Histotype

Type of internal tooth vascularization.

Inner face

Viewed from inside the mouth.

Longitudinally

Apico-basally directed structuring on a tooth.

Median groove

Groove running from the inner root base to the inner crown-root junction, dividing a holaulacorhizid type of root into two root lobes. It includes the main foramina of the vascularization system.

Mesial
Tooth edge or part toward junction (symphysis) of left and right jaw halves.

Neo-holaulacorhizy
Modification of the holaulacorhizid type of root, combining a shallow median groove and an extremely expanded pulp cavity.

Orthodont
Histotype of vascularization, by which a tooth is supplied primarily by an internal pulp cavity radiating into numerous tiny canals penetrating the orthodentine layer.

Osteodont
Histotype of vascularization, by which a tooth is supplied without any pulp cavity by scattered tiny cavities and canals penetrating the osteodentine layer of the root and the internal crown material.

Outer face
Viewed from outside the mouth.

Pseudo-apron
Apron-like vertical ridges that appear sometimes on lateral and posterior teeth.

Pseudo-osteodont
The former pulp cavity of an originally orthodont histotype of tooth being filled secondarily with osteodentine.

Pulp cavity
Cavity inside the tooth from which the vascularization is spread via canaliculi.

Root
Non-enamelled tooth part, that forms the junction with the jaw gum and provides vascularization of the tooth.

Root coating
Coating on the upper part of the root (probably enameloid)

Root stem
Root part between the crown base and root lobe section.

Secondary anaulacorhizid
Median groove of a holaulacorhizid type of root totally overgrown to form a closed tube internally connected or merged with the pulp cavity

Secondarily hemiaulacorhizid
Median groove of holaulacorhizid type of root overgrown to various extent, converting the median groove to an internal tube, which is merged with the pulp cavity.

Striae
Vertical ridges running from crown base toward apex.

Sulcus
Groove developed by the primary vascularization canals leading from root base to the main foramina in anaulacorhizid root type. It differs from the median groove in which several foramina are concentrated of the holaulacorhizid root type and the parallel grooves of the polyaulacorhizid root type, respectively, in that a sulcus lacks foramina.

Transverse
Mesio-distally directed.

Transverse keel
Transverse ridge dividing the crown into inner and outer face.

Uvula
Lobate extension of the inner crown base.

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Composition of the plates

As far as possible plates of isolated teeth of one juvenile (male or female) and of both male and female adults are presented for each supraspecific taxon.

The plates have a consistent composition: upper teeth are presented with their cusps downward and lower teeth with their cusps upward.

The choice of left or right jaw halves illustrated depends on the preservation quality of the specimen's tooth files only.

Legend

a = anterior position
la = latero-anterior
l = lateral position
lp = Latero-posterior
p = posterior position
c = commissural position

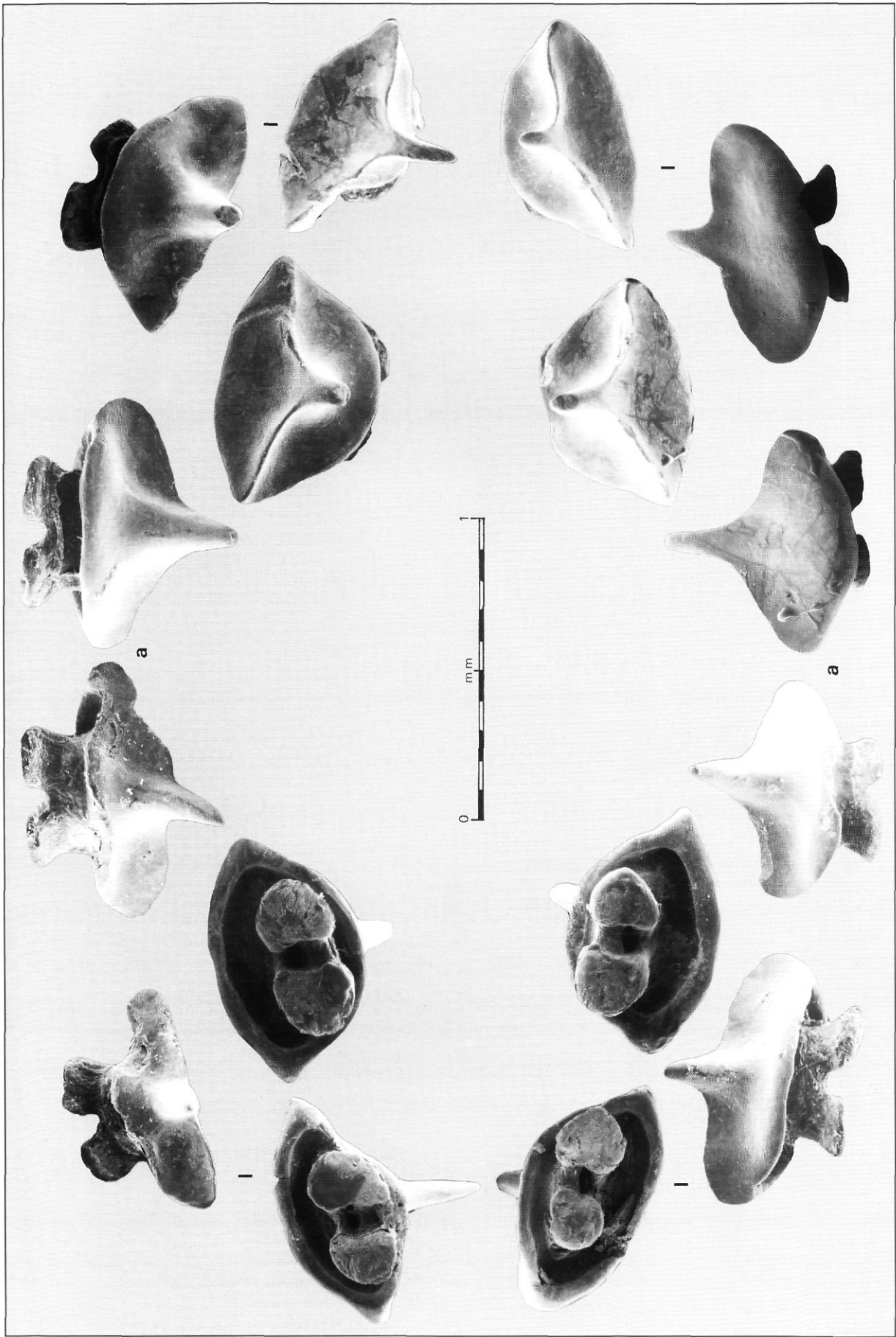


Plate 1. *Benthobatis marcidus* BEAN & WEED, 1909. Male 34.5 cm t.l., off Florida. Upper and lower teeth.

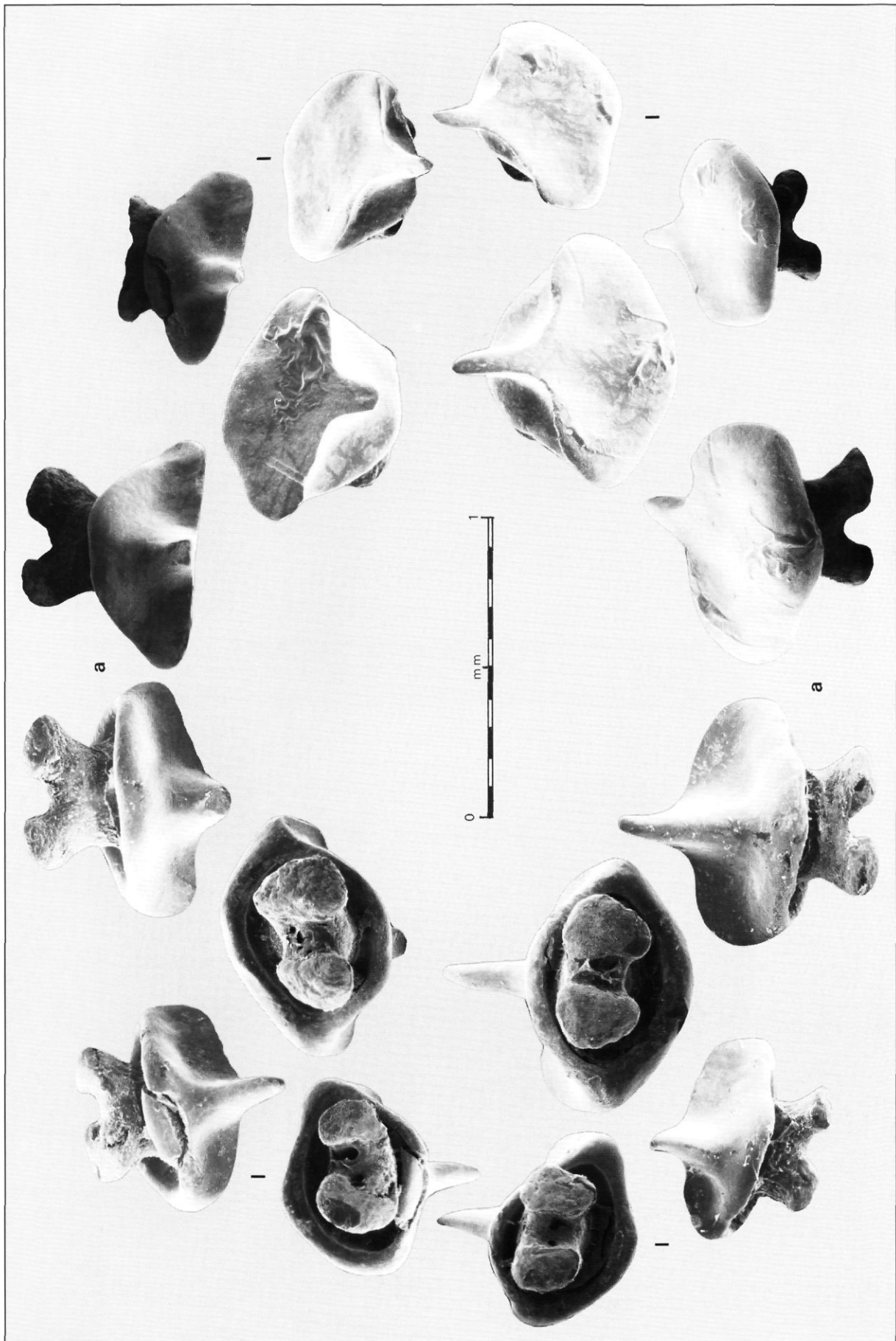


Plate 2. *Benthobatis marcida* BEAN & WEED, 1909, Female 38.5 cm t.l., off Florida. Upper and lower teeth.

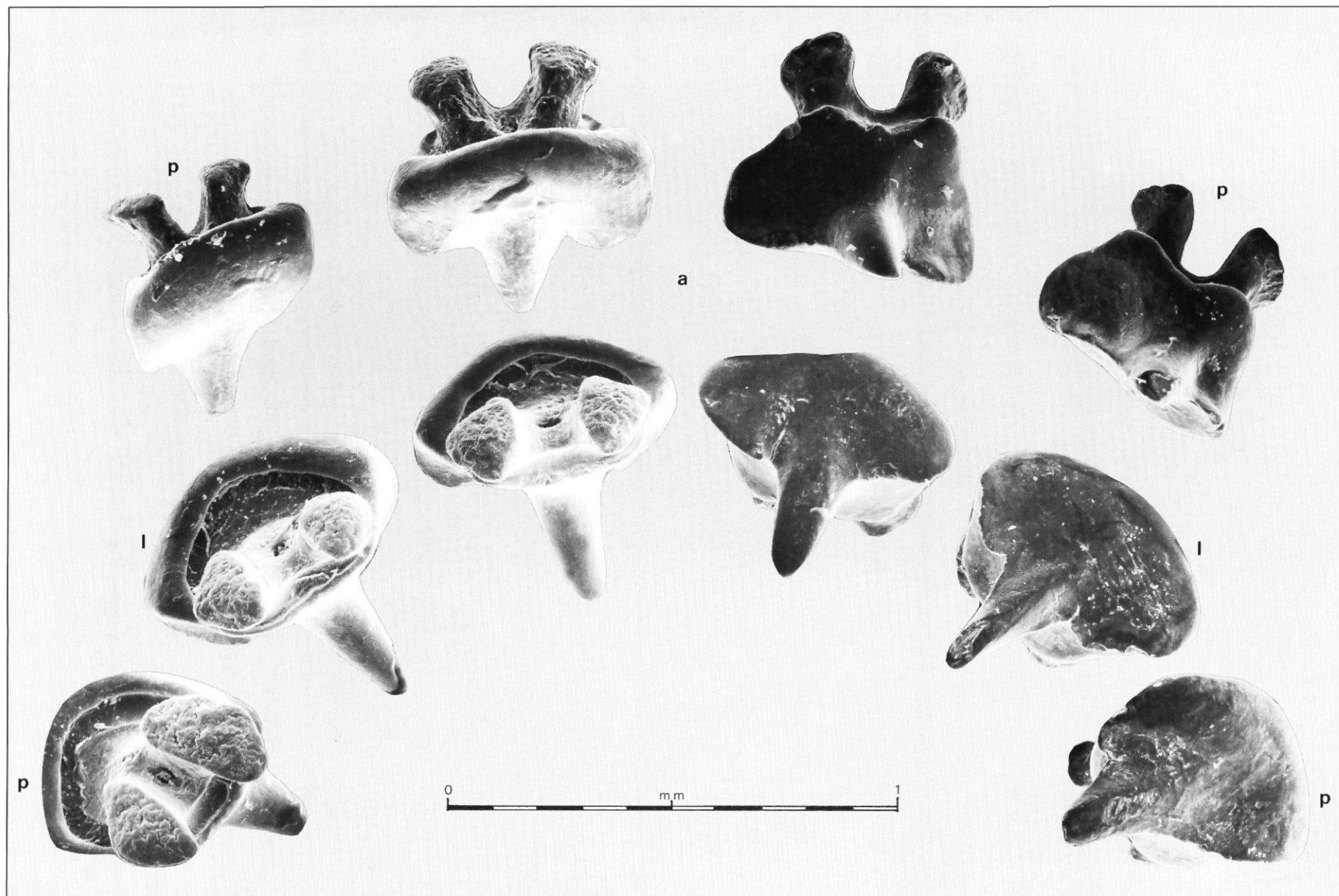


Plate 3. *Diplobatis ommata* (JORDAN & BOLLMAN, 1890). Female 15 cm t.l., off Panama. Upper teeth.

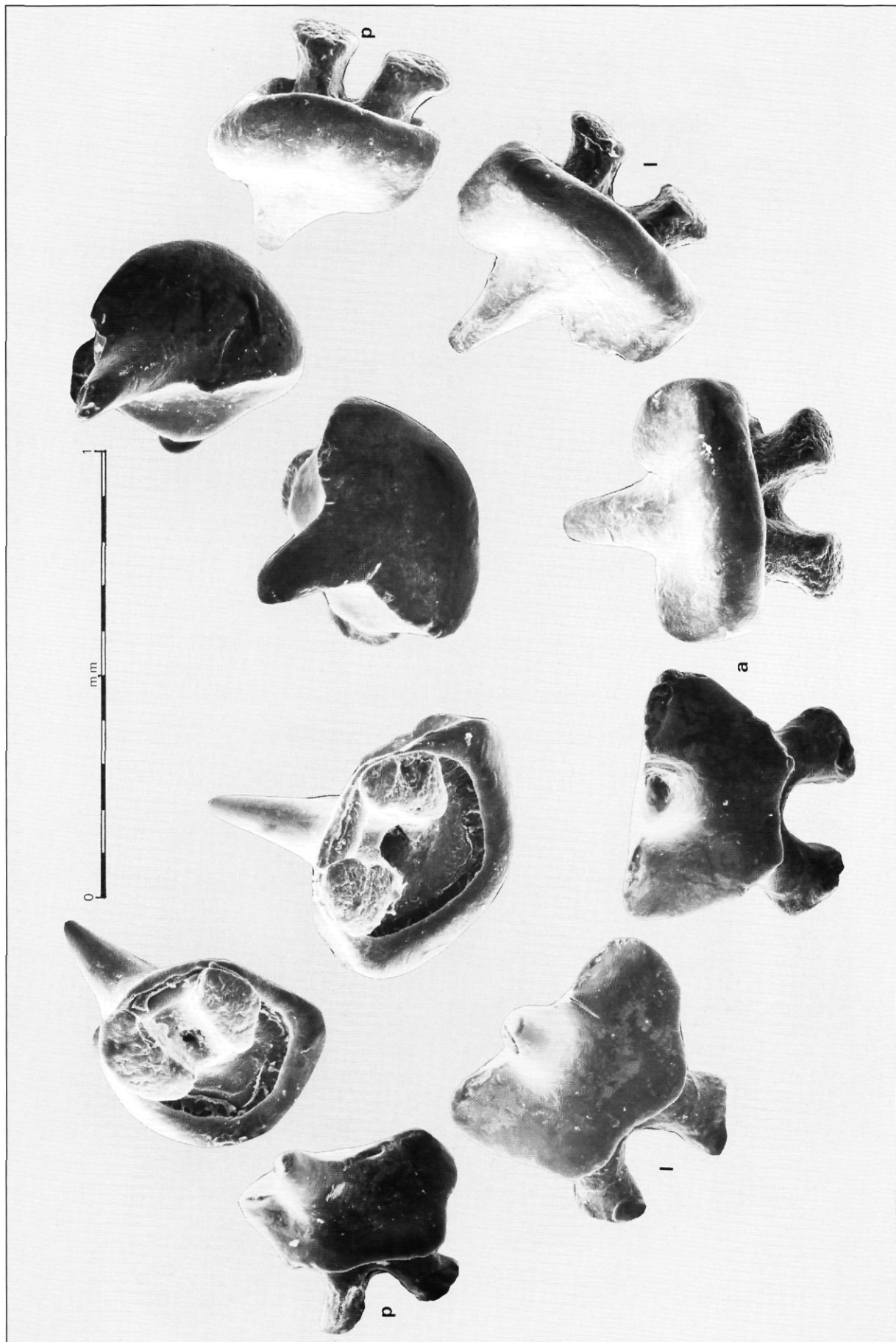


Plate 4. *Diplobatis ommata* (JORDAN & BOLLMAN, 1890). Female 15 cm t.l., off Panama. Lower teeth.

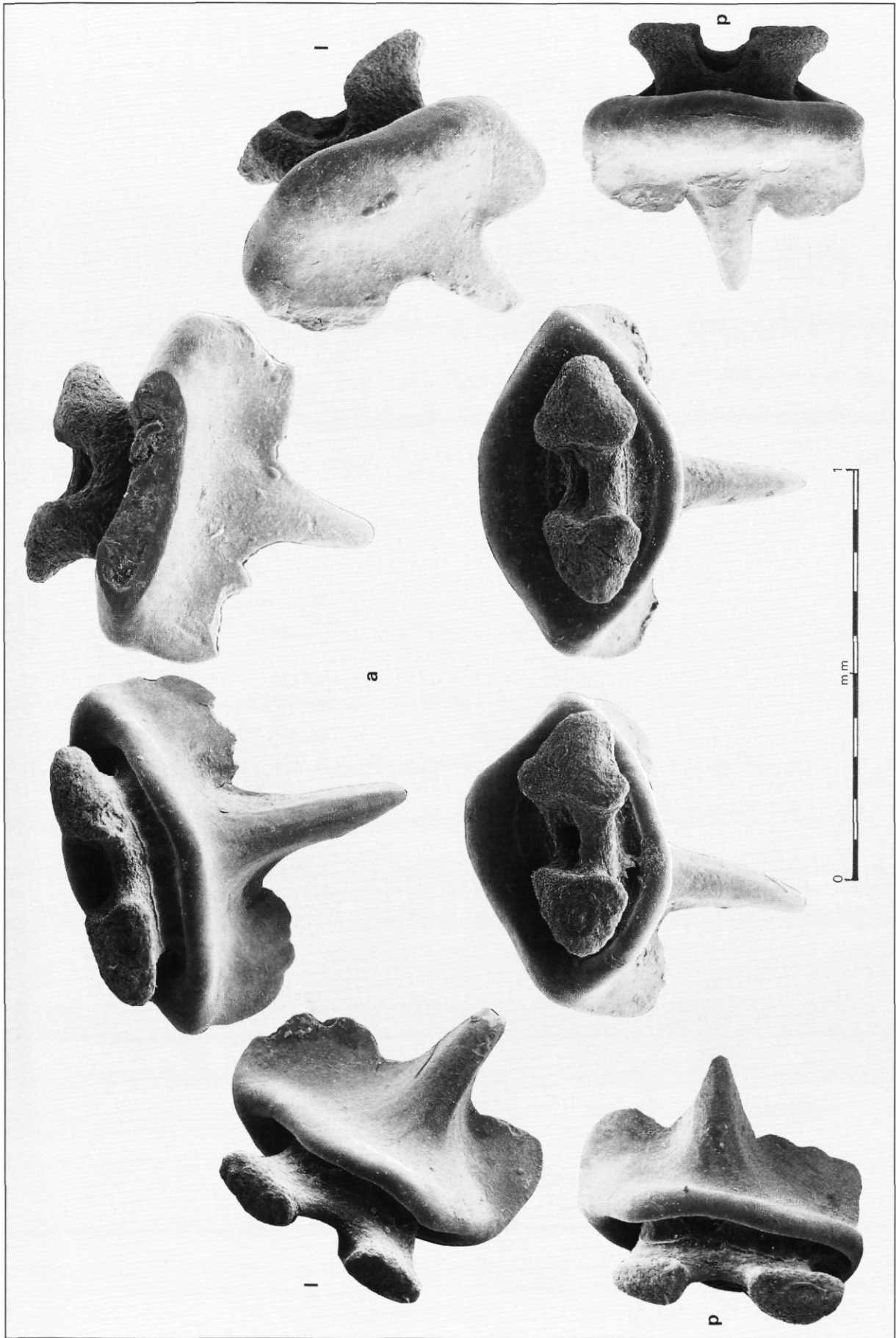


Plate 5. *Discopyge tschudii* HECKEL, 1846. Male 40 cm t.l., Coronel Bay. Upper teeth.

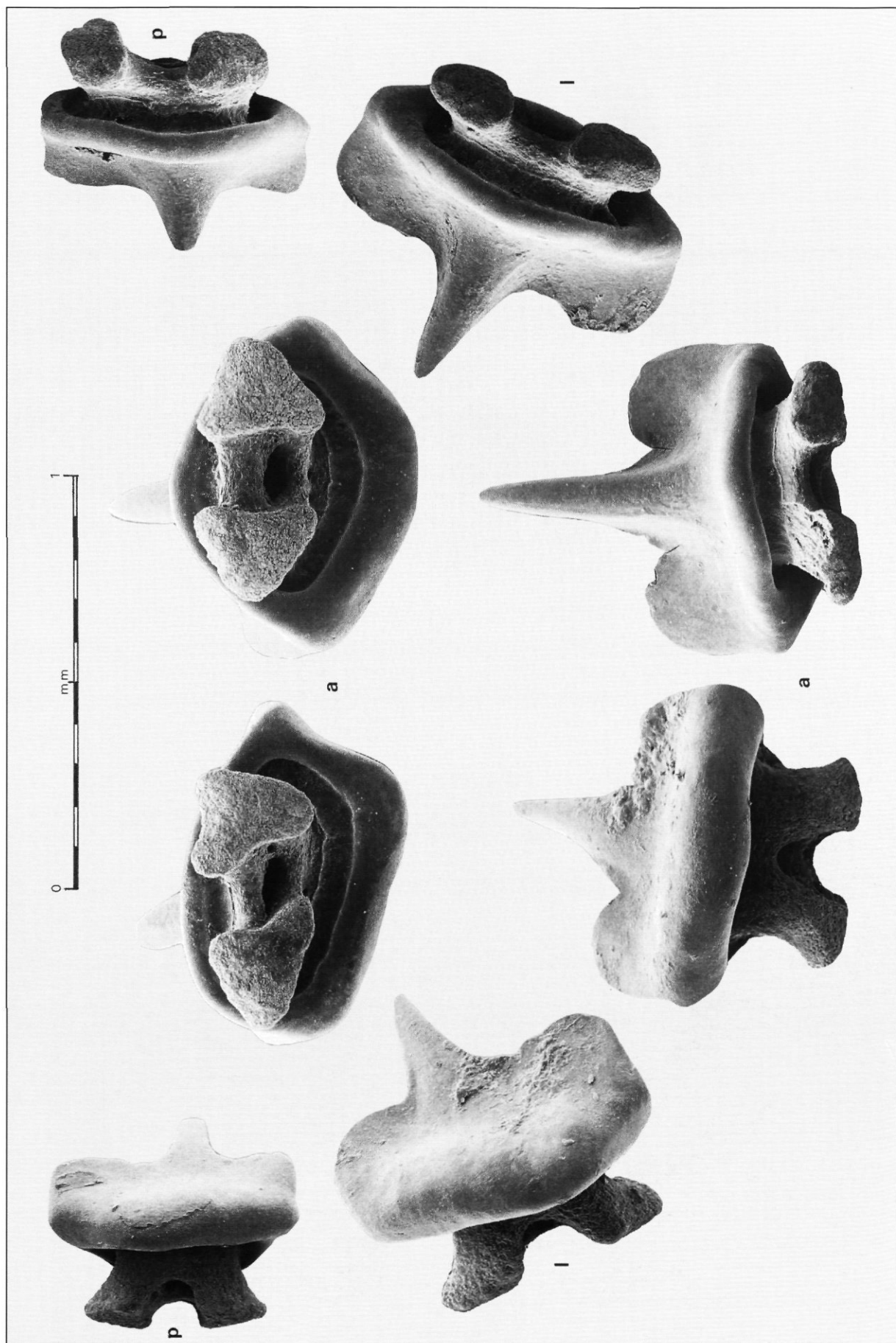


Plate 6. *Discopyge tschuidii* HECKEL, 1846. Male 40 cm t.l., Coronel Bay. Lower teeth.

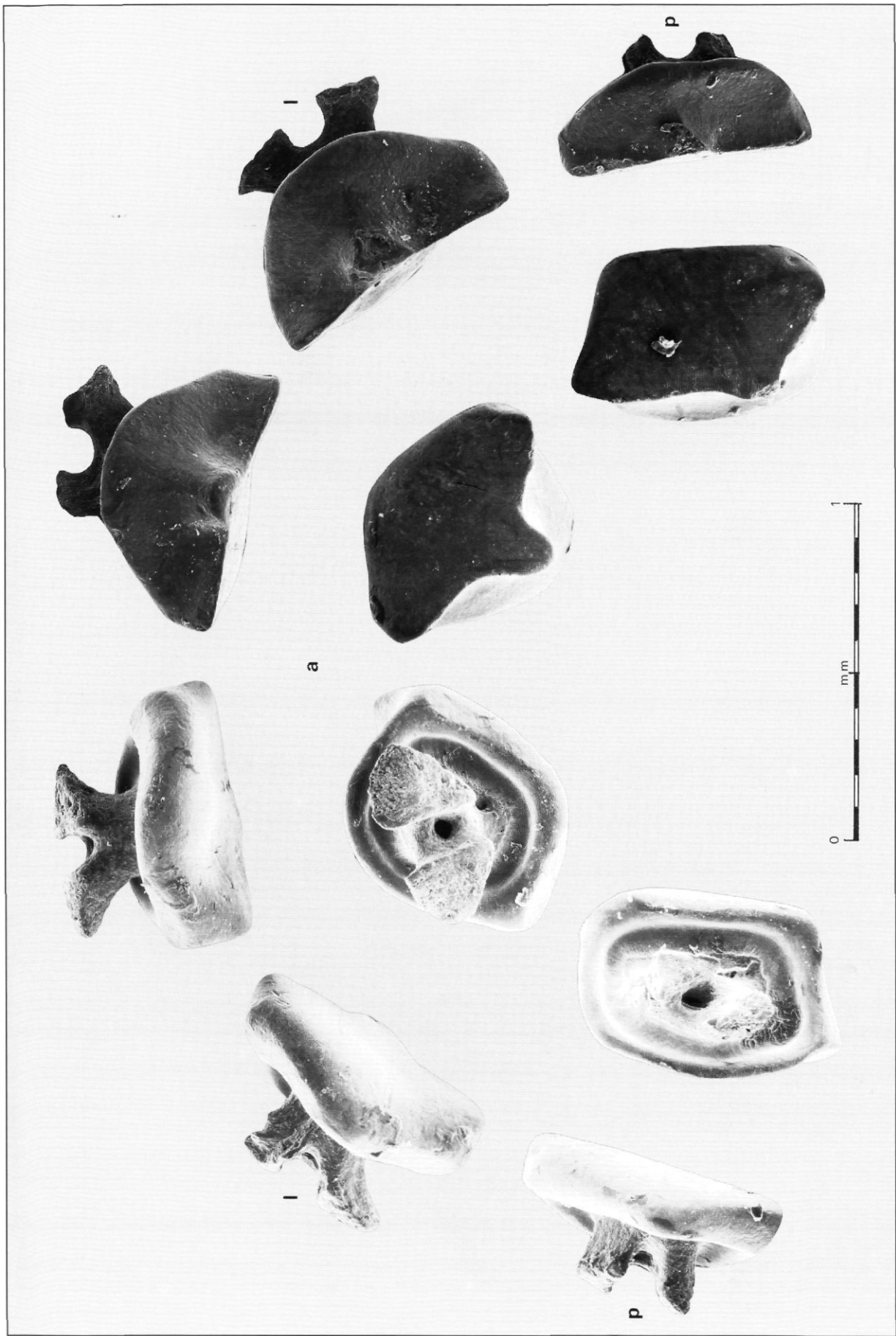


Plate 7. *Discopyge ischudii* HECKEL, 1846. Female 31 cm t.l., Coronel Bay. Upper teeth.

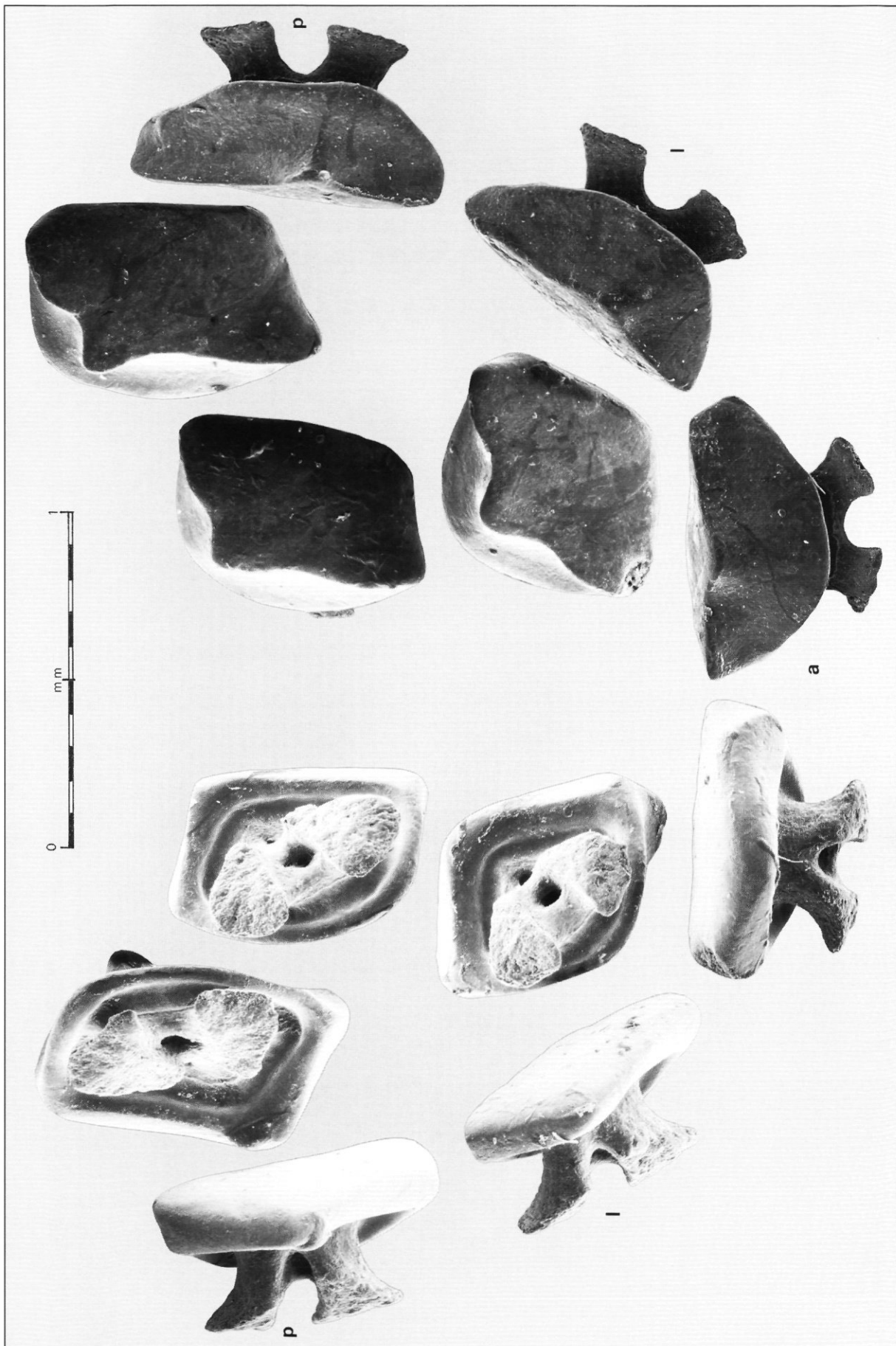


Plate 8. *Discopyge ischudii* HECKEL, 1846. Female 31 cm t.l., Coronel Bay. Lower teeth.

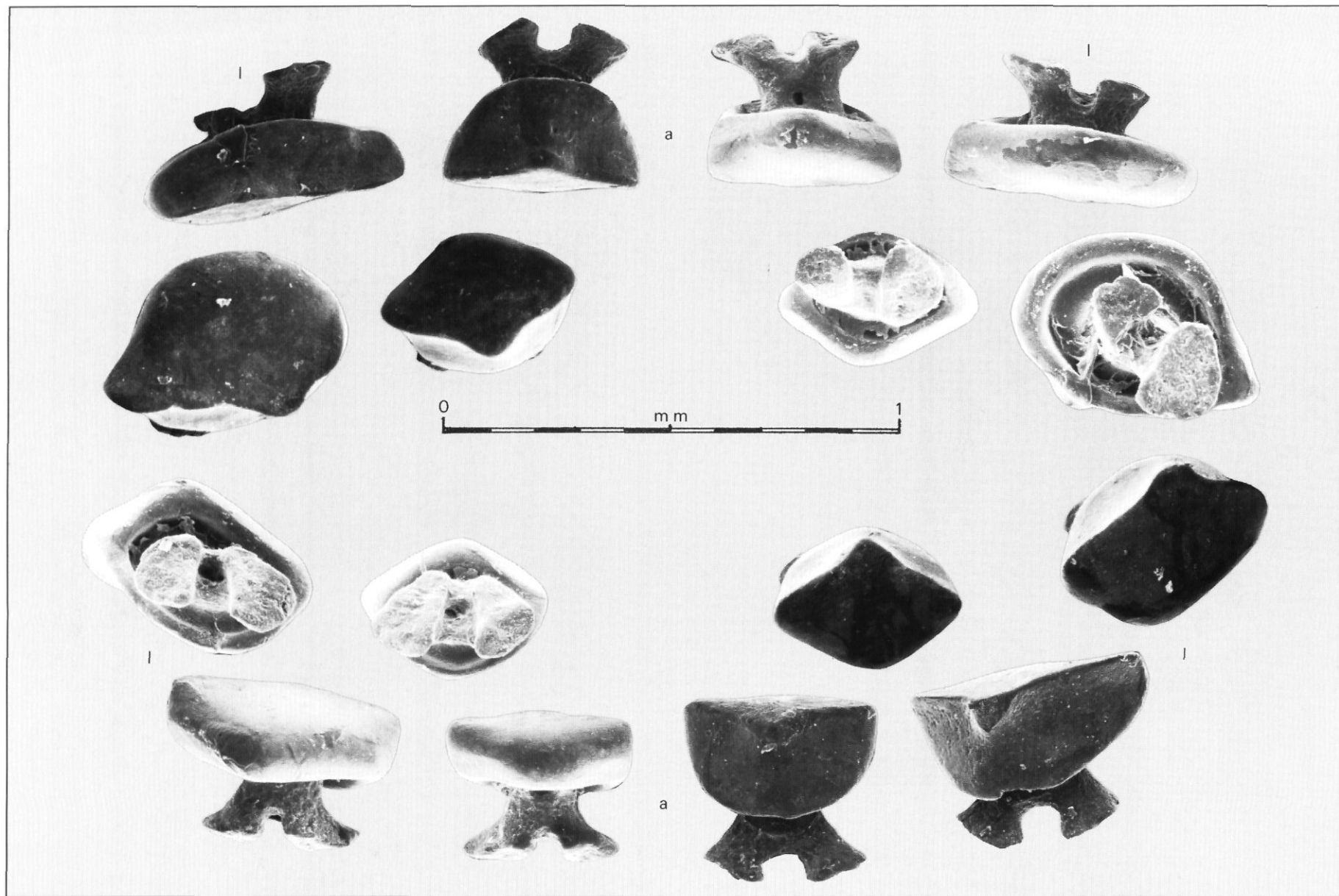


Plate 9. *Discopyge tschudii* HECKEL, 1846. Female 16.5 cm t.l., Mouth of Rio de la Plata. Upper and lower teeth.

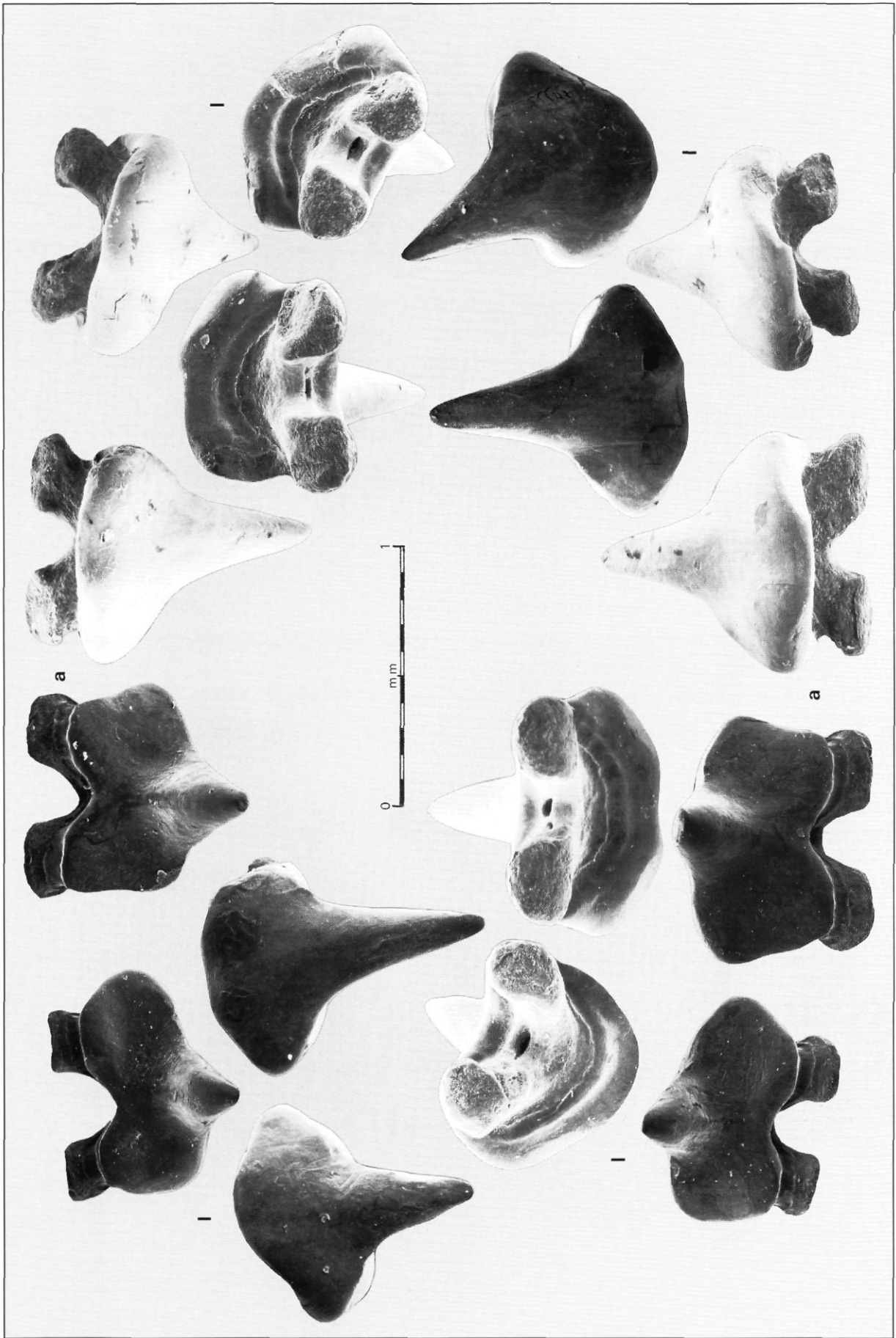


Plate 10. *Narceine brasiliensis* (OLFFERS, 1831). Female 54 cm t.l., off Suriname. Upper and lower teeth.

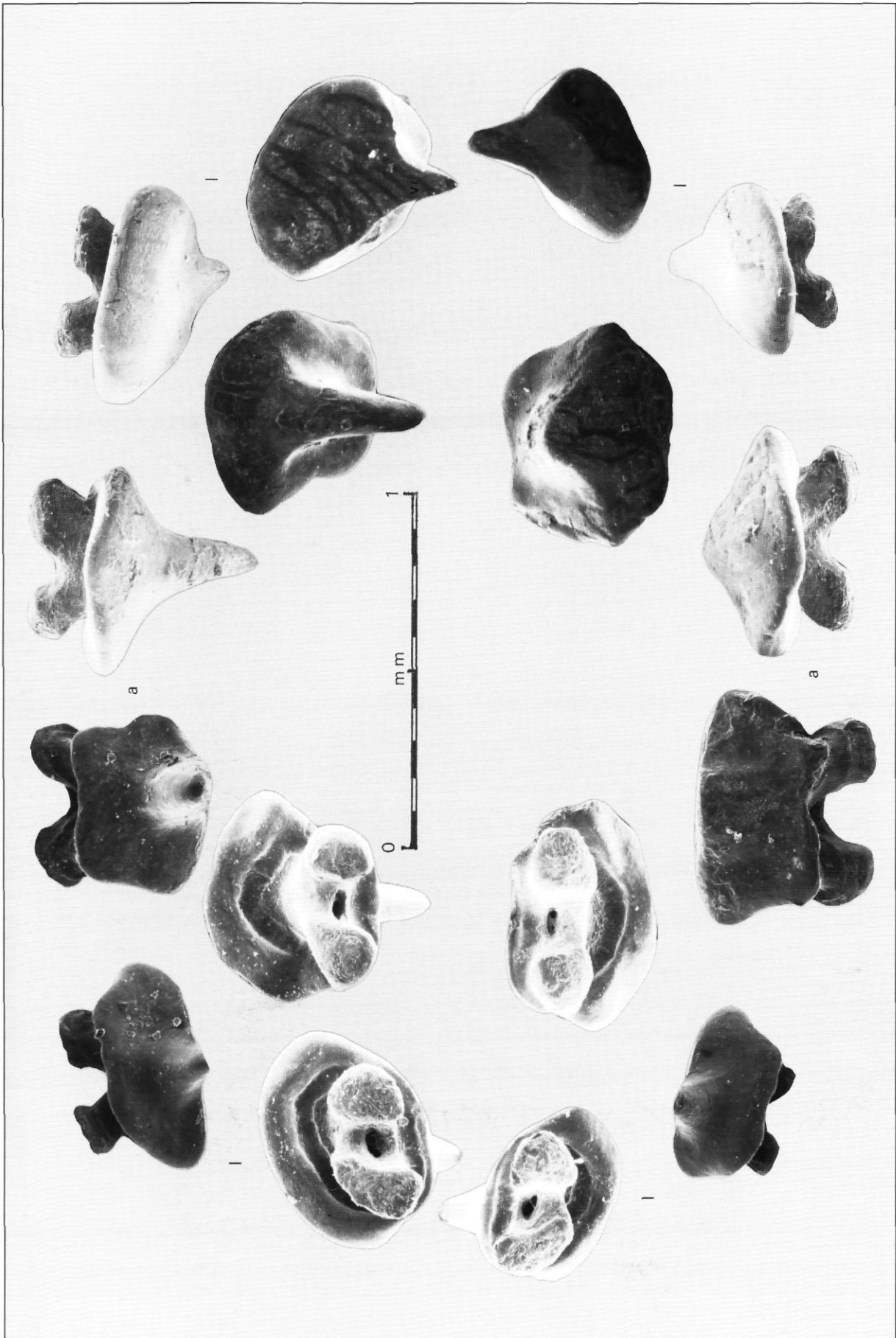


Plate 11. *Narcine brasiliensis* (OLFERS, 1831). Male 49 cm t.l., off Brasil. Upper and lower teeth.

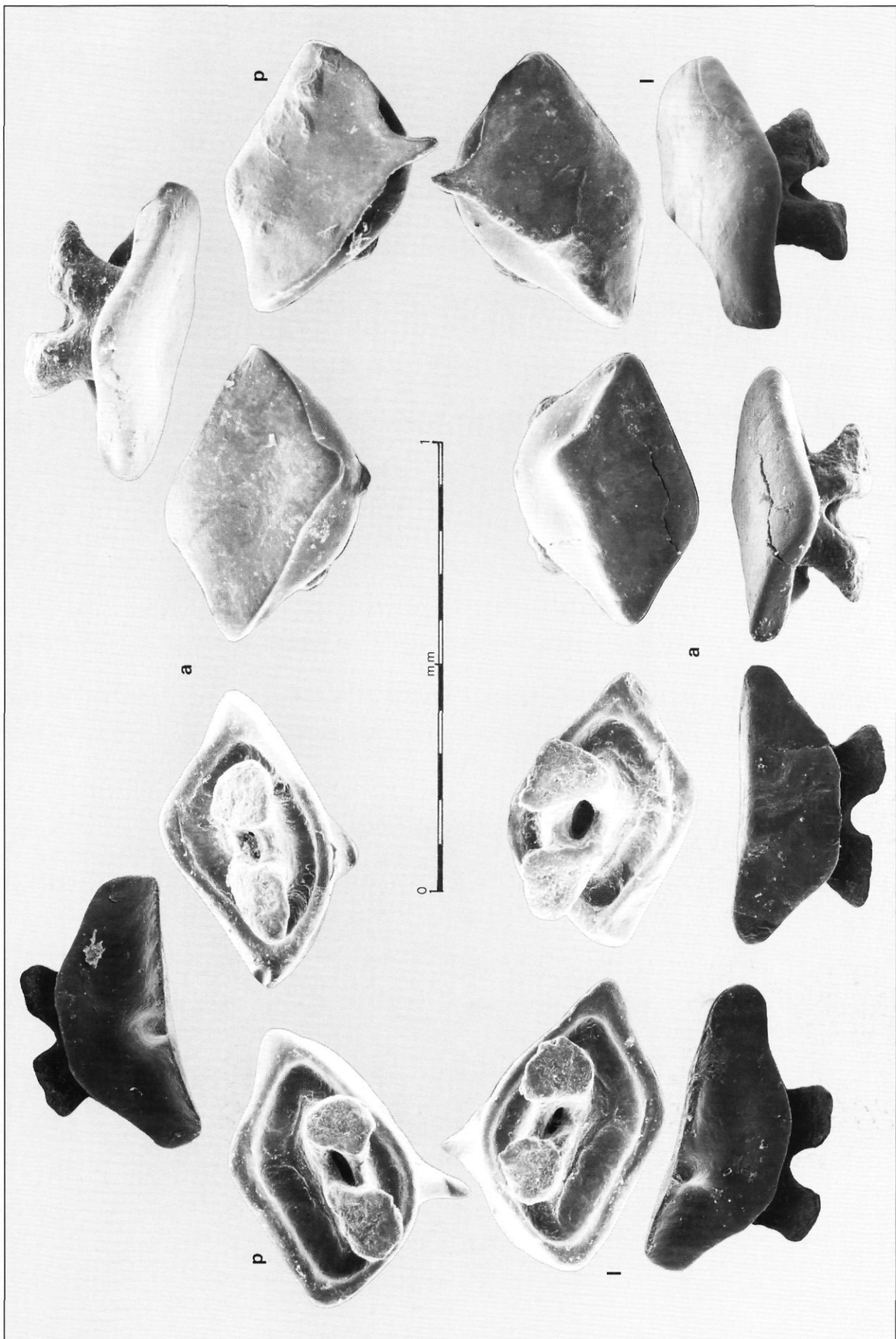


Plate 12. *Heteronarc garmani* REGAN, 1921. Female 22 cm t.l., off Somalia. Upper and lower teeth.

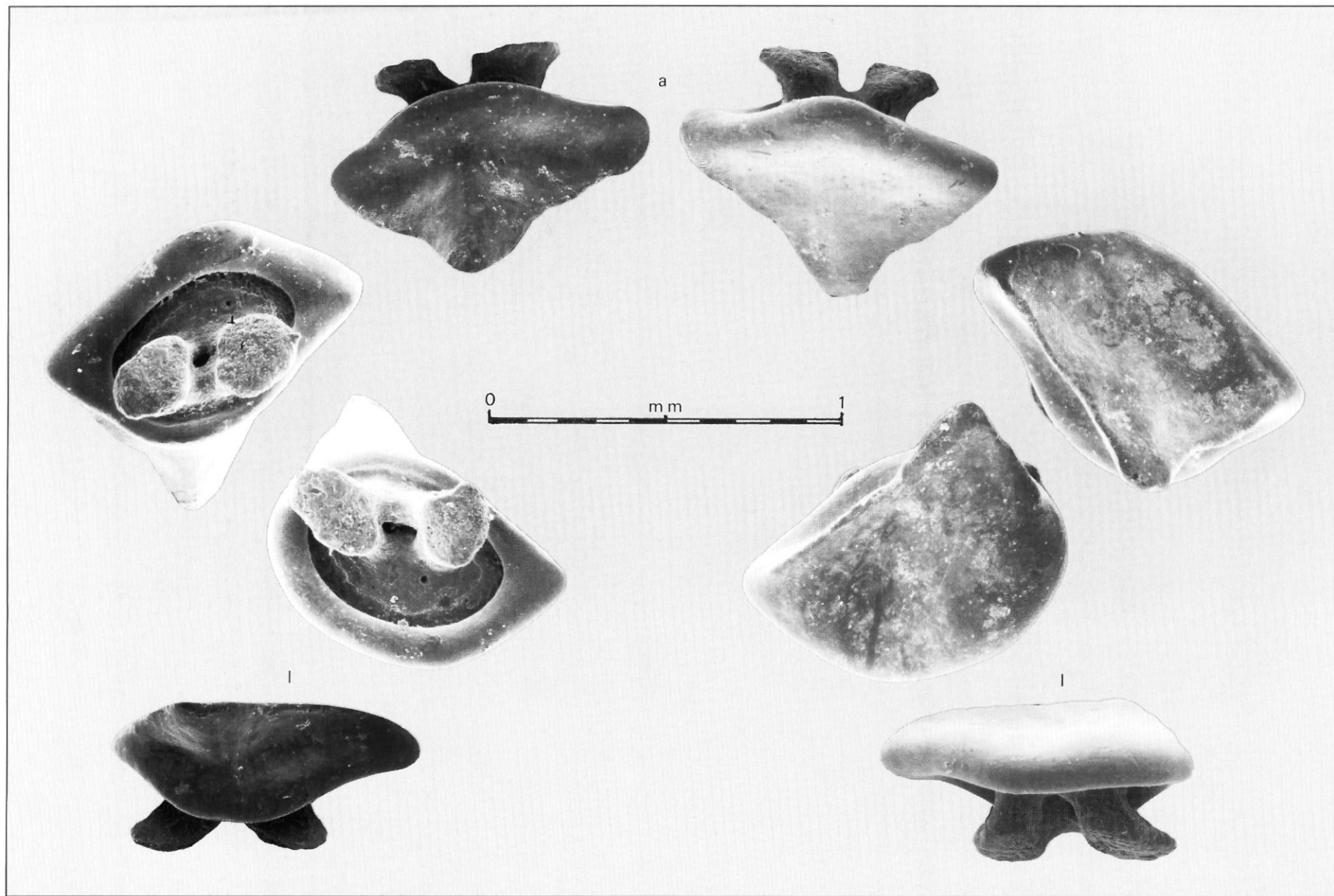


Plate 13. *Heteronarce mollis* (LYOD, 1907). Male 19.5 cm t.l., off Somalia. Upper and lower teeth.

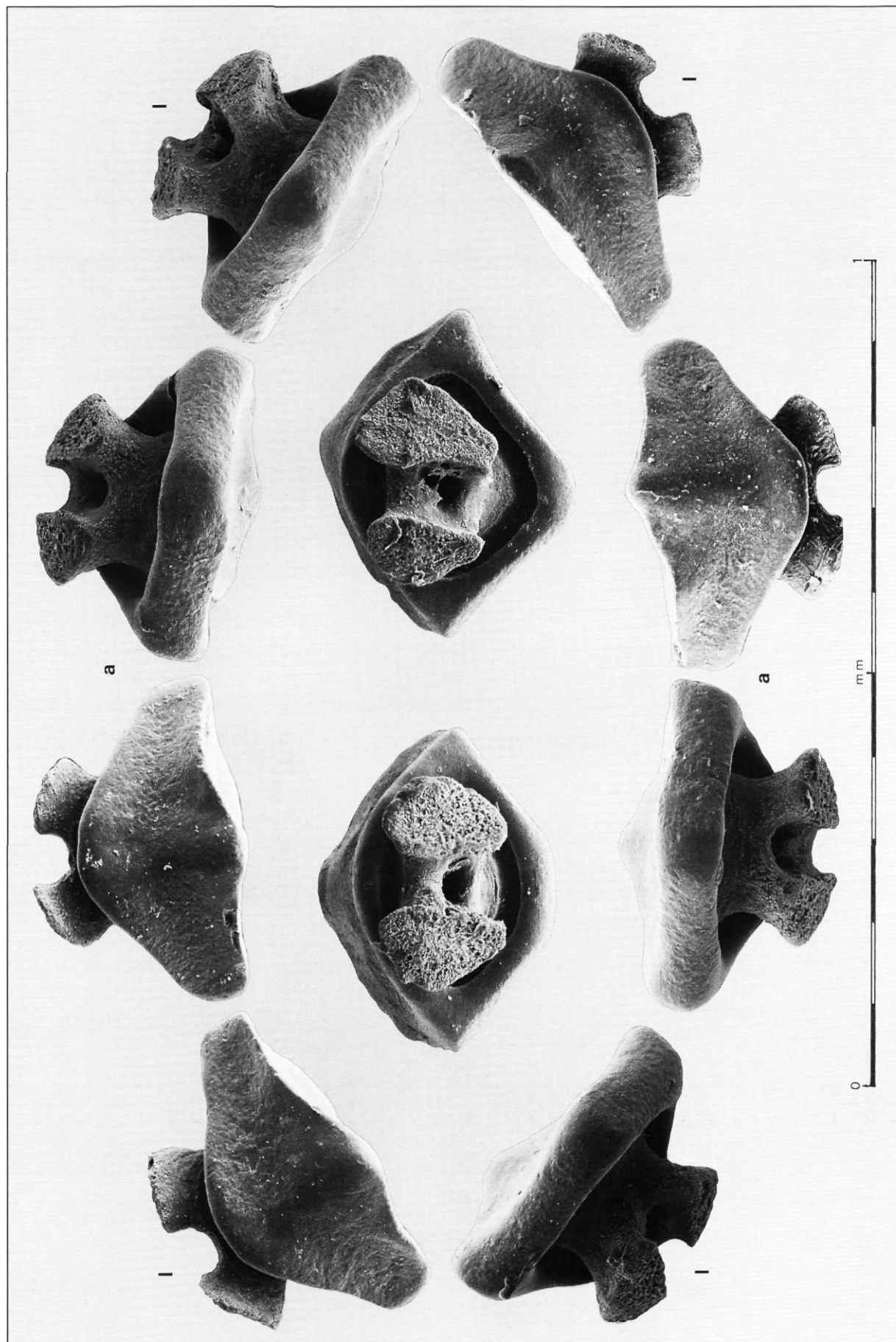


Plate 14. *Narke dipterygia* (BLOCH & SCHNEIDER, 1801). Female 18 cm t.l., off Puri, India. Upper and lower teeth.



Plate 15. *Temera hardwickii* GRAY, 1836. Male 10.5 cm t.l., Singapore. Upper and lower teeth.



Plate 16. *Bengalichthys impennis* ANNANDALE, 1909, Male 16 cm t.l., Gulf of Bengal. Upper and lower teeth.

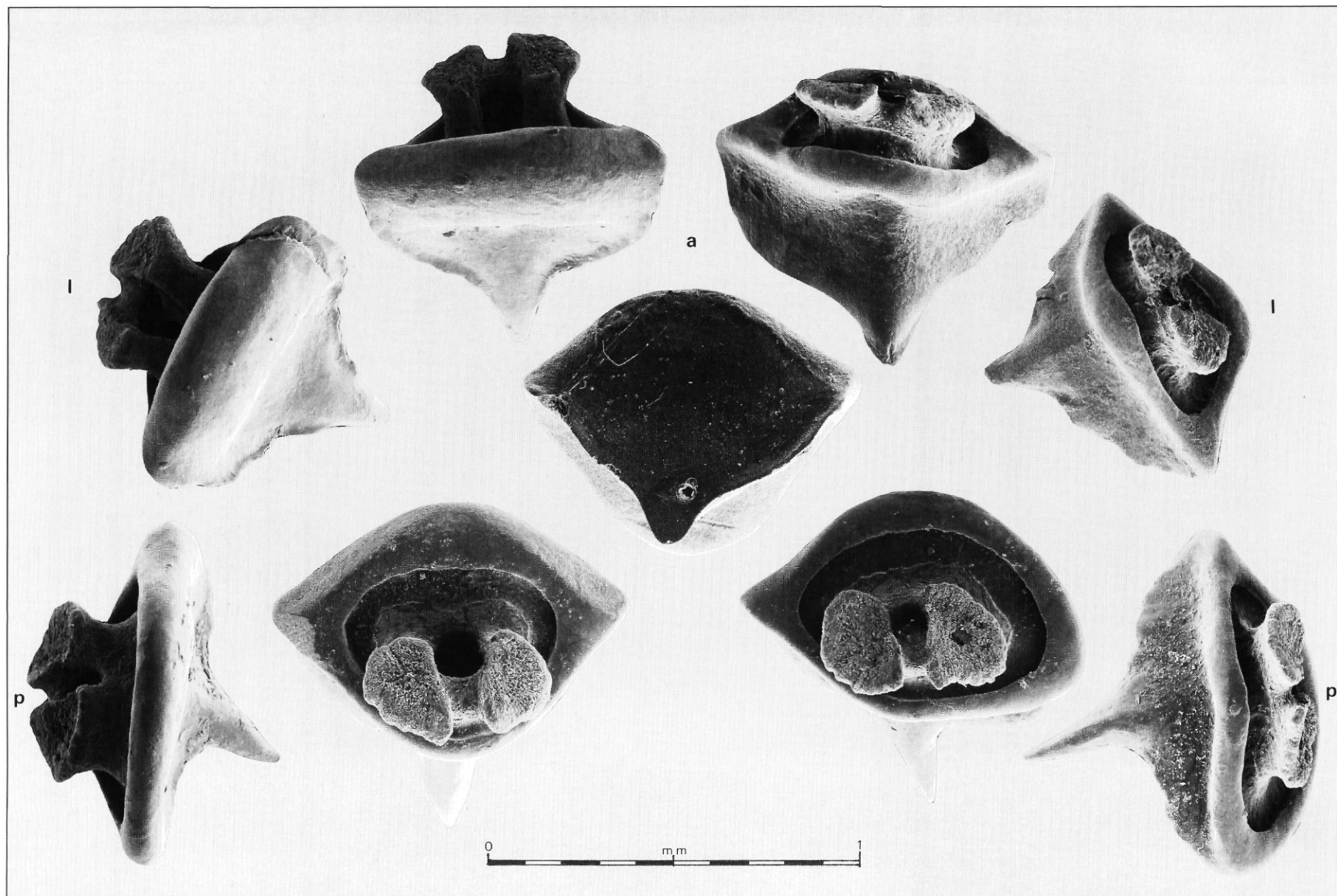


Plate 17. *Typhlonarke aysoni* (HAMILTON, 1902). Male 20 cm t.l., off South Island, New Zealand. Upper teeth.

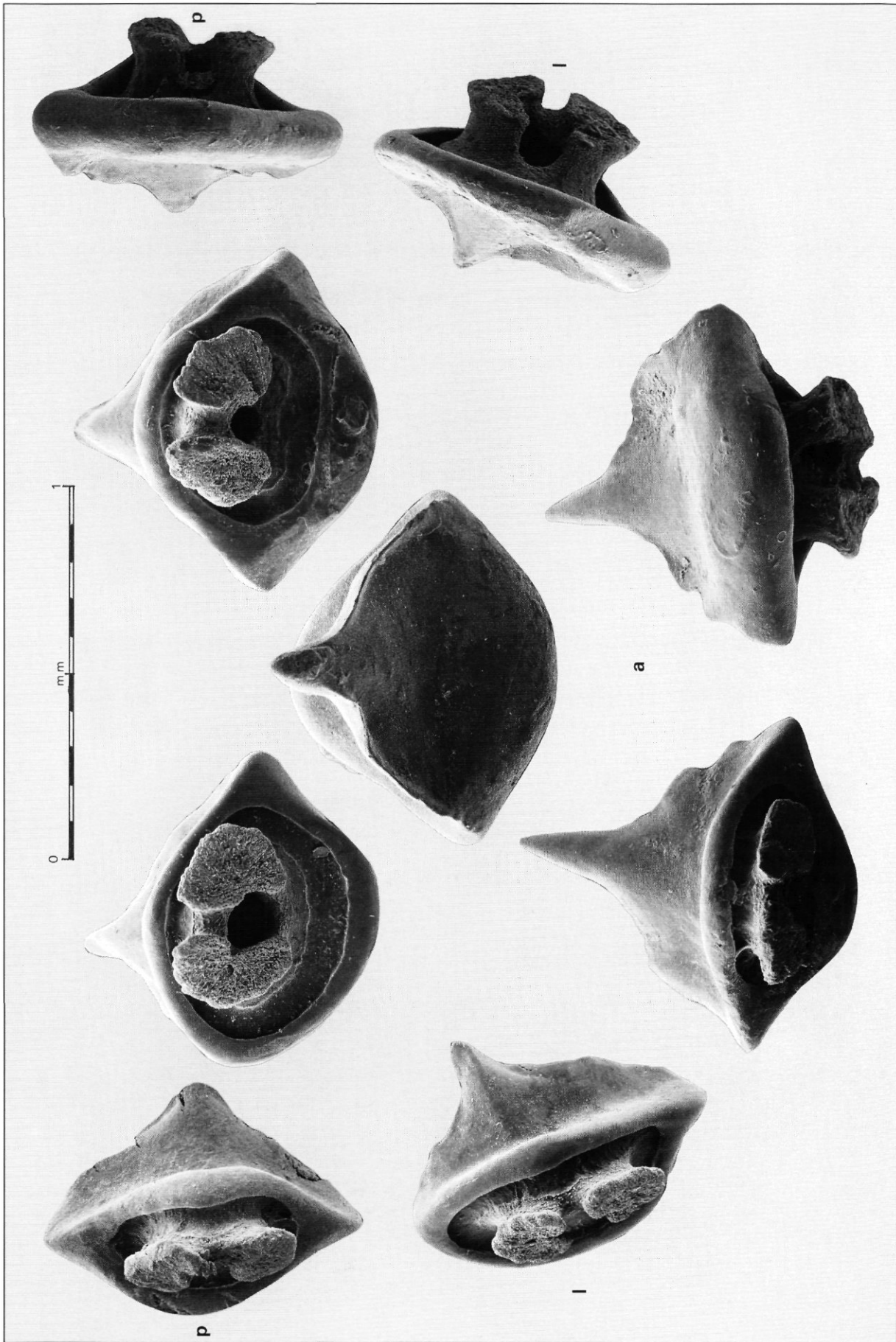


Plate 18. *Typhlonarke aysoni* (HAMILTON, 1902). Male 20 cm t.l., off South Island, New Zealand. Lower teeth.

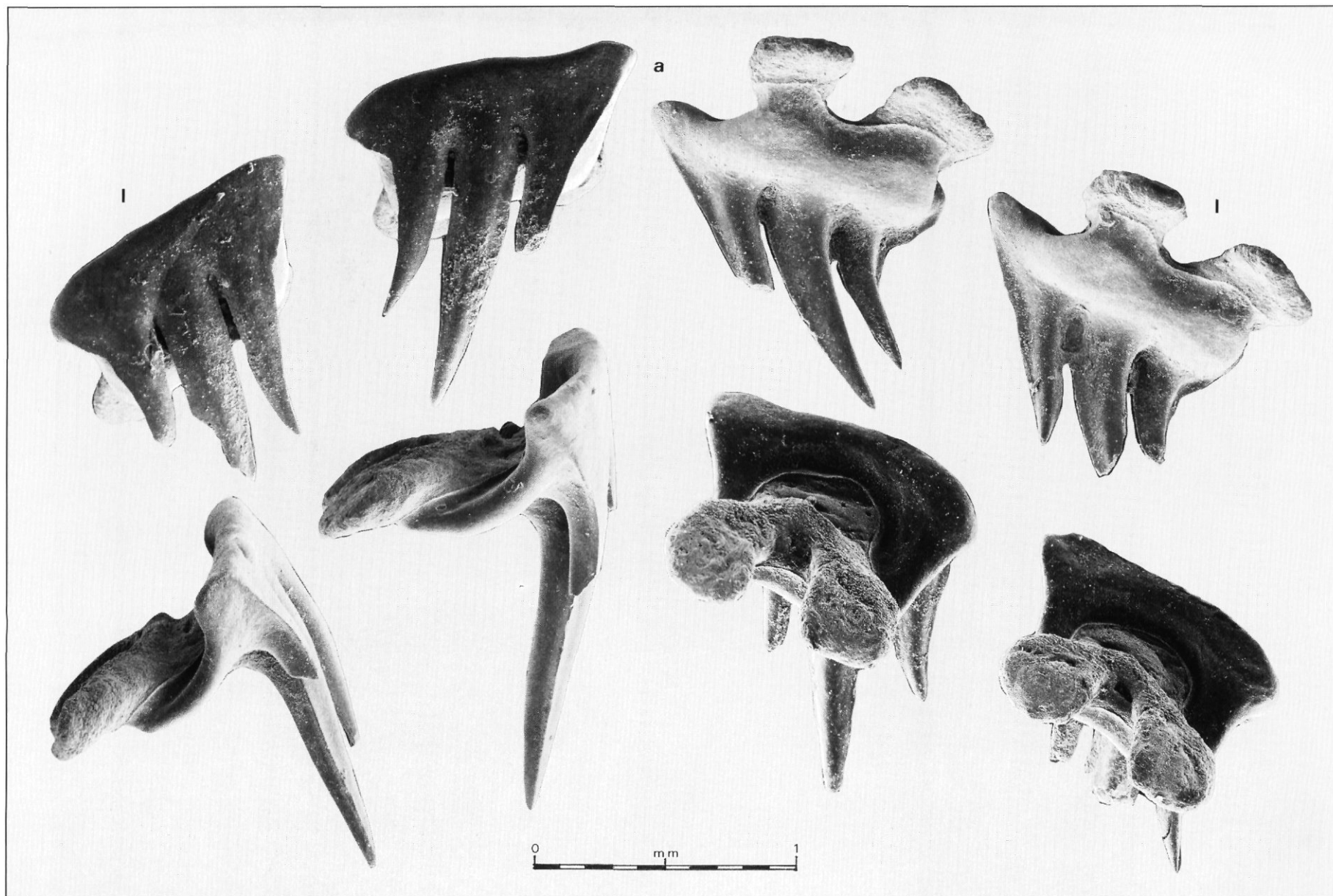


Plate 19. *Hypnos monoptygius* (SHAW & NODDER, 1794). Female 26 cm t.l., Port Jackson, Australia. Upper teeth.

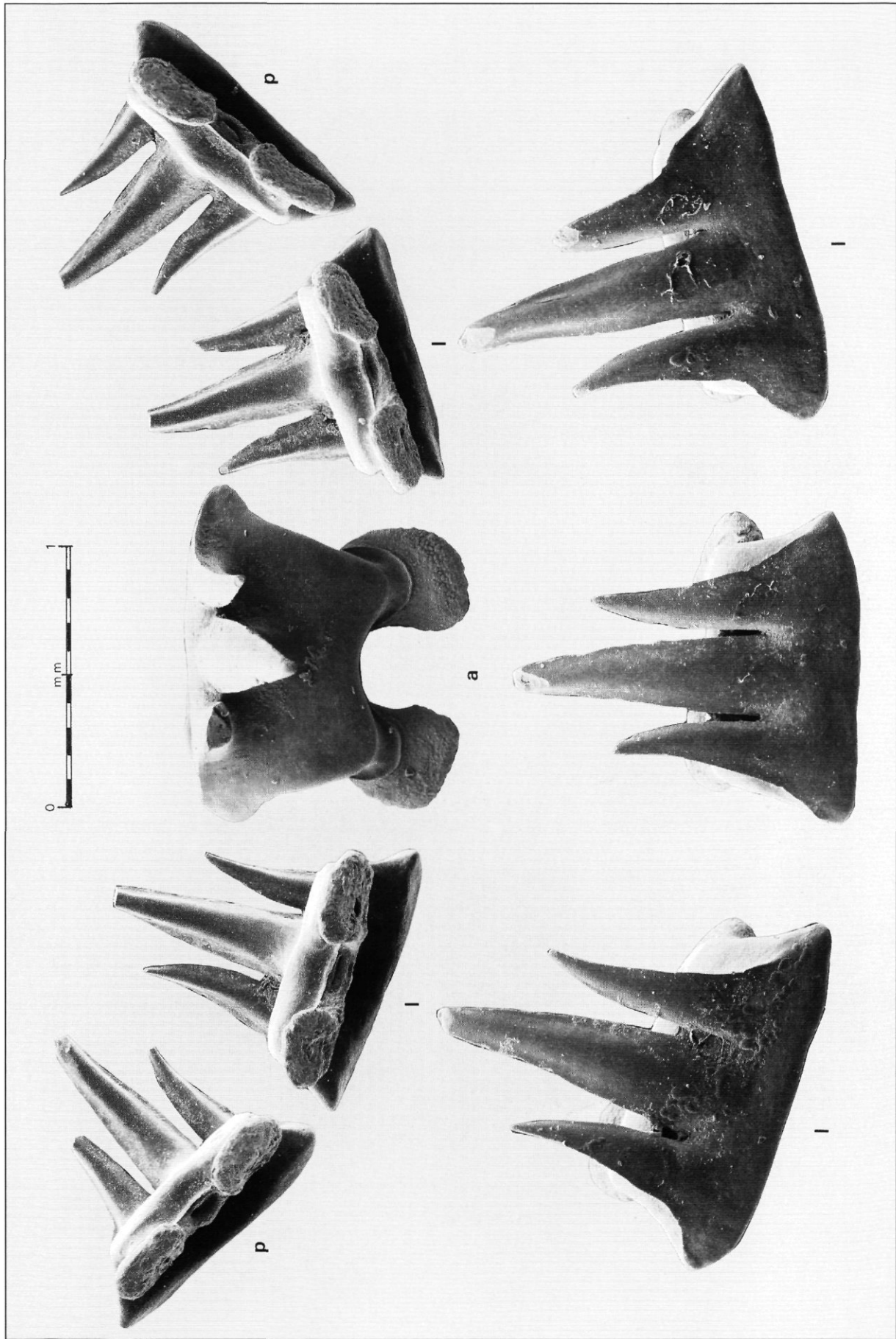


Plate 20. *Hymnos monopterygius* (SHAW & NODDER, 1794), Female 26 cm t.l., Port Jackson, Australia. Lower teeth.

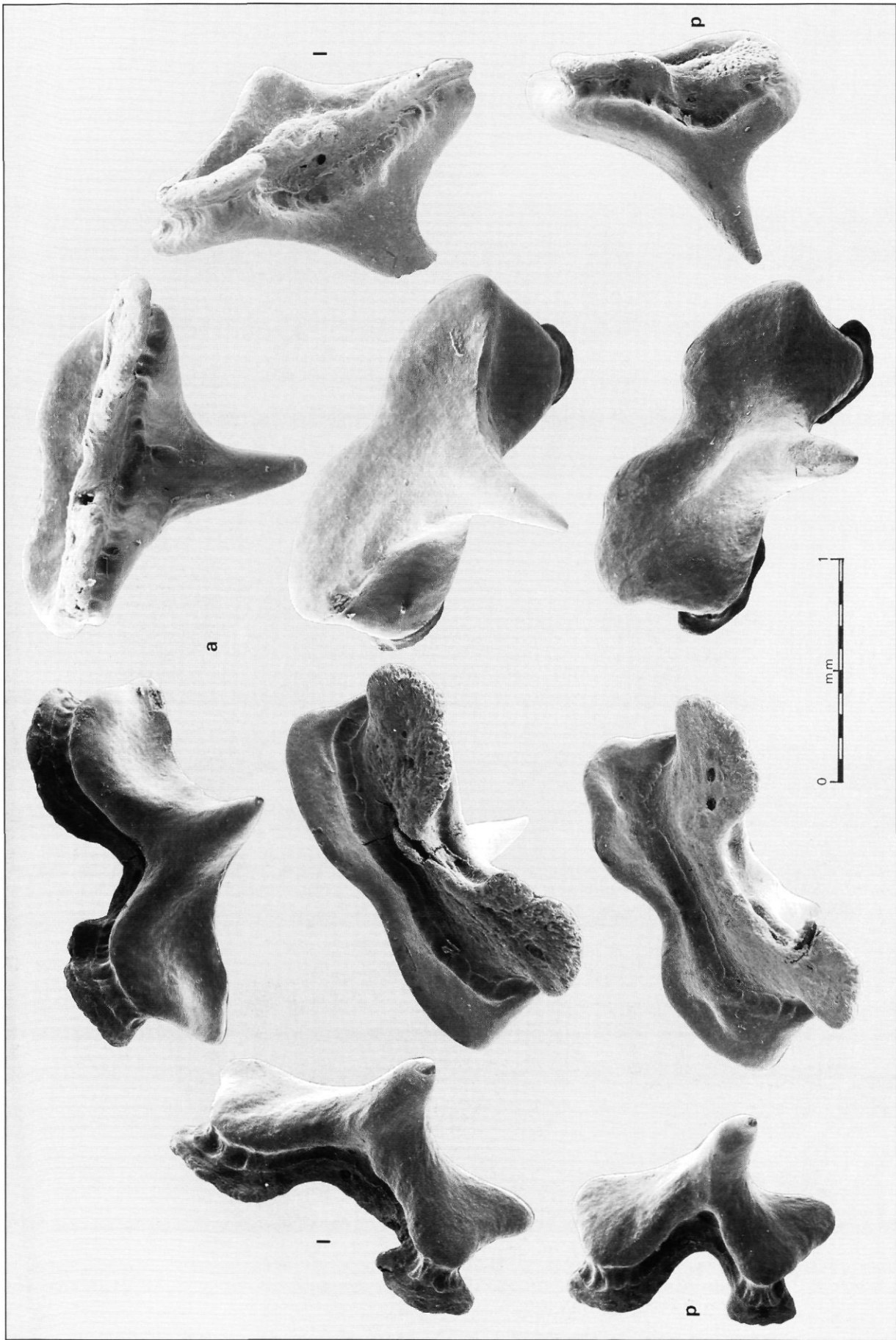


Plate 21. *Torpedo (Tetronarke) nobilitiana* BONAPARTE, 1835. Female 89 cm t.l., South England. Upper teeth.



Plate 22. *Torpedo (Tetronarke) nobilitiana* BONAPARTE, 1835. Female 89 cm t.l., South England. Lower teeth.



Plate 23. *Torpedo (Torpedo) torpedo* (LINNAEUS, 1758). Male 28 cm t.l., off Dakar, Senegal. Upper teeth.

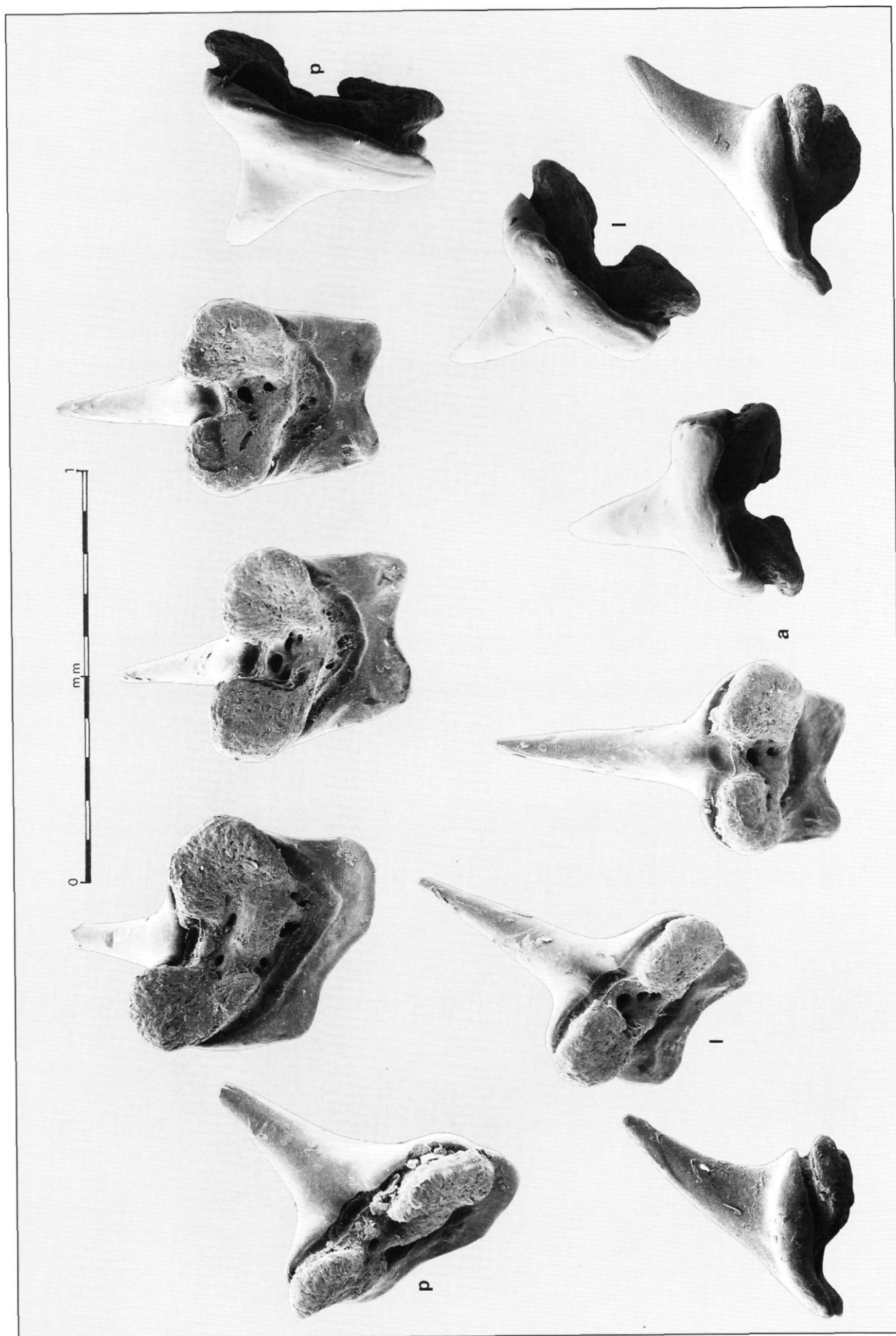


Plate 24. *Torpedo (Torpedo) torpedo* (LINNAEUS, 1758). Male 28 cm t.l., off Dakar, Senegal. Lower teeth.

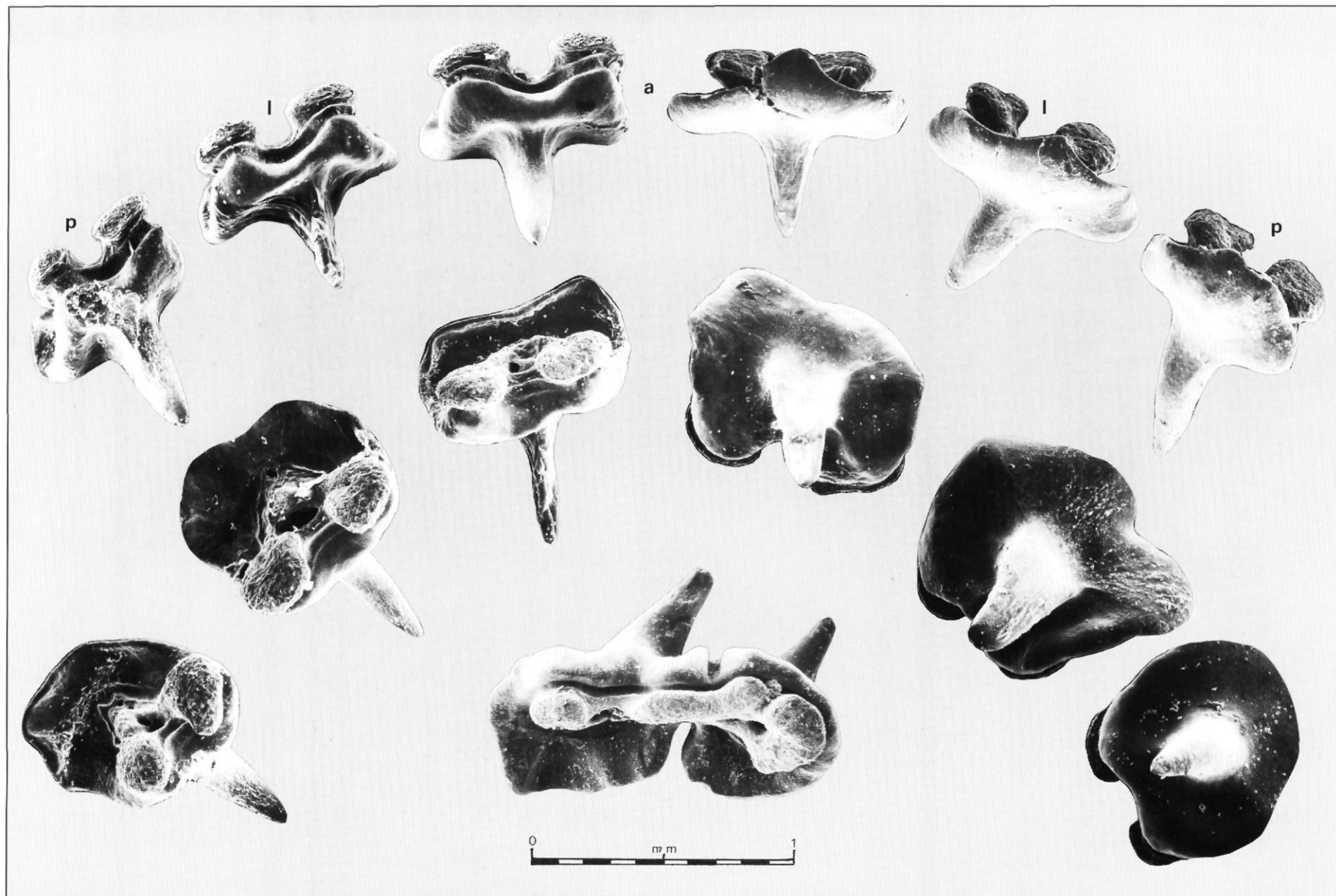


Plate 25. *Torpedo (Torpedo) torpedo* (LINNAEUS, 1758). Male 41 cm t.l., off Dakar, Senegal. Upper teeth. Central lower part of the plate, radicular view of an uncommon example of the fusion of two dental germinae of commissural teeth.

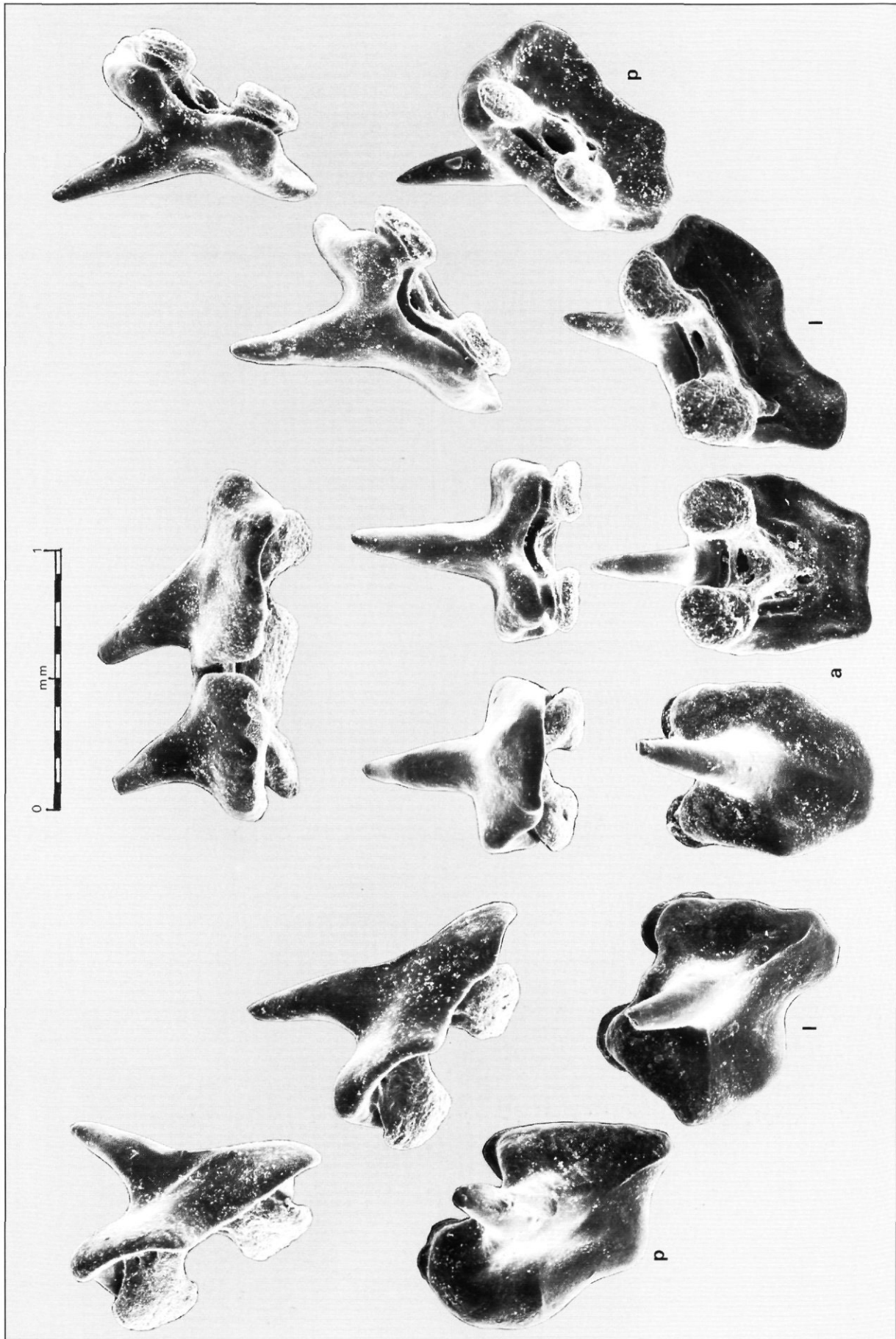


Plate 26. *Torpedo (Torpedo) torpeda* (LINNAEUS, 1758). Male 41 cm t.l., off Dakar, Senegal. Lower teeth. Central upper part of the plate, outer view of an uncommon example of the fusion of two dental germinae of commissural teeth.

