

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

Editor: M. STEHMANN

Part B: Batomorphii No. 1b: Order Rajiformes - Suborder Rajoidei - Family: Rajidae - Genera and Subgenera: *Bathyraja* (with a deep-water, shallow-water and transitional morphotype), *Psammobatis*, *Raja* (*Amblyraja*), *Raja* (*Dipturus*), *Raja* (*Leucoraja*), *Raja* (*Raja*), *Raja* (*Rajella*) (with two morphotypes), *Raja* (*Rioraja*), *Raja* (*Rostroraja*), *Raja lintea*, and *Sympterygia*

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

Abstract

Part B, No. 1a of this series, comprising of the Batomorphii the first section on the Rajoidei, is continued with further rajoid taxa. The tooth morphology of representatives of eleven more genera and subgenera *Bathyraja albomaculata*, *Bathyraja spinicauda*, *Psammobatis rudis*, *Raja* (*Amblyraja*) *radiata*, *Raja* (*Dipturus*) *batis*, *Raja* (*Leucoraja*) *naevus*, *Raja* (*Raja*) *clavata*, *Raja* (*Rajella*) *bathyphila*, *Raja* (*Rajella*) *fyllae*, *Raja* (*Rioraja*) *agassizi*, *Raja* (*Rostroraja*) *alba*, *Raja lintea* and *Sympterygia bonapartei* is described and illustrated by SEM-photographs. Differential diagnoses, systematic interpretations, as well as an odontological key will be given in a forthcoming issue dealing with the last rajoid taxa.

Key-words: Elasmobranchii - Batomorphii - Rajoidei - Odontology.

Résumé

Ce fascicule constitue le deuxième volet de l'étude odontologique des Rajoidei. La morphologie dentaire des représentants de onze autres genres et sous-genres, - *Bathyraja albomaculata*, *Bathyraja spinicauda*, *Psammobatis rudis*, *Raja* (*Amblyraja*) *radiata*, *Raja* (*Dipturus*) *batis*, *Raja* (*Leucoraja*) *naevus*, *Raja* (*Raja*) *clavata*, *Raja* (*Rajella*) *bathyphila*, *Raja* (*Rajella*) *fyllae*, *Raja* (*Rioraja*) *agassizi*, *Raja* (*Rostroraja*) *alba*, *Raja lintea* et *Sympterygia bonapartei* -, est décrite et illustrée (clichés MEB). Diagnose différentielle, interprétations systématiques et clef de détermination odontologique seront présentées dans le fascicule qui clôturera l'étude des Rajoidei.

Mots-clés: Elasmobranchii - Batomorphii - Rajoidei - Odontologie.

Kurzfassung

Teil B, Nr. 1a dieser Serie, der für die Batomorphii mit den Rajoidei begann, wird fortgesetzt mit Beschreibungen und Abbildungen durch REM-Photos der Zahnmorphologie elf weiterer Rajoidentaxa *Bathyraja albomaculata*, *Bathyraja spinicauda*, *Psammobatis rudis*, *Raja* (*Amblyraja*) *radiata*, *Raja* (*Dipturus*) *batis*, *Raja* (*Leucoraja*) *naevus*, *Raja* (*Raja*) *clavata*, *Raja* (*Rajella*) *bathyphila*, *Raja* (*Rajella*) *fyllae*, *Raja* (*Rioraja*) *agassizi*, *Raja* (*Rostroraja*) *alba*, *Raja lintea* und *Sympterygia bonapartei*. Differentialdiagnosen, systematische Bewertungen sowie ein odontologischer Bestimmungsschlüssel werden zum Abschluss der Rajoidei in einem späteren Beitrag folgen.

Schlüsselwörter: Elasmobranchii - Batomorphii - Rajoidei - Odontologie.

Part B:

Batomorphii - Order: Rajiformes - Suborder: Rajoidei

Introduction

This issue continues the previous issue of part B: 1a of this series, and presents odontological descriptions of eleven more genera and subgenera, plus different morphotypes of two of them, of the suborder Rajoidei. Three morphotypes were distinguished among the taxa of the genus *Bathyraja* by STEHMANN (1986) and are represented for this series by *B. albomaculata* for the shallow water morphotype, *B. richardsoni* for the deep water morphotype and by *B. spinicauda* for the transitional morphotype. Only *B. albomaculata* and *B. spinicauda* will be described and illustrated here, whereas *B. richardsoni* will be dealt with in a following issue. An intrageneric distinction between two morphotypes was

also recognized within the subgenus *Raja* (*Rajella*) (STEHMANN, unpublished data), which are here represented by *R. (Rajella) fyllae* and *R. (Rajella) bathyphila*, respectively.

Raja (Rioraja) agassizi (MÜLLER & HENLE, 1841) has been reported to be a composite species (MIRANDA ROBEIRO, 1903). As this was partly confirmed (STEHMANN, unpubl. results), only specimens corresponding with the original description of MÜLLER & HENLE (1841) were chosen for description and illustration. *Raja lintea* had not been assigned to a subgenus of *Raja* by STEHMANN (1970) because adult males were not available at that time. Subsequently, McEACHRAN (1990) placed *R. lintea* in *R. (Dipturus)* without giving any evidence or explanation. Its tooth morphology is presented here to provide additional arguments for its final classification. Furthermore, the tooth morphology of *Psammobatis rudis*, *Raja (Amblyraja) radiata*, *Raja (Dipturus) batis*, *Raja (Leucoraja) naevus*, *Raja (Raja) clavata*, *Raja (Rostroraja) alba* and *Sympterygia bonapartei* will be described and illustrated in this issue.

As mentioned in the previous issue 1a, results and comments on comparative rajoid tooth morphology will be given with in a following issue. The second group of genera and subgenera, investigated for their tooth morphology is listed below under **Material**.

Material

The following 324 specimens of 26 species were examined for this issue:

Bathyraja albomaculata

- ISH 1175-1966 ♂ 658 mm TL
 ISH 1334-1966 ♀ 650 mm TL
 ISH 1218-1966 ♀ 350 mm TL

Bathyraja spinicauda

- ISH 279-1959 ♂ 1385 mm TL
 ISH 123-1959 ♀ 1630 mm TL
 ISH 247-1985 ♀ 360 mm TL
 ISH 250-1985 ♂ 570 mm TL
 IRSNB uncat. ♀ 270 mm TL

Psammobatis rudis

- ISH 3570-1979 ♀ 660 mm TL
 ISH 3583-1979 ♀ 308 mm TL
 ISH 3583-1979 ♂ 465 mm TL

Psammobatis scobina

- Coll. Herman ♂ 330 mm disc (teeth only)

Raja (Amblyraja) badia

- CSIRO H-553-04 ♂ 1050 mm TL (teeth only)
 BCPM 979-11101 ♂ 944 mm TL (teeth only)
 HUMZ 78264 ♂ 883 mm TL (teeth only)
 HUMZ 79647 ♂ 716 mm TL (teeth only)
 SIO 87-77 ♀ 592 mm TL (teeth only)
 OSU 5035 ♀ 955 mm TL (teeth only)
 NMNZ P 23735 ♀ 905 mm TL (teeth only)
 NMNZ P 14857 ♀ 596 mm TL (teeth only)

Raja (Amblyraja) radiata

- ISH 3582-1979 ♀ 685 mm TL
 IRSNB uncat. ♀ 160 mm TL
 ISH 3582-1979 ♂ 270 mm TL

Coll. Hovestadt

♂ jaws only of 8 specimens with disc width ranging from 295 to 584 mm.

♀ jaws only of 10 specimens with disc width ranging from 310 to 543 mm.

Coll. Herman

♂ jaws only of 3 specimens from 590 to 650 mm TL
 ♀ jaws only of 2 specimens of 400 and 510 mm TL

Raja (Dipturus) batis

- ISH 169-1983 ♀ 589 mm TL
 ISH 179-1983 ♂ 447 mm TL

Coll. Hovestadt ♀ 1500 mm disc width (jaws only)

Coll. Hovestadt ♂ 1200 mm disc width (jaws only)

Coll. Hovestadt (additional)

♂ jaws only of 4 specimens with disc width ranging from 450 and 1050 mm.

♀ jaws only of 6 specimens with disc width ranging from 800 and 1500 mm.

Coll. Herman

♂ jaws only of 5 specimens from 850 to 2110 mm TL
 ♀ jaws only of 9 specimens from 860 to 2030 mm TL

Raja (Dipturus) doutrei

- MNHN cat.no. unknown ♂ 775 mm TL
 (single tooth only)

Raja (Dipturus) nidarosiensis

- Coll. Hovestadt ♂ 1500 mm disc width (jaws only)
 ♂ 1500 mm disc width (jaws only)
 ♀ 620 mm disc width (jaws only)
 ♀ 1730 mm disc width (jaws only)

Coll. Herman

♂ jaws only of 9 specimens from 1020 to 1910 mm TL
 ♀ jaws only of 9 specimens from 1260 to 1820 mm TL

Raja (Leucoraja) circularis

Coll. Hovestadt

♂ jaws of 5 specimens with disc width ranging from 350 to 400 mm.

♀ jaws of 5 specimens with disc width ranging from 500 to 700 mm.

Coll. Herman

♂ jaws only of 10 specimens from 740 to 910 mm TL
 ♀ jaws only of 7 specimens from 700 to 1050 mm TL

Raja (Leucoraja) fullonica

Coll. Hovestadt

♂ jaws of 2 specimens with disc width of 550 mm
 ♀ jaws of 10 specimens with disc width ranging from 450 and 600 mm.

Coll. Herman

♂ jaws only of 12 specimens from 705 to 1010 mm TL
 ♀ jaws only of 3 specimens from 760 to 980 mm TL

Raja (Leucoraja) naevus

- ISH 92-1969 ♂ 500 mm TL
 ISH 15-1962 ♀ 270 mm TL

ISH 94-1964 ♂ 310 mm TL

Coll. Hovestadt

♂ jaws only of 2 specimens with disc width of 330 and

400 mm.

♀ jaws only of 2 specimens with disc width of 330 and 420 mm.

Coll. Herman

♂ jaws only of 8 specimens from 370 to 570 mm TL

♀ jaws only of 4 specimens from 330 to 600 mm TL

Raja (Raja) asterias

Coll. Hovestadt

♂ jaws only of 2 specimens, 320 and 690 mm TL

♀ jaws only of 2 specimens, 610 and 660 mm TL

Raja (Raja) brachyura

Coll. Hovestadt

♂ jaws only of 4 specimens with disc width ranging from 300 to 620 mm.

♀ jaws only of 3 specimens with disc width ranging from 350 to 420 mm.

Coll. Herman

♂ jaws only of 5 specimens from 480 to 870 mm TL

♀ jaws only of 1 specimen of 480 mm TL

Raja (Raja) clavata

ISH 2027-1966 ♂ 774 mm TL (jaws only)

ISH 130-1958 ♀ 880 mm TL (jaws only)

ISH uncat. ♀ 237 mm TL (jaws only)

Coll. Hovestadt

♂ jaws only of 5 specimens with disc width ranging from 300 to 860 mm.

♀ jaws only of 12 specimens with disc width ranging from 300 to 900 mm.

Coll. Herman

♂ jaws only of 8 specimens from 410 to 905 mm TL

♀ jaws only of 9 specimens from 450 to 1020 mm TL

Raja (Raja) microocellata

Coll. Hovestadt

♂ jaws only of 2 specimens with disc width of 360 and 400 mm.

♀ jaws only of 2 specimens with disc width of 400 and 560 mm.

♂ jaws only of 3 specimens from 480 to 505 mm TL

♀ jaws only of 2 specimens of 500 and 540 mm TL

Coll. Herman

♂ jaws only of 3 specimens from 480 to 510 mm TL

♀ jaws only of 2 specimens of 500 and 540 mm TL

Raja (Raja) miraletus

Coll. Hovestadt

♂ jaws only of 7 specimens with disc width ranging from 220 to 760 mm.

♀ jaws only of 7 specimens with disc width ranging from 220 to 535 mm.

Coll. Herman

♂ jaws only of 10 specimens from 390 to 645 mm TL

♀ jaws only of 9 specimens from 390 to 645 mm TL

Raja (Raja) montagui

Coll. Hovestadt

♂ jaws only of 4 specimens with disc width ranging from 420 to 460 mm.

♀ jaws only of 5 specimens with disc width ranging from 270 to 330 mm.

Coll. Herman

♂ jaws only of 1 specimen of 330 mm TL

♀ jaws only of 5 specimens from 250 to 700 mm TL

Raja (Raja) undulata

Coll. Hovestadt

♂ jaws only of 6 specimens with disc width ranging from 350 to 560 mm.

♀ jaws only of 2 specimens with disc width 350 and 600 mm.

Coll. Herman

♂ jaws only of 2 specimens of 505 and 610 mm TL

♀ jaws only of 2 specimens of 500 and 605 mm TL

Raja (Rajella) bathyphila

ISH 177-1973h ♂ 325 mm TL

ISH 177-1973e ♀ 305 mm TL

ISH 952-1973a ♂ 882 mm TL

ISH 974-1973 ♀ 767 mm TL

Coll. Herman

♂ jaws only of 2 specimens of 610 and 620 mm TL

♀ jaws only of 3 specimens with disc width ranging from 220 to 270 mm.

Raja (Rajella) fyllae

ISH 646-1986 ♂ 424 mm TL

ISH 646-1986 ♀ 411 mm TL

Coll. Hovestadt ♂ 280 mm disc width (jaws only)

Coll. Hovestadt ♀ 270 mm disc width (jaws only)

Coll. Hovestadt (additional)

♂ jaws only of 4 specimens with disc width ranging from 270 to 280 mm.

Coll. Herman

♂ jaws only of 5 specimens from 365 to 470 mm TL

♀ jaws only of 5 specimens from 290 to 455 mm TL

Raja (Rioraja) agassizi

ISH 1102-1966a ♀ 420 mm TL

ISH 1102-1966b ♂ 476 mm TL

ISH 1102-1966c ♂ 273 mm TL

Raja (Rioraja) agassizi var. *meta* sensu M. ROBEIRO (1903)

ISH 1752-1968 ♀ 356 mm TL

ISH 1963-1968 ♂ 545 mm TL

ISH 1021-1966 ♂ 275 mm TL

Raja (Rostroraja) alba

AFRICANA ♀ 2147 mm TL

A7021 060 11-01B

ISH 36-1982 ♀ 310 mm TL

AFRICANA ♂ 1870 mm TL

A4302 046 016 2629

ISH 13-1984 ♂ 417 mm TL

Coll. Herman

♀ jaws only of 2 specimens of 470 and 730 mm TL

Raja lintea

ISH uncat. ♀ 1100 mm TL

ISH 265-1959 ♂ 950 mm TL

ISH uncat. ♂ 300 mm TL

Coll. Herman

♂ jaws only of 1 specimen of 700 mm TL

Sympterygia bonapartei

ISH 327-1978 ♂ 433 mm TL

ISH 1468-1966a ♂ 554 mm TL

ISH 1468-1966b ♀ 673 mm TL

IRSNB 17.733 ♂ 440 mm TL

Description of the odontological characters

Genus: *Bathyraja* ISHIYAMA, 1958

About 45 species of the genus *Bathyraja* are known in the world oceans, a few of which are still undescribed. STEHMANN (1986) distinguished a shallow-water, deep-water and transitional morphotype and grouped species accordingly but without further taxonomic subdivision of *Bathyraja*.

The deep-water morphotype comprises *B. abyssicola*, *B. isotrachys*, *B. longicauda*, *B. meridionalis*, *B. pallida*, *B. peruana*, *B. richardsoni*, *B. cf. richardsoni* (sensu McEACHRAN & MIYAKE, 1984) *B. schroederi*, *B. spinosissima*, *B. trachura*, *B. sp. n.* (STEHMANN in press) and an undescribed species from off West Australia. The shallow-water morphotype comprises *B. albomaculata*, *B. aleutica*, *B. brachyrops*, *B. interrupta*, *B. maccaini*, *B. macloviana*, *B. magellanica*, *B. murrayi*, *B. parmifera*, *B. simoterus*, *B. smirnovi* and *B. trachouros*. The transitional morphotype comprises *B. aguja*, *B. caerulonicans*, *B. diplotaenia*, *B. eatonii*, *B. griseocauda*, *B. irrasa*, *B. lindbergi*, *B. maculata*, *B. matsubarai*, *B. minispinosa*, *B. multispinis*, *B. notoroensis*, *B. papilionifera*, *B. shuntovi* (reallocated to this morphotype, STEHMANN in press), *B. scaphiops*, *B. smithii*, *B. spinicauda*, *B. violacea* and an undescribed species from the Antarctic waters. *B. richardsoni* was selected to represent the deep-water morphotype but was not yet available for this issue and will follow later. The shallow water morphotype will be represented by *B. albomaculata* and the transitional morphotype by *B. spinicauda*.

Bathyraja albomaculata (NORMAN, 1937)
(Plates: 1 to 6; textfigure 1)

Raja albomaculata NORMAN, 1937. Discovery rep. 16: 22, fig. 5, London.

HETERODONTY

The dentition is gradient monognathic heterodont. Sexual heterodonty is shown in adults only by the presence of a well developed, more or less triangularly shaped, pointed cusp in teeth of males, whereas females have a rather low cusp with a semi-central cone.

Only teeth of males present ontogenetic heterodonty by bearing a small cone without cutting edges in juveniles, which grows to a distinct cusp in maturing specimens.

VASCULARIZATION

The teeth show an adapted, holaulacorhizid root type with a broad, elongated pulp cavity in the root area, from which the vascular tubes of the circumpulpar dentine radiate into crown and root. Osteodentine was not observed, and inner lateral foramina are absent. (See textfigure 1)



Textfigure 1.
Bathyraja albomaculata tooth histological cross-section.

FEMALES

The crown base is semi-circular in occlusal view. The principal cusp is slightly oblique distally in lateral teeth but upright in posterior teeth. Uvula, apron or ornamentation are absent. The inner face is convex, the outer one flat to slightly convex.

The root stem is rather high and oval to almost circular in cross-section. The root widens in all directions, forming a large base with two well developed root lobes. Both have flat bases, and are separated by a well developed, broad and deep median groove with a large central foramen. Root coating is absent.

MALES

The crown base of males is more or less oval in occlusal view; outer edge arched and inner edge bluntly angled medially. The anterior teeth bear a well developed, more or less broad, triangularly shaped, pointed cusp, which is directed inward, with cutting edges slightly arching concavely.

Lateral teeth have a lower cusp, which is stronger oblique distally with cutting edges curving slightly distally. Commissural teeth possess a lower cusp, which is not directed distally but upright. Apron or ornamentation are absent but a poorly developed uvula is observed. The inner surface is slightly concave, the outer one flat to slightly convex.

The root stem is high and oval shaped in cross-section. The root widens in all directions but stronger at the distal part, forming a large base. Two well developed root lobes are separated by a deep and broad median groove with a large central foramen. Root coating is absent.

Bathyraja spinicauda (JENSEN, 1914)
(Plates: 7 to 11; textfigure 2)

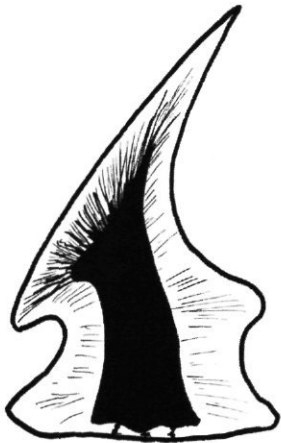
Raja spinicauda JENSEN, 1914. Mindeskr. for Japetus Steenstrups fods. 2(30): 30-32, figs. 10-11, 1 pl., Kobenhavn.

HETERODONTY

The dentition is gradient monognathic heterodont. Sexual heterodontology is shown in adults only by the presence of a well developed, rather broad, pointed cusp in teeth of males with a flat outer surface, whereas females have a well developed but narrower, slightly lower principal cusp with a convex outer face. Ontogenetic heterodontology is shown by a small cone without cutting edges in juveniles, which grows to a distinct cusp in maturing specimens.

VASCULARIZATION

The teeth show an adapted, holaulacorhizid root type with a large pulp cavity, from which the vascular tubes of the circumpulpar dentine radiate into crown and root. Osteodentine was not observed, and inner lateral foramina are absent. (See textfigure 2)



Textfigure 2.
Bathyraja spinicauda tooth histological cross-section.

FEMALES

The crown base is more or less oval in occlusal view; outer edge arched and inner edge bluntly angled medially. The principal cusp of anterior, lateral and posterior teeth are neither inclined nor oblique distally but are always upright. An apron or ornamentation absent but a well developed uvula is present. The inner and outer faces are both convex.

The broad root stem is rather high and oval to almost circular in cross-section. The root widens in all directions, forming a large base with two well developed root lobes. Both have more or less flat bases, and are separated by a well developed, broad and deep median groove with several irregular, large central foramina. Root coating is absent.

MALES

The crown base of males is more or less oval in occlusal view outer edge arched and inner edge bluntly angled medially. The anterior teeth bear a well developed, elongated cusp, which is directed inward, with cutting edges slightly arching concavely.

Lateral teeth have a slightly lower cusp, which is slightly oblique distally with cutting edges curving slightly distally. Commissural teeth possess a lower cusp, which is not directed distally but upright. An apron or ornamentation is absent but a well developed uvula is present. The inner surface is flat, the outer one flat to slightly convex.

The root stem is high and oval shaped in cross-section. The root widens in all directions but stronger at the distal part, forming a large base. Two well developed root lobes are separated by a deep and broad median groove with several small central foramina. Root coating is absent.

Genus: *Psammobatis* GÜNTHER, 1870

This genus comprises eight species: *P. bergi*, *P. glansdissimilis*, *P. lentiginosa*, *P. normani*, *P. parvacauda*, *P. rudis* (type species), *P. rutrum* and *P. scobina*.

Psammobatis rudis GÜNTHER, 1870
(Plates: 12 to 14; textfigure 3)

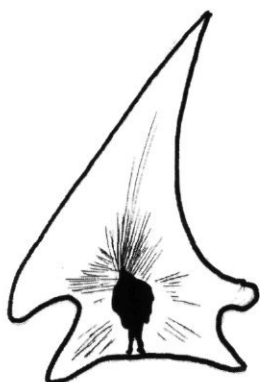
Psammobatis rudis GÜNTHER, 1870. Catalogue of Fishes in the British Museum VIII: 470.

HETERODONTY

The dentition is gradient monognathic heterodont. Sexual heterodontology is present in adults only, in that male teeth bear a true cusp, which is higher and more elongated on anterior teeth, becoming lower on teeth toward the commissure. Females only possess a transverse keel, which is slightly higher on anterior teeth. In relation to anterior and lateral teeth the posteriors of females as well as juveniles are fairly broader. Ontogenetic heterodontology is documented only in juvenile males by a low tooth cusp, which grows to large size in maturing specimens.

VASCULARIZATION

The teeth show an adapted, holaulacorhizid root type in that a well developed but small pulp cavity is present in the root area, from which the vascular tubes of the circumpulpar dentine radiate into crown and root. Osteodentine was not observed, and inner lateral foramina are absent. (See textfigure 3)



Textfigure 3.
Psammobatis rudis tooth histological cross-section.

FEMALES

The crown base is semi-oval in occlusal view. Inner and outer faces are separated by a transverse keel, which is convexly arched in inner direction as well as mesio-distally. Apron, uvula and ornamentation are absent. The inner face shows a slightly concave surface, the outer one is slightly convex.

The root stem is relatively low and oval in cross-section. The root widens in all directions forming a large base. A deep, well developed median groove separates the root lobes and includes a large central foramen. Root coating is absent

MALES

The crown base is semi-oval in occlusal view, with a slightly arched outer and a strongly arched inner edge. The arching of the inner edge is directed distally in lateral and posterior teeth. The anterior teeth bear a well developed, broad based, elongated cusp, which is more or less strongly directed inward but gradually diminishing in height in lateral and posterior teeth. Inner surface convex, outer one flat. Apron, uvula and ornamentation are absent.

The root stem is relatively low and oval in cross-section. The root widens in all directions, forming a large base. A deep, well developed median groove separates the root lobes and includes a large central foramen. Root coating is absent

Genus: *Raja* LINNAEUS, 1758

This genus comprises the 9 subgenera *R. (Amblyraja)*, *R. (Atlantoraja)*, *R. (Dipturus)*, *R. (Leucoraja)*, *R. (Okamejei)*, *R. (Raja)*, *R. (Rajella)*, *R. (Rioraja)* and *R. (Rostroraja)*. Like several other species is *Raja lintea* not yet definitely assigned to a subgenus and the description and illustration here of its tooth morphology may assist in its subgeneric assignment. The tooth morphology

of the subgenera *R. (Amblyraja)*, *R. (Dipturus)*, *R. (Leucoraja)*, *R. (Raja)*, *R. (Rajella)* and *Raja lintea* will be dealt with in this issue

Subgenus: *Raja (Amblyraja)* MALM, 1877

The subgenus *Raja (Amblyraja)* comprises the following 10 specific taxa: *badia*, *dolleojuradoi*, *frerichsi*, *georgiana*, *hyperborea*, *jenseni*, *radiata* (type species), *reversa*, *robertsi* and *taaf*.

Raja (Amblyraja) radiata DONOVAN, 1808
(Plates: 15 to 17; textfigure 4)

Raja radiata DONOVAN, 1808. The Natural History of British Fishes, 5: 2 pp., pl. 114, London.

HETERODONTY

The dentition is gradient monognathic heterodont. Indistinct sexual heterodonty present in adults only in that females show a lower principal cusp and a broader crown base. Ontogenetic heterodonty is documented by much lower cusps on teeth of juveniles diminishing to a cone only on posterior teeth.

VASCULARIZATION

The teeth show an adapted holaulacorhizid root type with a broad, elongated pulp cavity in the root area, from which the vascular tubes of the circumpulpar dentine radiate into crown and root. Osteodentine was not observed, and inner lateral foramina are absent. (See textfigure 4)



Textfigure 4.
Raja (Amblyraja) radiata tooth histological cross-section.

FEMALES AND MALES

The crown base is semi-oval in occlusal view, with an arched outer and medially, bluntly angled inner edge. Mesial and distal areas of the crown are concavely arched

and join at the apex of a narrow, rather high principal cusp. Mesial and distal cutting edges are mostly absent or if present poorly developed. The principal cusp of lateral and posterior teeth are neither inclined nor oblique distally but upright. Apron, as well as inner and outer ornamentation are absent, but a well developed uvula is present. The inner surface is flat to slightly concave, and the outer one is slightly convex.

The root stem is rather high and oval-shaped in cross-section. The bilobated root strongly widens in all directions, forming a large base with a weakly undulated margin. A well developed, deep basal groove encloses a rather large central aperture. Root coating is present in the upper region near the crown-root junction.

Subgenus: *Raja (Dipturus)* RAFINESQUE 1810

The subgenus *Raja (Dipturus)* comprises the following 27 specific taxa: *batis* (type species), *bullisi*, *crosnieri*, *flaviostris*, *doutrei*, *garricki*, *gigas*, *gudgeri*, *innominata*, *johannisdavisi*, *kwangtungensis*, *laevis*, *lanceorostrata*, *leptocauda*, *macrocauda*, *nasuta*, *nidarosiensis*, *olseni*, *oregoni*, *oxyrhinchus*, *pullopunctata*, *springeri*, *stenorhynchus*, *teevani*, *tengu*, *trachyderma* and *whitleyi*.

Raja (Dipturus) batis LINNAEUS, 1758 (Plates: 18 to 22; textfigure 5)

Raja batis LINNAEUS, 1758. *Systema naturae* ed X: 231.

HETERODONTY

The dentition is gradient monognathic heterodont. Indistinct sexual heterodonty present in adults only, in that males show a somewhat higher principal cusp. Ontogenetic heterodonty is documented by a much lower principal cusp in juveniles.

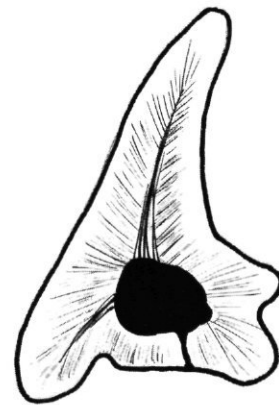
VASCULARIZATION

The teeth of this genus show an adapted holaulacorhizid root type in that a string of vascular vessels penetrate the crown area from a rather large but low pulp cavity. Both, pulp cavity and vascular string have tubes of the circum-pulpar dentine radiating into root and crown. Osteodentine was not observed, and inner lateral foramina are absent. (See textfigure 5)

MALES AND FEMALES

The crown base is more or less quadrangular in occlusal view, with both outer and inner edges bluntly angled medially. The well developed, massive crown is pointed inward, and the extended mesial and distal cutting edges

are concavely arched. The principal cusp of lateral and posterior teeth is neither inclined, nor oblique, but upright. The outer surface is slightly convex. The arched outer crown base overhangs the crown-root junction and is shaped like a very broad apron on anterior teeth. Besides some poorly developed costules, a true ornamentation is absent. The convex inner surface is also smooth. The root stem is relatively low and oval in cross-section. The root strongly widens in all directions, forming a large base, with smooth outer margins. A well developed, broad and deep basal groove encloses several small central foramina. The basal groove is narrower at posterior teeth, with only one or two central foramina remaining. Root coating is absent.



Textfigure 5.
Raja (Dipturus) batis tooth histological cross-section.

Subgenus: *Raja (Leucoraja)* MALM, 1877

The subgenus *Raja (Leucoraja)* comprises the following 10 specific taxa: *circularis*, *erinacea*, *fullonica* (type species), *garmani*, *leucosticta*, *melitensis*, *naevus*, *ocellata*, *wallacei*, and *yucatanensis*.

Raja (Leucoraja) naevus MÜLLER & HENLE, 1841 (Plates: 23 to 27; textfigure 6)

Raja naevus MÜLLER & HENLE, 1841 *Systematische Beschreibung der Plagiostomen*: 138.

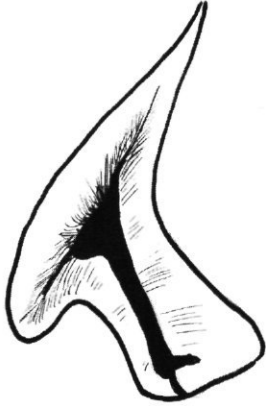
HETERODONTY

The dentition is gradient monognathic heterodont. Sexual heterodonty is absent. Ontogenetic heterodonty is documented by a much lower principal cusp in juveniles.

VASCULARIZATION

The teeth show an adapted holaulacorhizid root type with a narrow, elongated pulp cavity in the root area, that widens in the lower part of the root area. The vascular

tubes of the circumpulpar dentine radiate from the pulp cavity into crown and root. Osteodentine was not observed, and inner lateral foramina are absent. (See textfigure 6)



Textfigure 6.
Raja (*Leucoraja*) *naevus* tooth histological cross-section.

FEMALES AND MALES

The crown base shows inner and outer edges with a strong protuberance medially. The principal cusp is a nearly centrally situated elongated cone, which is strongly directed inward. The principal cusp of lateral and posterior teeth is not inclined or oblique distally, but upright. The mesial and distal cutting edges are poorly developed or often even absent. The mesial and distal area of the crown is strongly concavely arched at the base. The outer crown base shows a well developed, quadrangular shaped apron overhanging the crown-root junction. The apron has often a small central median depression, because the teeth in a row are at this point transversely interlocked with each other. The smooth outer surface is slightly convex. The smooth inner surface is strongly convex, with a well developed uvula.

The root stem is moderately high and more or less oval in cross-section. Vertically, the root widens to form an extremely large base. The central part of the inner face protuberates to support the extended uvula. A deep but narrow basal median groove encloses several tiny central foramina. Root coating is only present on the crown-root junction.

Subgenus: *Raja (Raja)* LINNAEUS, 1758

The subgenus *Raja (Raja)* comprises the following 14 specific taxa: *africana*, *asterias*, *brachyura*, *clavata* (type species), *herwigi*, *maderensis*, *microocellata*, *miraletus*, *montagui*, *polystigma*, *radula*, *rouxi*, *straeleni* and *undulata*.

Raja (Raja) clavata LINNAEUS, 1758
(Plates: 28 to 32; textfigure 7)

Raja clavata LINNAEUS, 1758. *Systema naturae* ed X: 232.

HETERODONTY

The dentition is gradient monognathic heterodont. Sexual heterodonty present in adults only, in that male teeth bear a -90--91-degree true cusp, which is higher and more elongated on anterior teeth, becoming lower on teeth toward the commissure. Females only possess a transverse keel, which is slightly higher on anterior teeth. Ontogenetic heterodonty is documented by a low keel, that is bluntly angled medially in juveniles, which grows to a massive large cusp in maturing males and to a high transverse keel in maturing females.

VASCULARIZATION

The teeth show an adapted holaulacorhizid root type in that a fine string of vascular vessels penetrates the crown section from a relatively small pulp cavity. Tubes of the circumpulpar dentine radiate from both, pulp cavity and vascular string into the root and crown. Osteodentine was not observed, and inner lateral foramina are absent. (See textfigure 7)



Textfigure 7.
Raja (*Raja*) *clavata* tooth histological cross-section.

FEMALES

The crown base of anterior and lateral teeth is almost quadrangular in occlusal view, whereas posteriors are semi-oval. Inner and outer faces are separated by a blunt transverse keel, which is convexly arched in inner direction as well as mesio-distally. Apron, uvula and ornamentation are absent. The surface of inner and outer faces are convex.

The root is small in relation to the crown. The root stem is relatively low and oval in cross-section. The root widens only slightly and a deep, well developed median groove separates the root lobes and includes a few foramina. Sometimes a single small foramen can be observed on the outer face of the root. Both root lobes have a convex base. Root coating is absent.

MALES

The crown base is semi-oval in occlusal view, with a slightly arched outer and a strongly arched inner edge. The anterior teeth bear a well developed, broad based, elongated cusp, which is more or less directed inward but gradually diminishing in height in lateral and posterior teeth. Inner surface is convex. The outer one is convex on anterior teeth but flattening from the antero-lateral to the posteriors. Apron, uvula and ornamentation are absent.

The root stem is relatively low and oval in cross-section. The root widens in all directions, forming a convex base. A deep, well developed median groove separates the root lobes and includes a large central foramen. (occasionally a second groove may be present). Root coating is absent

Subgenus: *Raja (Rajella)* STEHMANN, 1970

Two morphotypes can be distinguished within the subgenus *Raja (Rajella)*, based on size and appearance of species (STEHMANN, unpubl. results). Relatively small growing species with roundish disc and overproportionally long tail are represented by the following taxa: *annandalei*, *bigelowi*, *caudaspinosa*, *fyllae* (type species) and *nigerrima*. Medium-sized species (up to about 1 m tl) with rhombic disc and tail about as long as disc of the other morphotype are represented by: *barnardi/confundens*, *bathyphila*, *dissimilis*, *kukujevi*, *leopardus*, *purpuriventralis*, *radivula* and *sadowskii*. A few of the latter species, however, undergo remarkable ontogenetic change in their appearance, e.g. *sadowskii*, from young resembling the former morphotype to half grown and adult specimens of the latter morphotype's phenotype. The "rhombic" morphotype is here represented by *R. bathyphyla*, the "roundish" one by the type species *R. fyllae*.

Raja (Rajella) bathyphila HOLT & BYRNE, 1908
(Plates: 33 to 35; textfigure 8)

Raja bathyphila HOLT & BYRNE, 1908. Fish. Irel. Scient. Inv. (1906) 1908, V: 51-53.

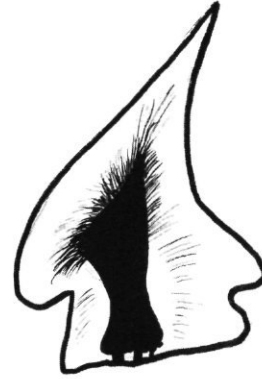
HETERODONTY

The dentition is gradient monognathic heterodont. A well developed sexual heterodonty is presented in adults only, in that females have a lower principal cusp and a broader crown base. Ontogenetic heterodonty is documented by much lower cones on teeth of juveniles.

VASCULARIZATION

The teeth show an adapted holaulacorhizid root type with a broad, elongated pulp cavity in the root area, from

which the vascular tubes of the circumpulpar dentine radiate into crown and root. Osteodentine was not observed, and inner lateral foramina are absent. The inner and outer foramina could not be made visible. (See text-figure 8)



Textfigure 8.
Raja (Rajella) bathyphila tooth histological cross-section.

FEMALES

The crown base is semi-circular in occlusal view, with an arched outer edge and an inner one with a medial protuberation. The crown bears a well developed, centrally situated cone, which is directed inward at anterior teeth, diminishing in height and directed slightly more distally on lateral and posterior teeth. Mesial and distal cutting edges are absent. Apron, inner and outer ornamentation are absent, but a well developed uvula is present. Both inner and outer surfaces are convex.

The root stem is relatively low and more or less oval in cross-section. The root widens in all directions to form a large base with a multilobed inner face. In the folds of the multilobation a foramen may be present. A deep basal groove is well developed and encloses several irregularly shaped central foramina. Only a small area with root coating is present on the upper part of the root stem.

MALES

The crown base is more or less oval in occlusal view, has a strongly arched outer edge and an inner one with a protuberation medially. The crown bears a centrally situated, narrow, very elongated cone directed inward at anterior teeth but diminishing in height and directed slightly more distally on lateral and posterior teeth. Mesial and distal cutting edges are absent. Apron, inner and outer ornamentation are absent, but a well developed uvula is present. Both inner and outer surfaces are convex.

The root stem is relatively high and more or less oval in cross-section. The root base widens in all directions to form a large base with slightly undulated margins. A deep basal groove is well developed and encloses one or two central foramina. Root coating is present on the upper part of the root stem.

Raja (Rajella) fyllae LÜTKEN, 1888
(Plates: 36 to 38; textfigure 9)

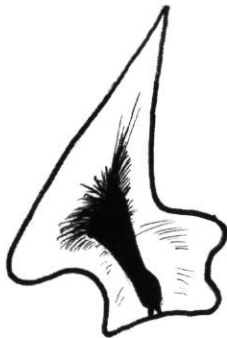
Raja fyllae LÜTKEN, 1888. Vidensk. Meddr. dansk naturh. Foren. 1887 (1888): 1-4, pl.1.

HETERODONTY

Although the dentition is gradient monognathic heterodont, there is a significant difference in the morphology of anterior and lateral teeth and latero-posterior and posterior teeth. The anterior and lateral teeth have an elongated principal cusp arising from a broad crown base, with mesial and distal cutting edges arched concavely. The outer surface is convex. The latero-posterior and posterior teeth have a lower principal cusp with mesial and distal cutting edges arched convexly way. The outer surface is flat or even concave. A transitional type of morphology is found in antero-lateral and lateral sections of the jaws, where teeth have a broader principal cusp than the anterior ones and a flat outer surface. Sexual heterodonty shown in adults only, in that female teeth have a low principal cusp with a low, semi-central cone and poorly developed mesial and distal cutting edges. Ontogenetic heterodonty is documented by female-like characters in all juveniles, but mesial and distal cutting edges absent in juvenile teeth.

VASCULARIZATION

The teeth show an adapted holaulacorhizid root type with a broad, elongated pulp cavity in the root area, from which the vascular tubes of the circumpulpar dentine radiate into crown and root. Osteodentine was not observed, and inner lateral foramina are absent. The inner and outer foramina could not made visible. (See textfigure 9)



Textfigure 9.
Raja (Rajella) fyllae tooth histological cross-section.

FEMALES

(Illustration will follow in the forthcoming issue)

The crown base is semi-circular in occlusal view, with an arched outer edge being flattened medially and an inner edge bluntly angled medially. The poorly developed cusp

is reduced to a cone, with indistinct mesial and distal cutting edges. The cones of lateral and posterior teeth are neither oblique nor inclined distally but upright. The inner and outer surfaces are slightly convex. An apron, ornamentation, or a true uvula are absent. The root stem is relatively low and more or less oval in cross-section. The root widens in all directions forming a large base with a multilobed inner face. A deep basal groove is well developed and encloses one or two central foramina. Root coating is present on the upper part of the stem. The outer face of the root shows sometimes a distal and/or mesial foramen and the inner face some foramina in the folds of the multilobation.

MALES

The crown base is semi-circular in occlusal view, with an arched outer edge being flattened medially and an inner edge bluntly angled medially. The anterior and antero-lateral teeth bear a well developed broad-based cusp with a narrow, elongated, inward directed cone with mesial and distal cutting edges convexly arched.

The cone of the cusp becomes gradually reduced in height toward the commissure. The inner surface is strongly convex, the outer one slightly convex. An apron, ornamentation or true uvula are absent.

Latero-posterior and posterior teeth have a lower principal cusp with mesial and distal cutting edges arched convexly. This gives the outer face of the crown a heart-shape appearance. The inner face is convex, the outer one is flat to fairly concave on teeth close to the commissure. The principal cups of lateral and posterior teeth are neither inclined nor oblique distally but upright.

The root stem is relatively low and more or less oval in cross-section. The root base widens in all directions to form a large base with a multilobed inner face. Sometimes, a foramen is present in the folds of the multilobation. The outer face of the root shows sometimes a distal or/and mesial foramen. A deep basal groove is well developed and encloses one or two central foramina. Root coating is present on the upper part of the root stem.

Subgenus: *Raja (Rioraja)* WHITLEY, 1939

The subgenus *Raja (Rioraja)* is monotypic by original description.

Raja (Rioraja) agassizi (MÜLLER & HENLE, 1841) (Plates: 39 to 41; textfigure 10)

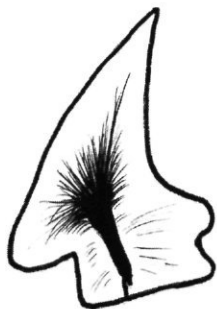
Uraptera agassizi MÜLLER & HENLE, 1841. Systematische Beschreibung der Plagiostomen: 155-156, pl. 50.

HETERODONTY

Although the dentition is gradient monognathic heterodont there is a significant difference in the morphology of anterior, lateral and posterior teeth. The anterior teeth and lateral teeth in males have an elongated principal cusp arising from a broad crown base with mesial and distal cutting edges arched concavely. The mesial cutting edge is often longer than the distal one. The convex outer surface shows a well developed outer cutting edge. The lateral teeth in females and posterior teeth only possess a transversal keel. Sexual heterodonty is present in adults only, in that female teeth show a less developed principal cusp in anterior teeth and a transverse keel in females. Ontogenetic heterodonty is documented by female-like characters in all juveniles.

VASCULARIZATION

The teeth show an adapted holaulacorhizid root type with a broad, elongated pulp cavity in the root area, from which the vascular tubes of the circumpulpar dentine radiate into crown and root. Osteodentine was not observed, and inner lateral foramina are absent. (See text-figure 10)



Textfigure 10.
Raja (Rioraja) agassizi tooth histological cross-section.

FEMALES

The crown base is oval in occlusal view, with the outer edge less arched than the inner one. The lateral teeth are broader than the anterior ones and their cones are more eccentric distally. An arched transversal keel is high at anterior teeth but gradually becoming lower on teeth toward the commissure. The inner and outer surfaces are slightly convex. An apron, ornamentation, or uvula are absent. The root stem is relatively low and more or less oval in cross-section. The root gradually widens in all directions to form a large base. A deep basal groove is well developed and encloses one or two central foramina. Root coating is absent.

MALES

The crown base is semi-circular to oval in occlusal view, with the outer edge less arched than the inner one. The anterior and antero-lateral teeth bear a broad based well developed cusp, with a narrow, elongated, inward directed cone and with mesial or distal cutting edges arched convexly. The outer face shows a well developed outer cutting edge running from just above the crown base to the apex of the crown.

The cone of the cusp becomes gradually reduced in height on teeth toward the commissure and slightly inclined distally. The inner surface is strongly convex, the outer one is slightly convex. An apron, ornamentation or true uvula are absent.

Lateral and posterior teeth only possess a transverse keel. The inner face is convex, whereas the outer one is flat to fairly concave on teeth close to the commissure. The outer cutting edge is absent on lateral and posterior teeth.

The root stem is moderately high and more or less oval in cross-section. The root widens in all directions to form a large base. A shallow basal groove is well developed and encloses one or two central foramina. Root coating is present near the crown-root area.

Subgenus: *Raja* (*Rostroraja*) HULLEY, 1972

The subgenus is monotypic with *Raja* (*Rostroraja*) *alba*.

Raja (*Rostroraja*) *alba* LACEPEDE, 1803
(Plates: 42 to 46; textfigure 11)

Raja alba LACEPEDE, 1803. Histoire naturelle des Poissons. 5: 661-663, pl. 20 (fig. 1).

HETERODONTY

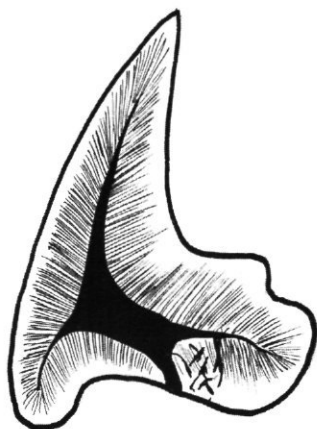
The dentition is gradient monognathic heterodont. Sexual heterodonty is absent. Ontogenetic heterodonty is documented by a much lower principal cusp in juveniles.

VASCULARIZATION

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

FEMALES AND MALES

The crown base shows inner and outer edges with a strong protuberation medially. The principal cusp of anterior and lateral teeth is a nearly centrally situated elongated cone,



Textfigure 11.
Raja (Rostroraja) alba tooth histological cross-section.

which is strongly directed inward and that of the lateral ones is slightly inclined toward the commissure. Anterior teeth have a very elongated principal cusp, gradually lowering in lateral, and diminished to an angled transverse keel in posterior teeth. The mesial and distal cutting edges of anterior and lateral teeth are concavely arched. The outer crown base shows a well developed, quadrangular shaped apron overhanging the crown-root junction. The apron has often a small central median depression, because the teeth in a row are at this point transversely interlocked with each other. The smooth outer surface is slightly convex. The smooth inner surface is strongly convex, with a well developed broad uvula. The root stem is low and more or less oval in cross-section. Vertically, the root widens to form an extremely large base. The central part of the inner face protuberates to support the extended uvula. A deep but narrow basal median groove encloses a large central foramen. Root coating is only present on the crown-root junction.

Raja lintea FRIES, 1838
(Plates: 47 to 51; textfigure 12)

Raja lintea FRIES, 1838. K. svenska Vetensk. Akad. Handl. 1838: 154-157, Stockholm.

HETERODONTY

The dentition is gradient monognathic heterodont. Indistinct sexual heterodonty present in adults only in females show a lower principal cusp and a broader crown base. Ontogenetic heterodonty is documented by much lower cusps on teeth of juveniles diminishing to a cone only on posterior teeth.

VASCULARIZATION

The teeth show an adapted holaulacorhizid root type with a large pulp cavity in the root area, from which the vascular tubes of the circumpulpar dentine radiate into crown and root. Osteodentine was not observed, and inner lateral foramina are absent. (See textfigure 12)



Textfigure 12.
Raja lintea tooth histological cross-section.

MALES AND FEMALES

The crown base is semi-oval in occlusal view, with an arched outer and medially, bluntly angled inner edge. Mesial and distal areas of the crown are concavely arched and join at the apex of a narrow, rather high principal cusp. Mesial and distal cutting edges are mostly absent or if present poorly developed. The principal cusp of lateral and posterior teeth are neither inclined nor oblique distally but upright. Apron, as well as inner and outer ornamentation are absent, but a well developed uvula is present. The inner surface is flat to slightly concave, and the outer one is slightly convex.

The root stem is rather high and oval shaped in cross-section. The bilobed root strongly widens in all directions, forming a large base, of which its margin is weakly undulated. A well developed, deep basal groove encloses a rather large central aperture. Root coating is present in the upper region near the crown-root junction.

Genus: *Sympterygia* MÜLLER & HENLE, 1837

The genus *Sympterygia* comprises the following four specific taxa: *acuta*, *bonapartei* (type species), *brevicaudata* and *lima*.

Sympterygia bonapartei MÜLLER & HENLE, 1841
(Plates: 52 to 56; textfigure 13)

Sympterygia bonapartei MÜLLER & HENLE, 1841.
Systematische Beschreibung der Plagiostomen: 155, pl. 50.

HETERODONTY

Although the dentition is gradient monognathic heterodont there is a significant difference in the morphology of anterior, lateral and posterior teeth. The anterior teeth have an elongated principal cusp arising from a broad crown base with mesial and distal cutting edges arched concavely. The mesial cutting edge is longer than the distal one. The convex outer surface shows a well developed outer cutting edge. The lateral and posterior teeth have a lower principal cusp with mesial and distal cutting edges arched convexly. An outer cutting edge is absent. The outer surface is flat or even concave. Sexual heterodonty is present in adults only, in that female teeth show a low principal cusp with a transverse keel. Ontogenetic heterodonty is documented by female-like characters in all juveniles, but mesial and distal cutting edges absent in juvenile teeth.

VASCULARIZATION

The teeth show an adapted holaulacorhizid root type with a broad, elongated pulp cavity in the root area, from which the vascular tubes of the circumpulpar dentine radiate into crown and root. Osteodentine was not observed, and inner lateral foramina are absent. (See text-figure 13)



Textfigure 13.
Sympterygia bonapartei tooth histological cross-section.

FEMALES

The crown base is oval in occlusal view with the outer edge less arched than the inner one. The lateral teeth are broader than the anterior ones and possess a transverse keel, whereas anterior ones have a triangularly shaped principal cusp with a slightly concavely arched mesial and distal cutting edge. The inner and outer surfaces are slightly concave and anterior teeth sometimes have a poorly developed outer cutting edge. An apron, ornamentation, or uvula are absent. The root stem is relatively low and more or less oval in cross-section. The root gradually widens in all directions to form a large base. A deep basal

groove is well developed and encloses one or two central foramina. Root coating is absent.

MALES

The crown base is semi-circular to oval in occlusal view, with the outer edge less arched than the inner one. The anterior and antero-lateral teeth bear a broad based well developed cusp, with a narrow, elongated, inward directed cone and with mesial or distal cutting edges arched convexly. The outer face shows a well developed outer cutting edge running from just above the crown base to the apex of the crown.

The cone of the cusp becomes gradually reduced in height on teeth toward the commissure and slightly inclined distally. The inner surface is strongly convex, the outer one is slightly convex. An apron, ornamentation or true uvula are absent.

Lateral and posterior teeth have a lower principal cusp, with mesial and distal cutting edges arched convexly. The inner face is convex, whereas the outer one is flat to fairly concave on teeth close to the commissure. The outer cutting edge is absent on lateral and posterior teeth.

The root stem is relatively low and more or less oval in cross-section. The root widens in all directions to form a large base. A deep basal groove is well developed and encloses one or two central foramina. Root coating is absent.

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STEHMANN, M.
Bundesforschungsanstalt für Fischerei.
Palmaille 9,
D-22767 Hamburg, Germany.

HERMAN, J.
Service Géologique de Belgique,
Rue Jenner 13,
B-1040 Brussels, Belgium.

HOVESTADT-EULER, M. and HOVESTADT, D.C.
Merwedelaan 6,
NL-4535 ET Terneuzen, The Netherlands.

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**
Symphyseal/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 symphyseal 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 symphyseal tooth row (symmetry).
- Row**
Tooth row from inner face to outer face of jaw.
- Symphysial**
Teeth at junction of both halves of a jaw.
- Transversal**
Outer/inner direction of a row.

CONCERNING THE TOOTH

- An-, Hemi-, Hol- and Polyaulacorhizid**
Concerning their vascularization, E. Casier (1947) recognised and described 4 phylogenetically significant root types within the orthodont histotypes of elasmobranch teeth.
- Aaulacorhizid**
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.

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-holaulacorhizid

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 orthodontine layer.

Osteodont

Histotype of vascularization, by which a tooth is supplied without any pulp cavity by scattered tiny cavities and canals penetrating the osteodontine 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 osteodontine.

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.

Secondarily 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.

Transversal

Mesio-distally directed.

Transverse keel

Transverse ridge dividing the crown into inner and outer face.

Uvula

Lobate extension of the inner crown base.

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

- s = symphyseal position
- a = anterior position
- l = lateral position
- p = posterior position
- c = commissural position

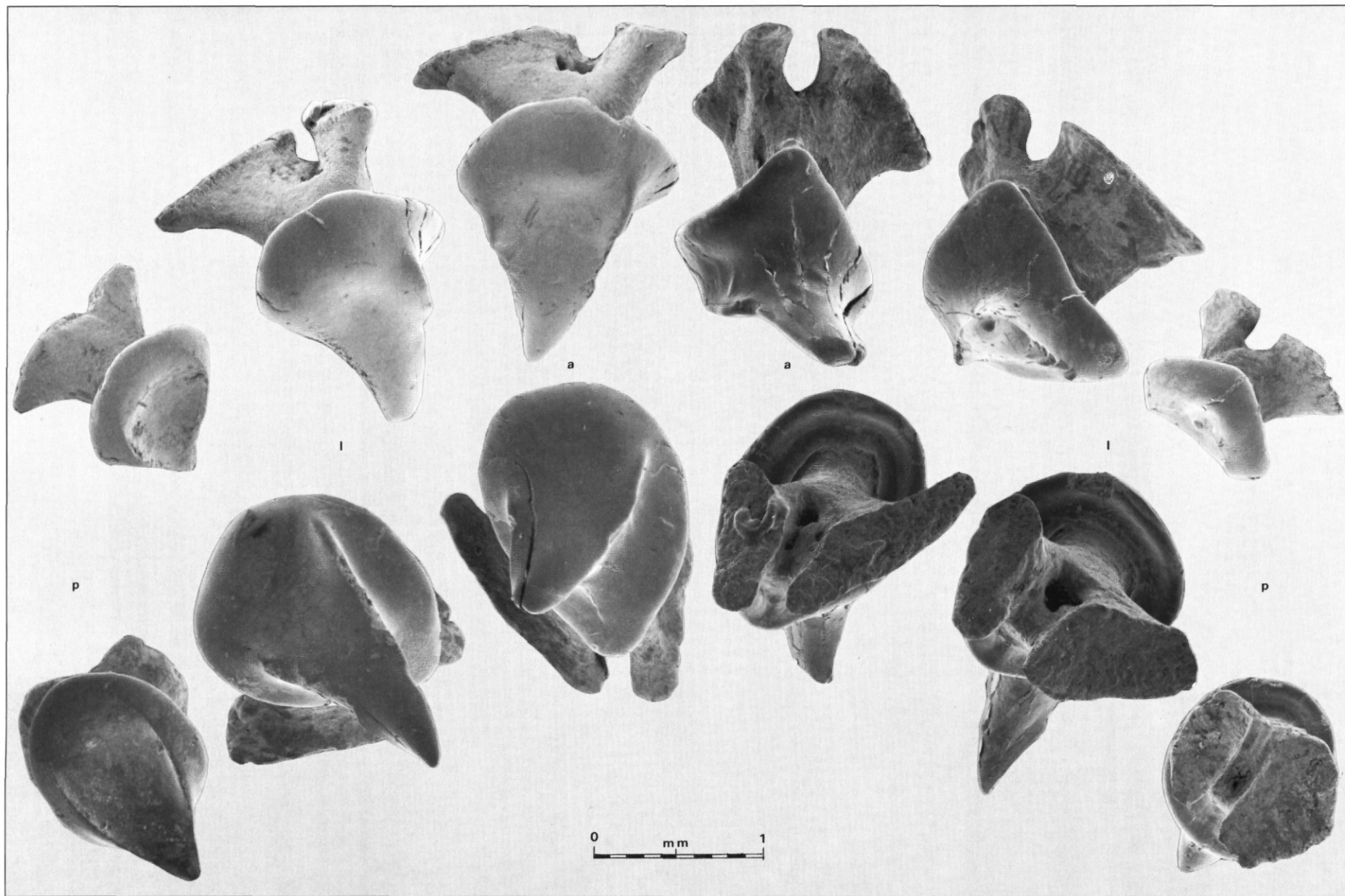


Plate 1. - *Bathyraja albomaculata* (NORMAN, 1937). Male 66 cm (t.l.), South Atlantic, west off central Argentina. Upper teeth.

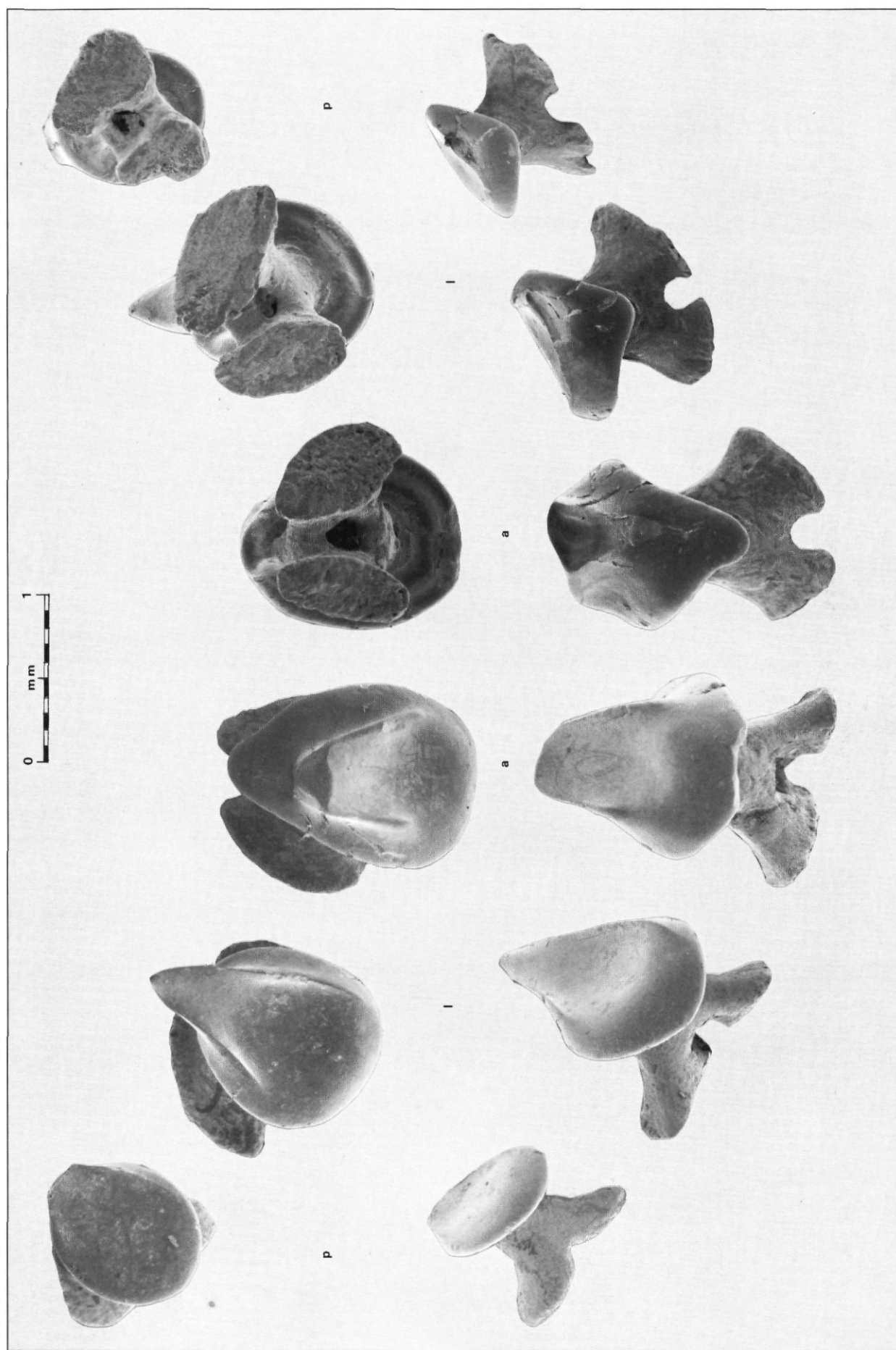


Plate 2. — *Bathyraja albomaculata* (NORMAN, 1937). Male 66 cm (t.l.), South Atlantic, west off central Argentina. Lower teeth.

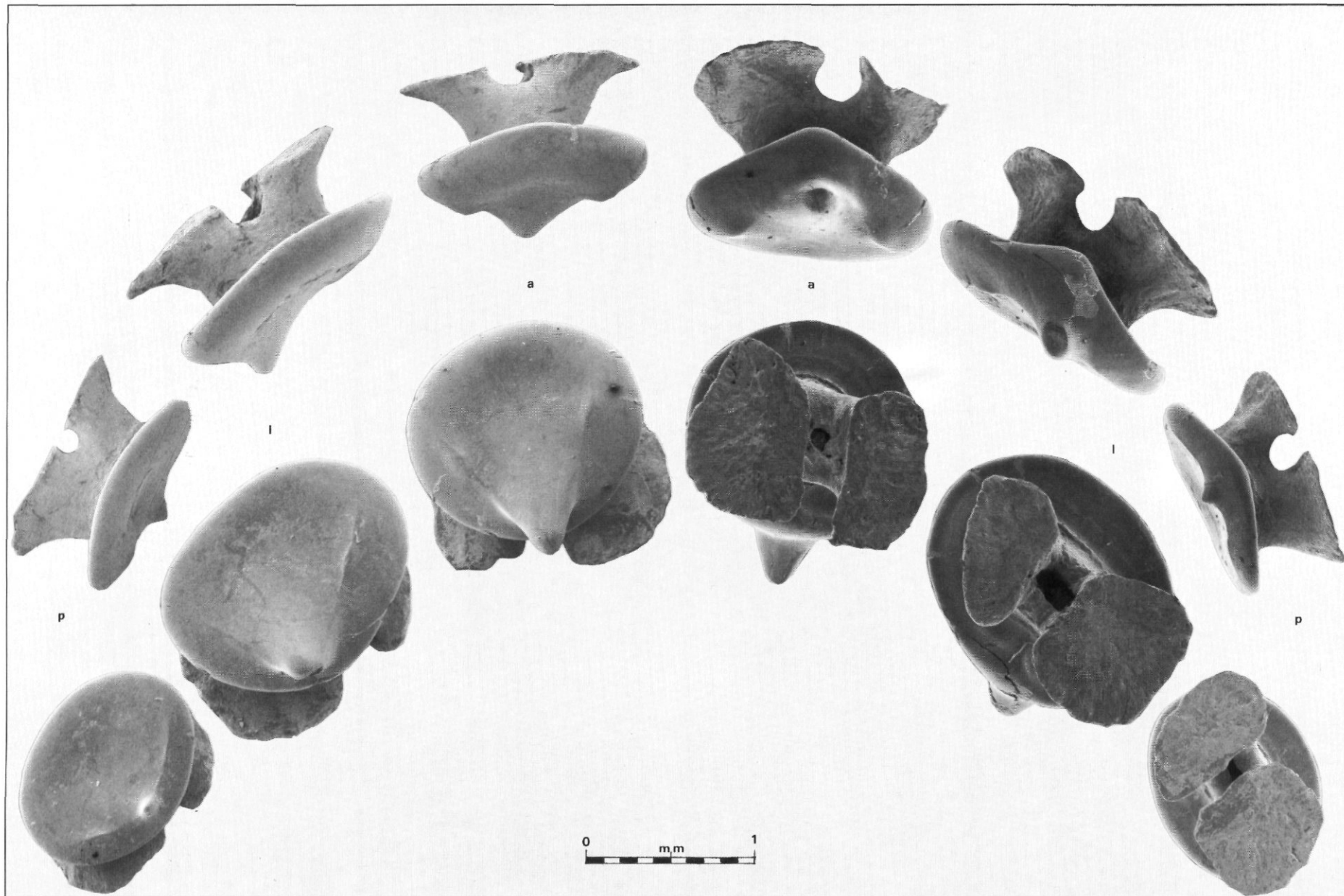


Plate 3. — *Bathyraja albomaculata* (NORMAN, 1937). Female 65 cm (t.l.), South Atlantic, west off central Argentina. Upper teeth.

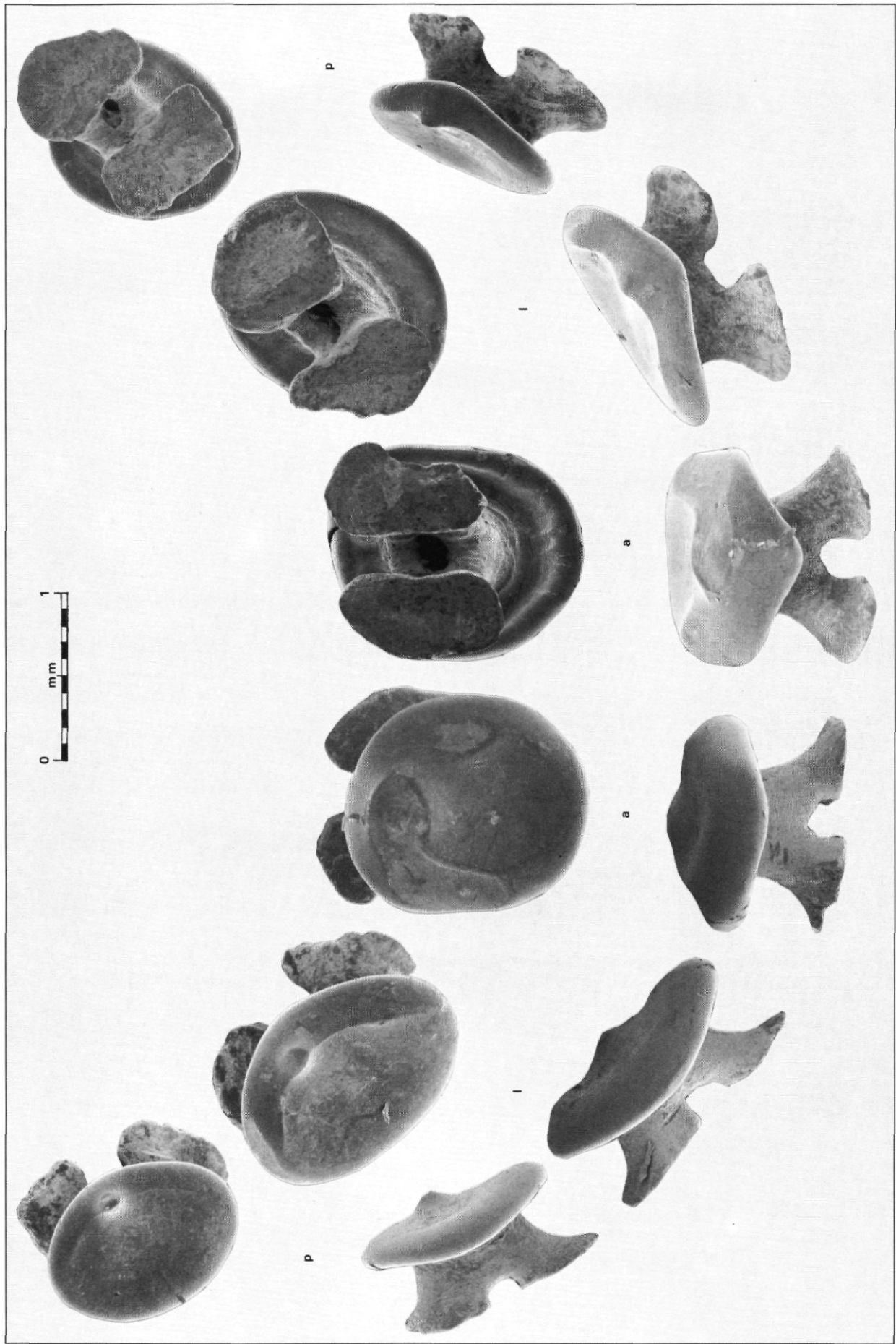


Plate 4. - *Bathyraja albomaculata* (NORMAN, 1937). Female 65 cm (t.l.), South Atlantic, west off central Argentina. Lower teeth.

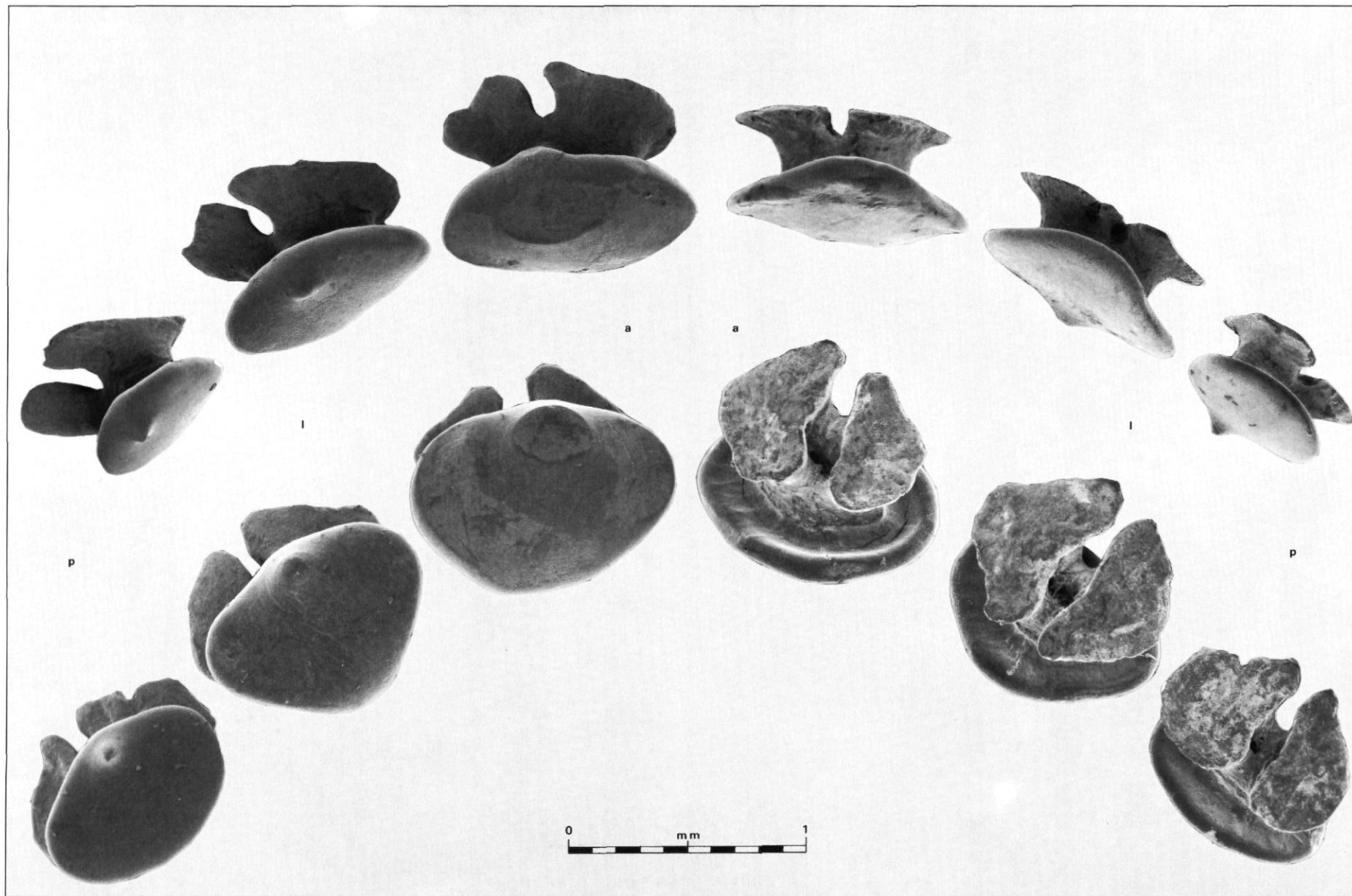


Plate 5. — *Bathyraja albomaculata* (NORMAN, 1937). Female 35 cm (t.l.), South Atlantic, west off central Argentina. Upper teeth.

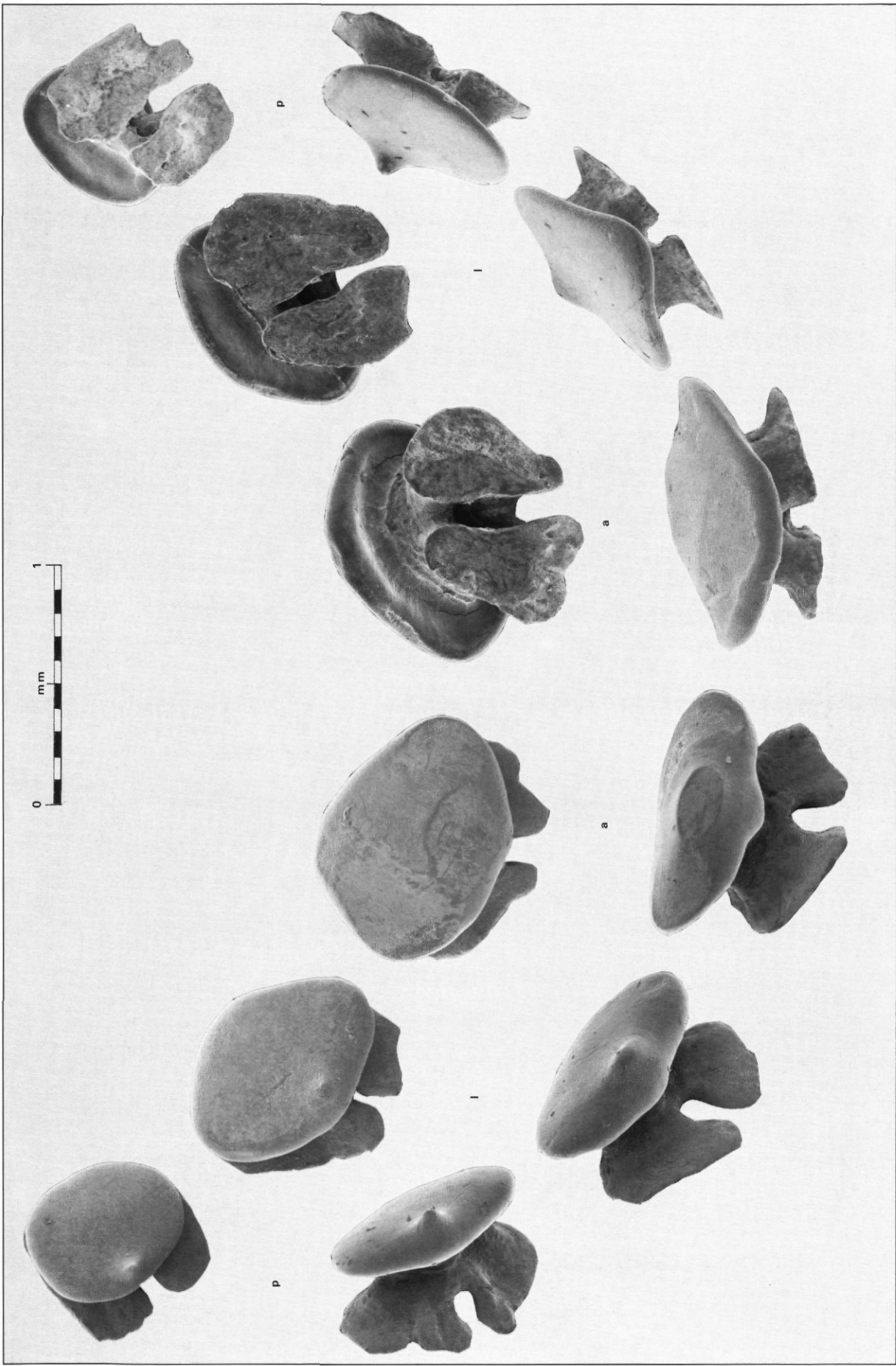


Plate 6. - *Bathyrhaja albomaculata* (NORMAN, 1937). Female 35 cm (t.l.). South Atlantic, west off central Argentina. Lower teeth.

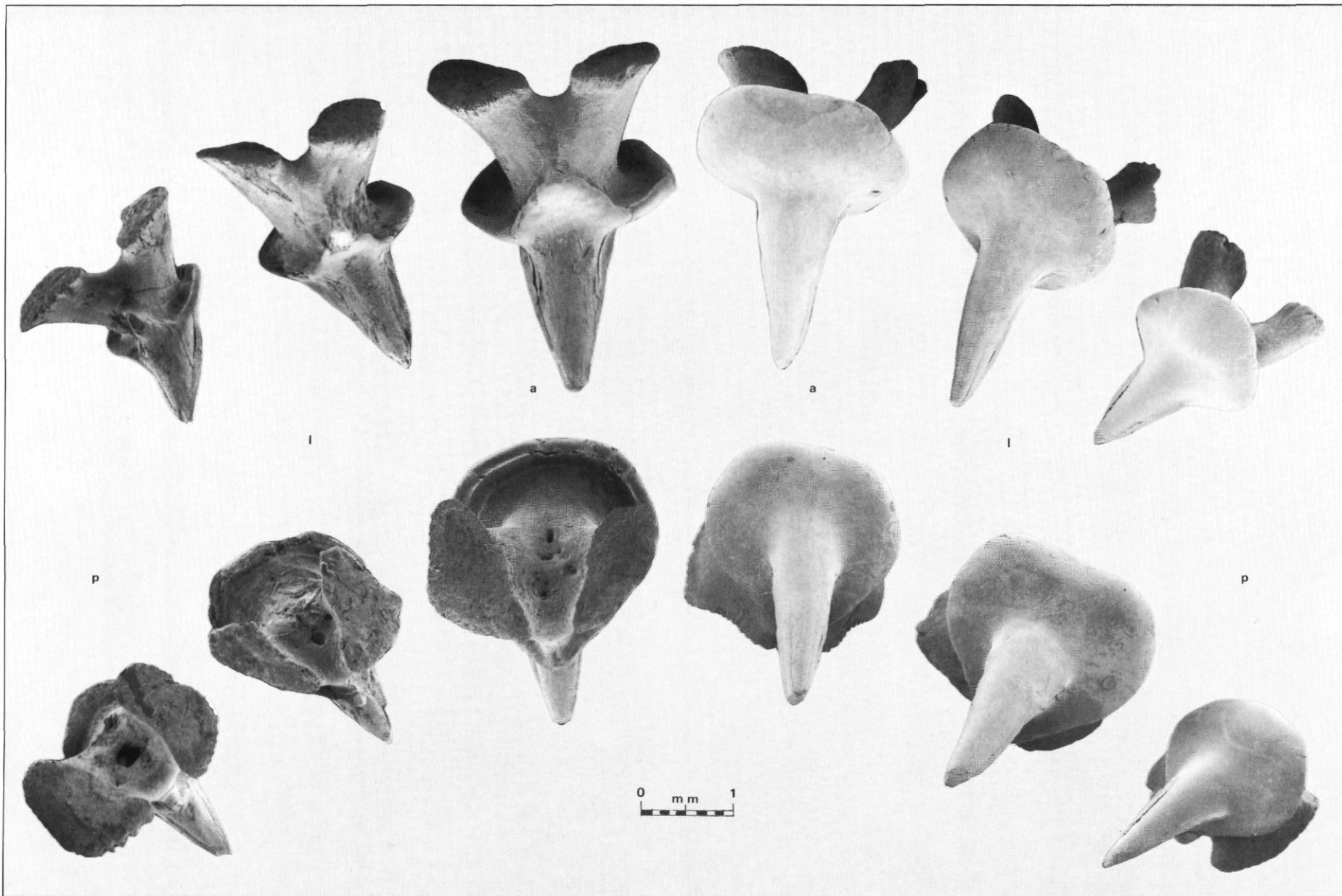


Plate 7. — *Bathyraja spinicauda* (JENSEN, 1914). Male 138,5 cm (t.l.), North-West Atlantic. Upper teeth.

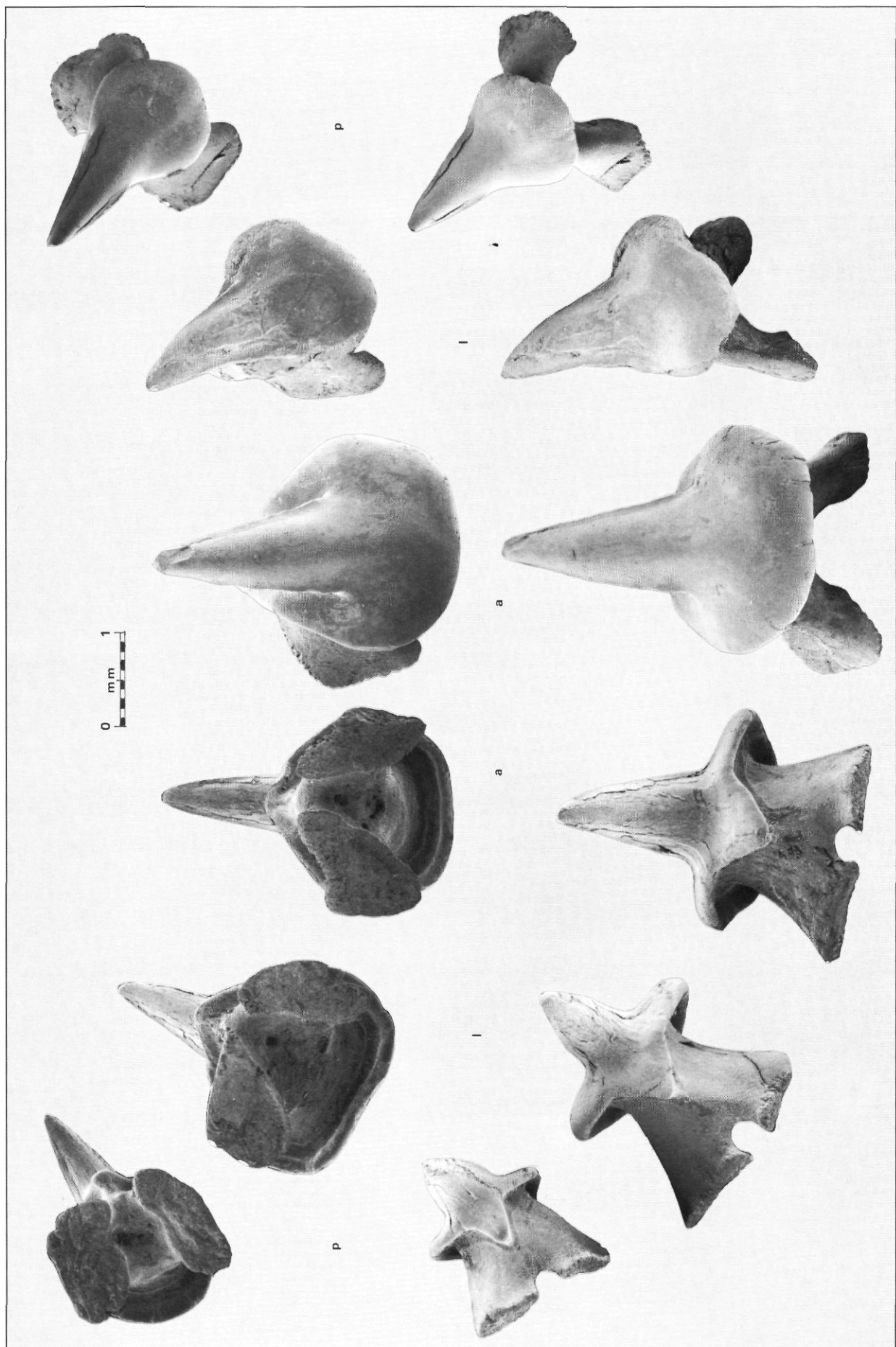


Plate 8. — *Bathyraja spinicauda* (JENSEN, 1914). Male 138,5 cm (t.l.), North-West Atlantic. Lower teeth.

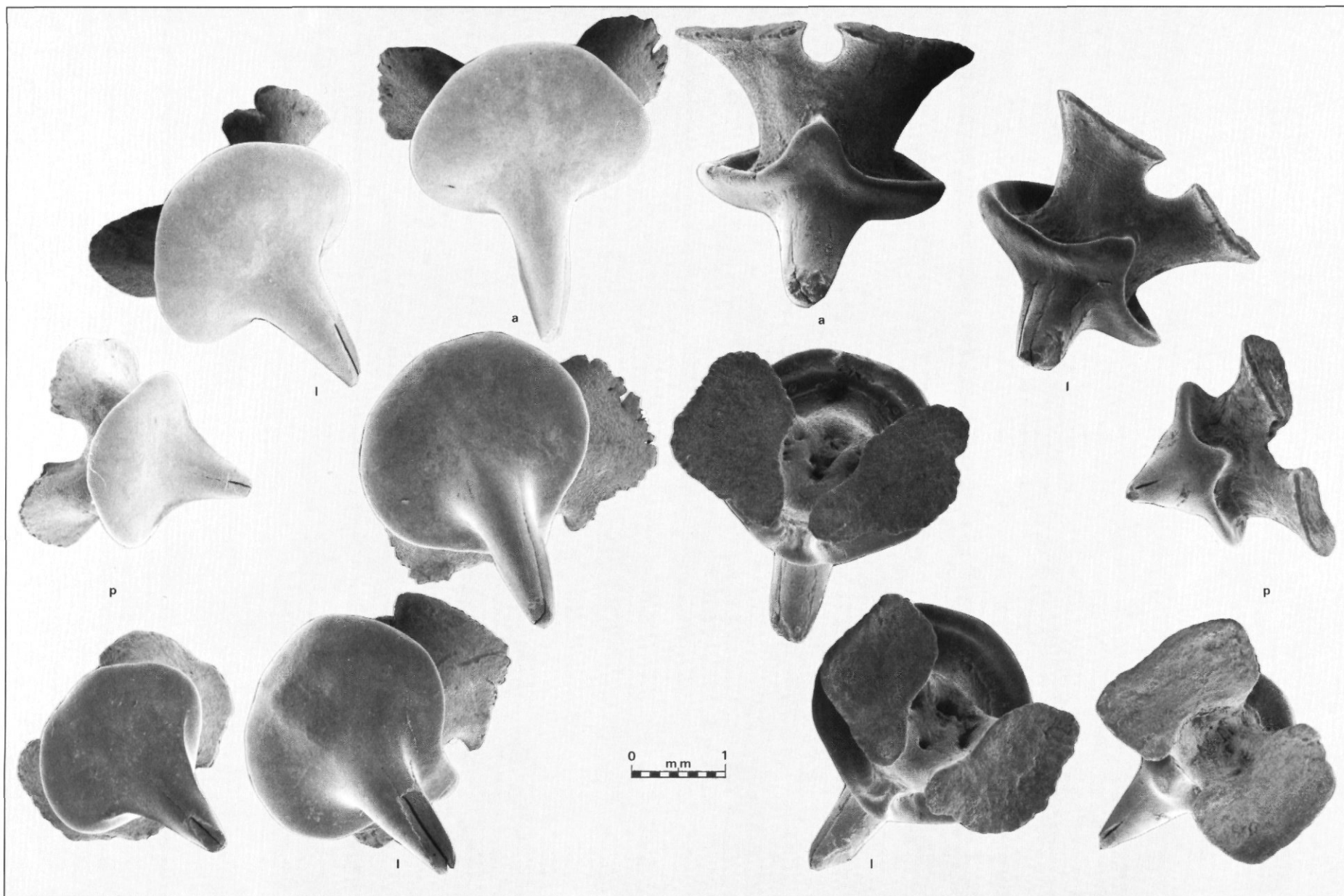


Plate 9. — *Bathyraja spinicauda* (JENSEN, 1914). Female 163 cm (t.l.), North-West Atlantic. Upper teeth.

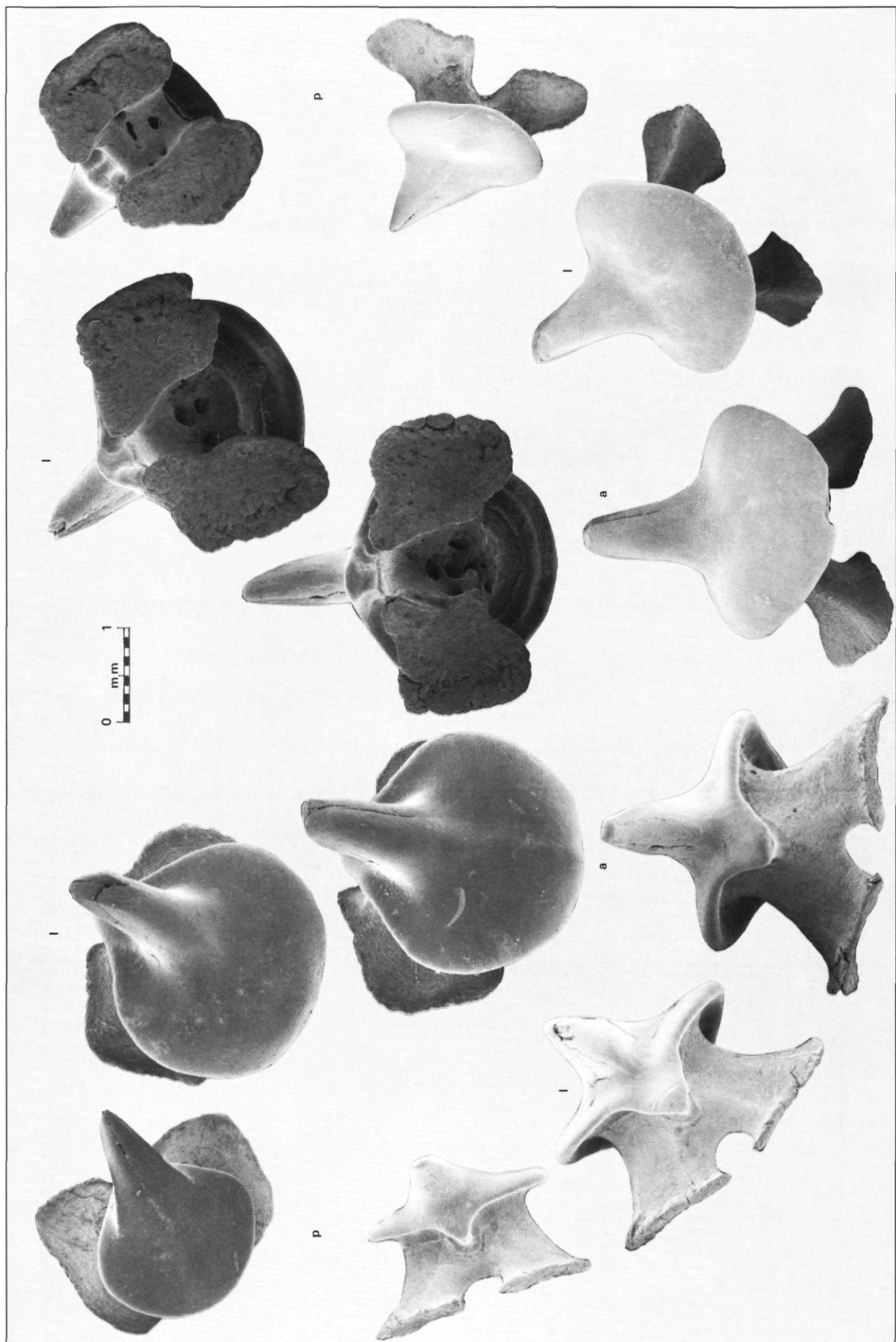


Plate 10. — *Bathyraja spinicauda* (JENSEN, 1914). Female 163 cm (t.l.), North-West Atlantic. Lower teeth.

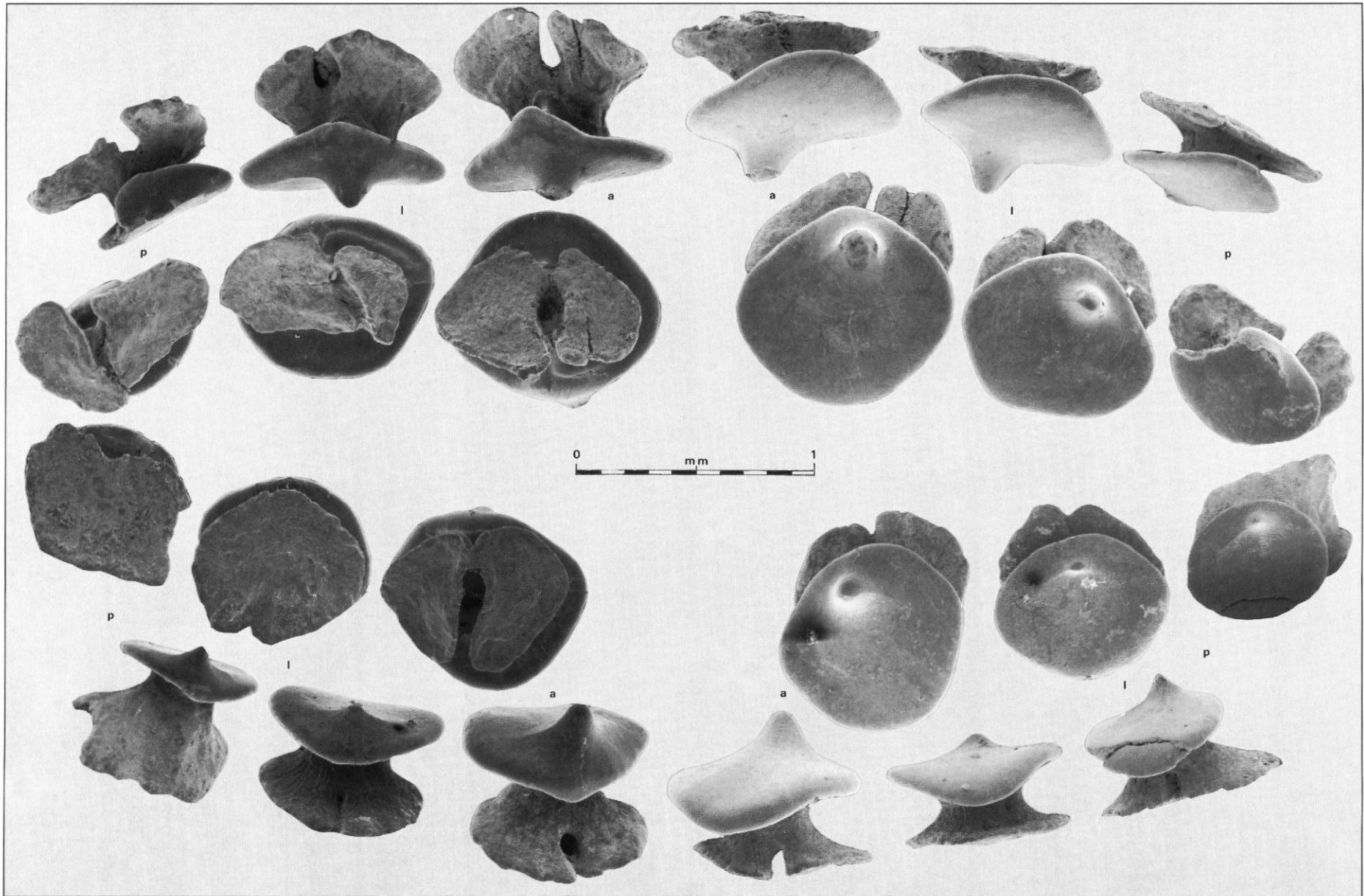


Plate 11. — *Bathyraja spinicauda* (JENSEN, 1914). Female 36 cm (t.l.), North Atlantic, South Labrador. Upper and lower teeth.

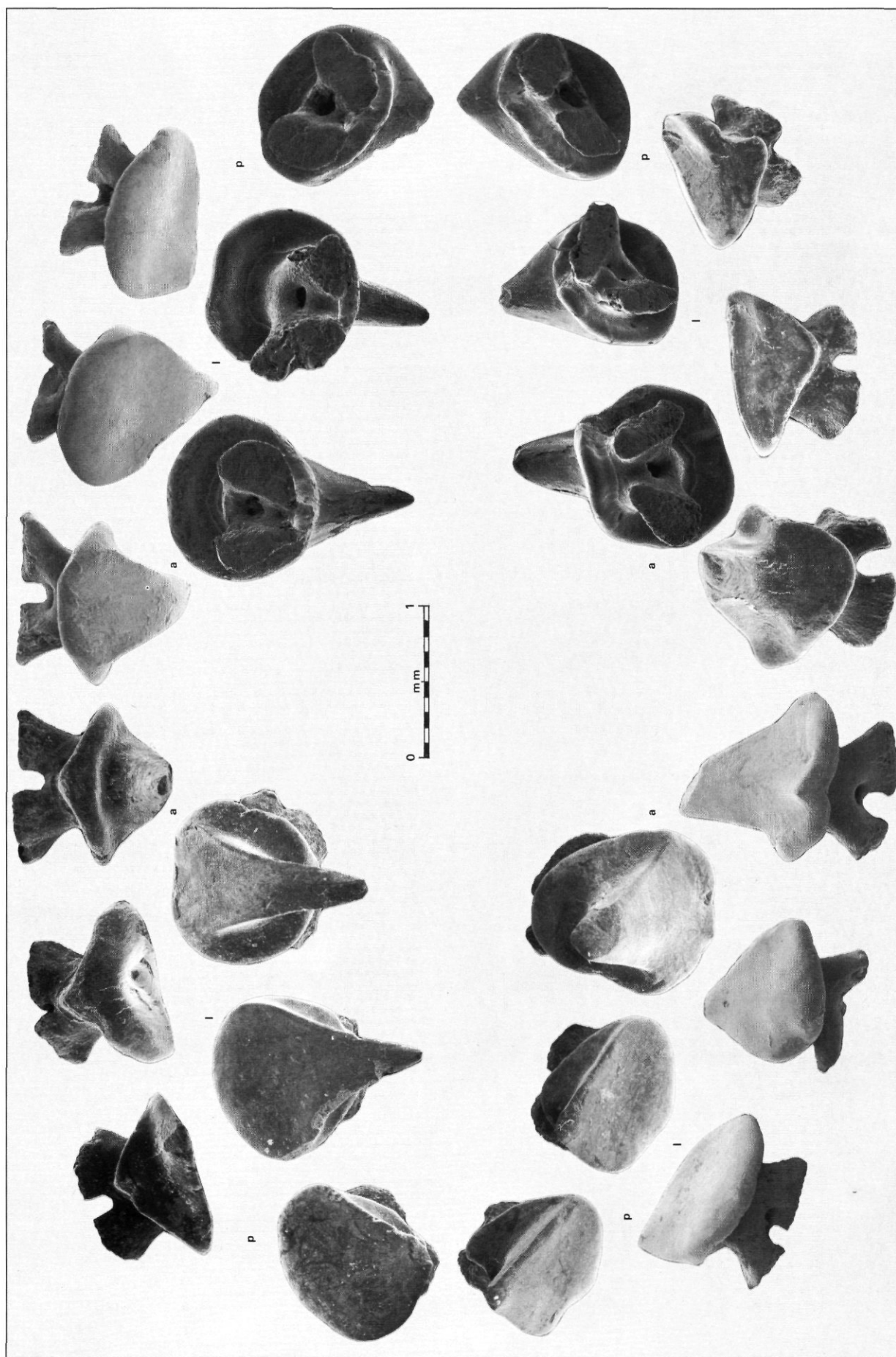


Plate 12. — *Psammobatis rudis* GÜNTHER, 1870. Male 43 cm (t.l.), South Atlantic, South Argentina. Upper and lower teeth.

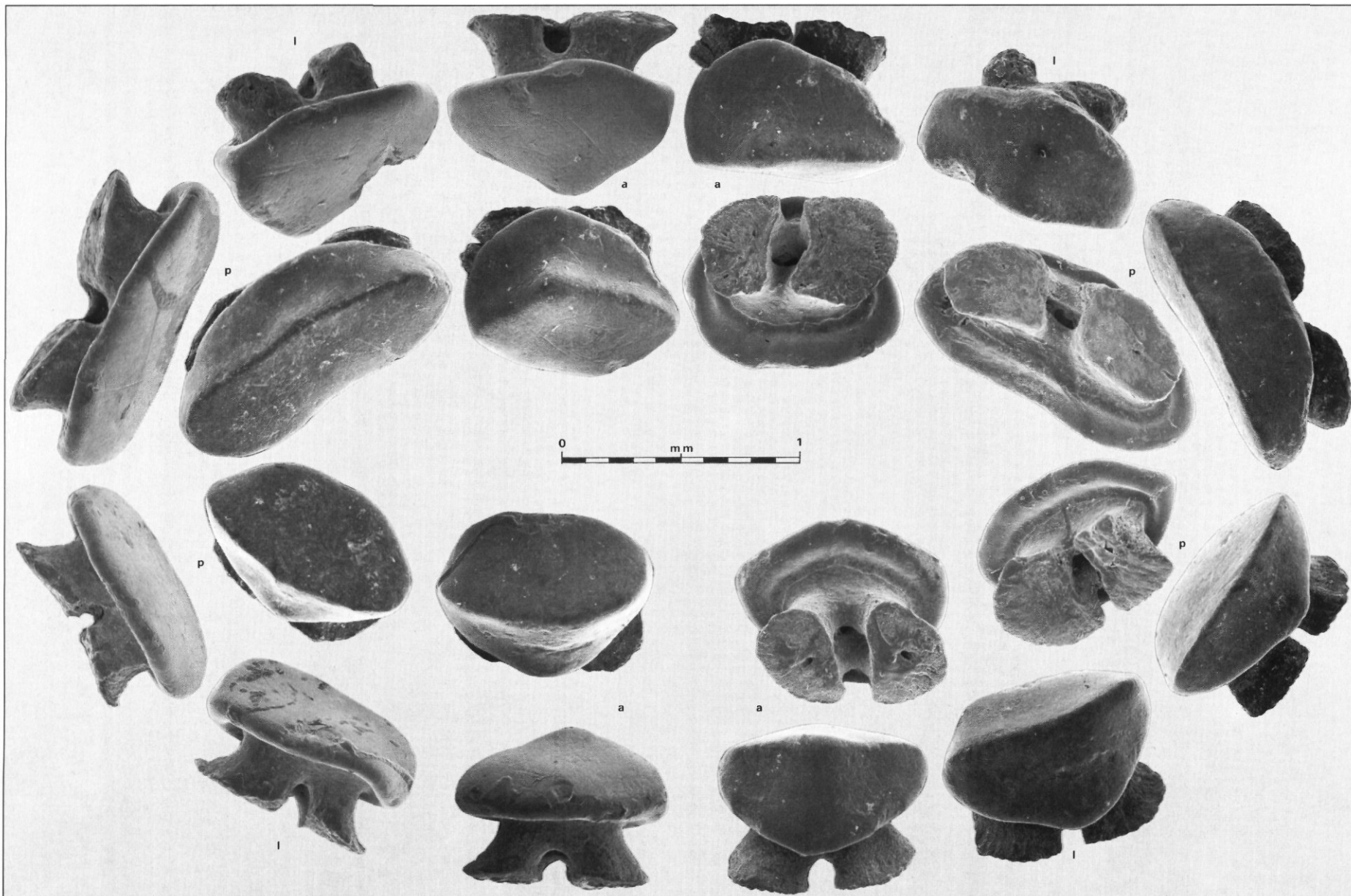


Plate 13. — *Psammobatis rudis* GÜNTHER, 1870. Female 32,5 cm (t.l.), South Atlantic, South Argentina. Upper and lower teeth.

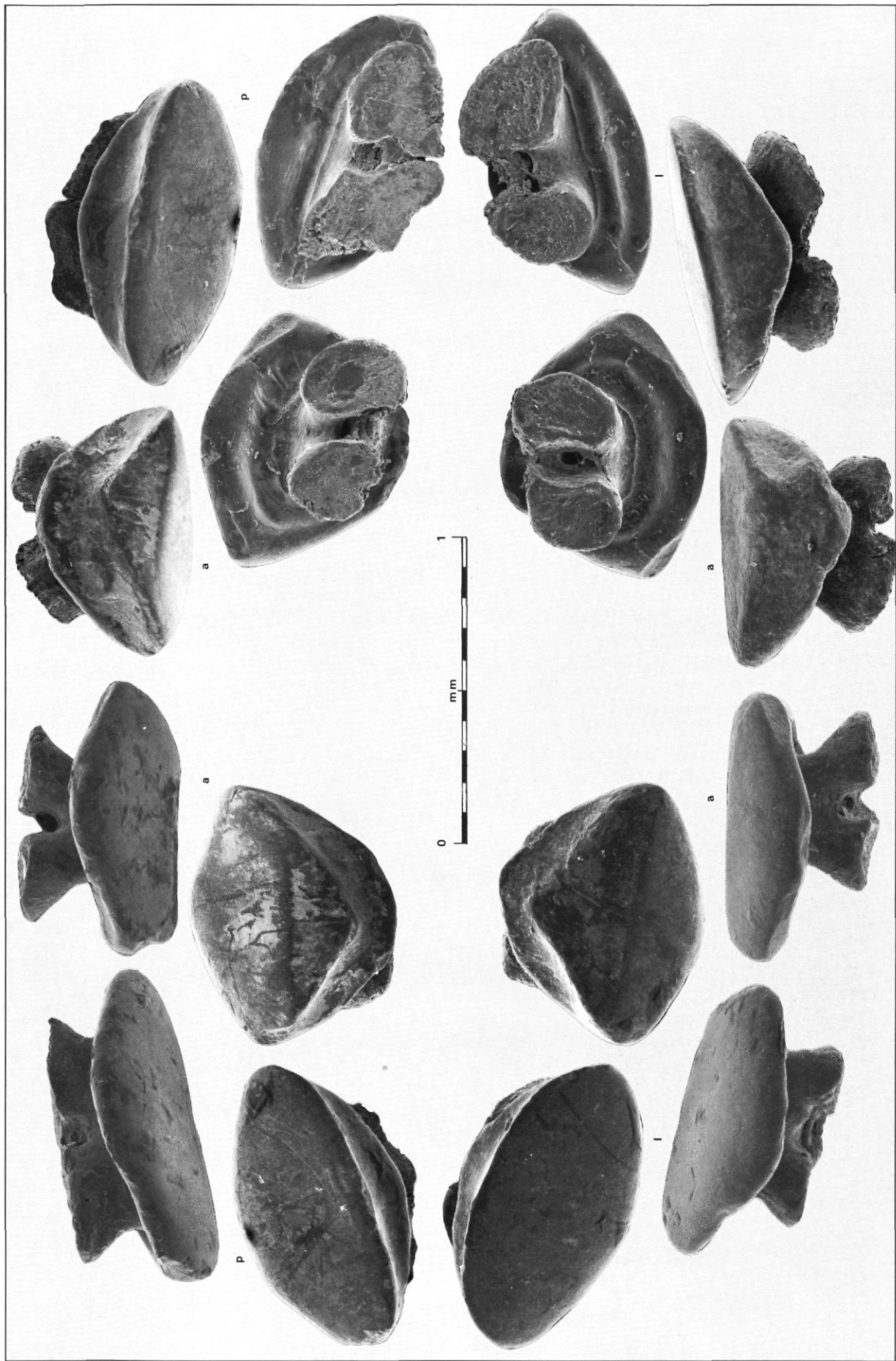


Plate 14. - *Psammobatis rudis* GÜNTHER, 1870. Male 21 cm (t.l.). South Atlantic, South Argentina. Upper and lower teeth.

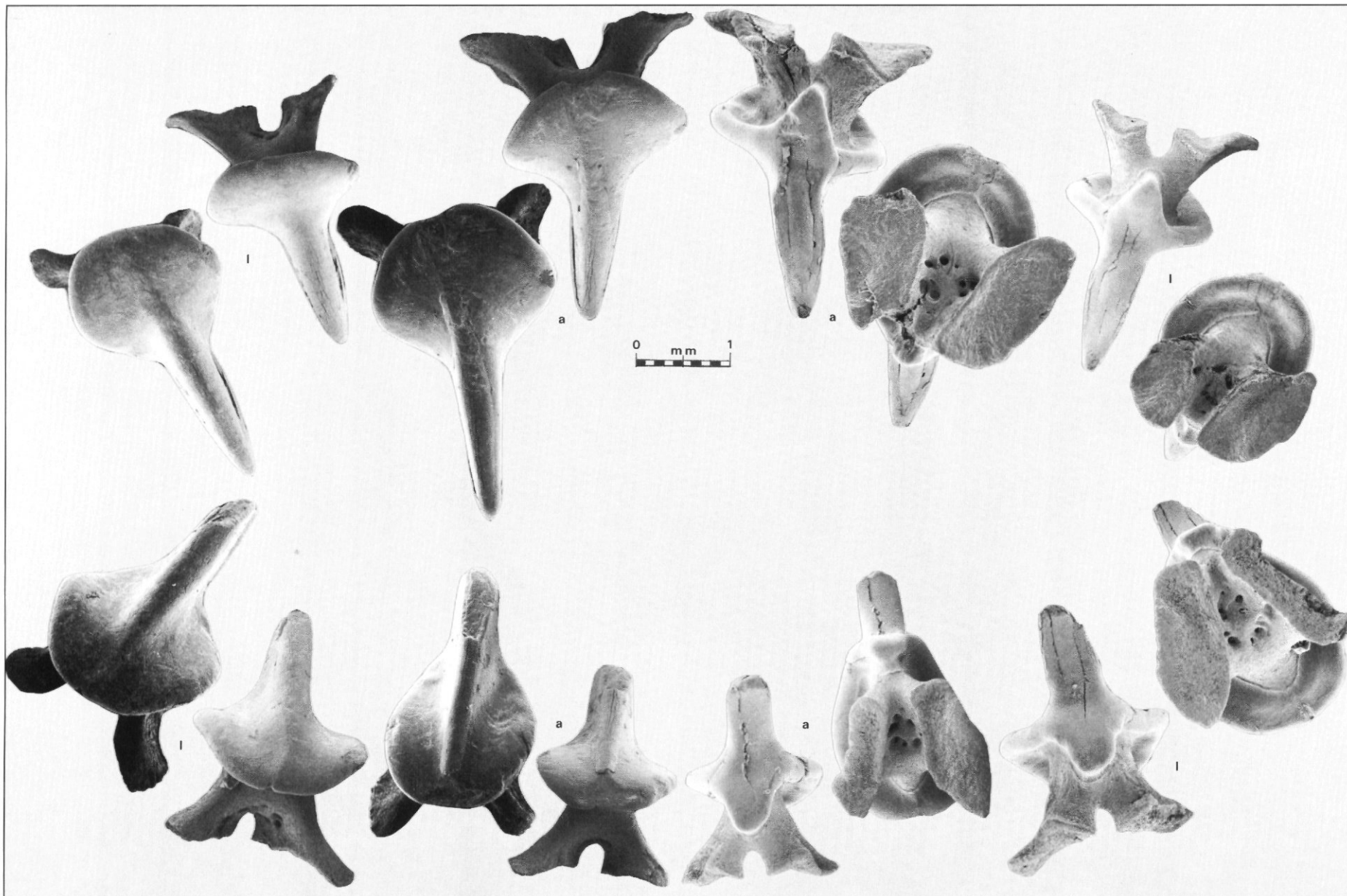


Plate 15. – *Raja (Amblyraja) radiata* DONOVAN, 1808. Male 58,5 cm (t.l.), North Atlantic, East Greenland. Upper and lower teeth.

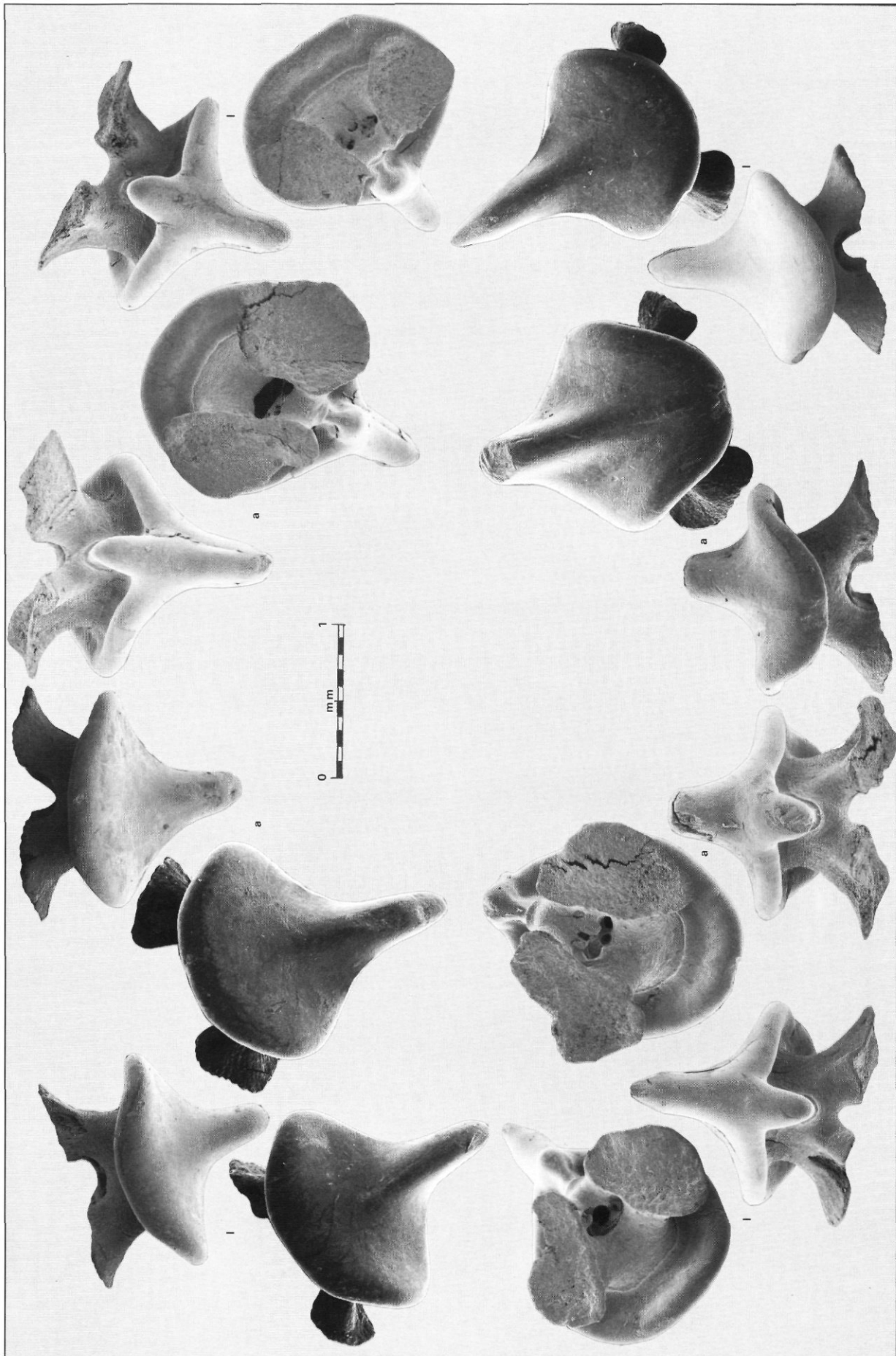


Plate 16. - Raja (Amblyraja) radiata DONOVAN, 1808. Female 54 cm (t.l.), North Atlantic, East Greenland. Upper and lower teeth.

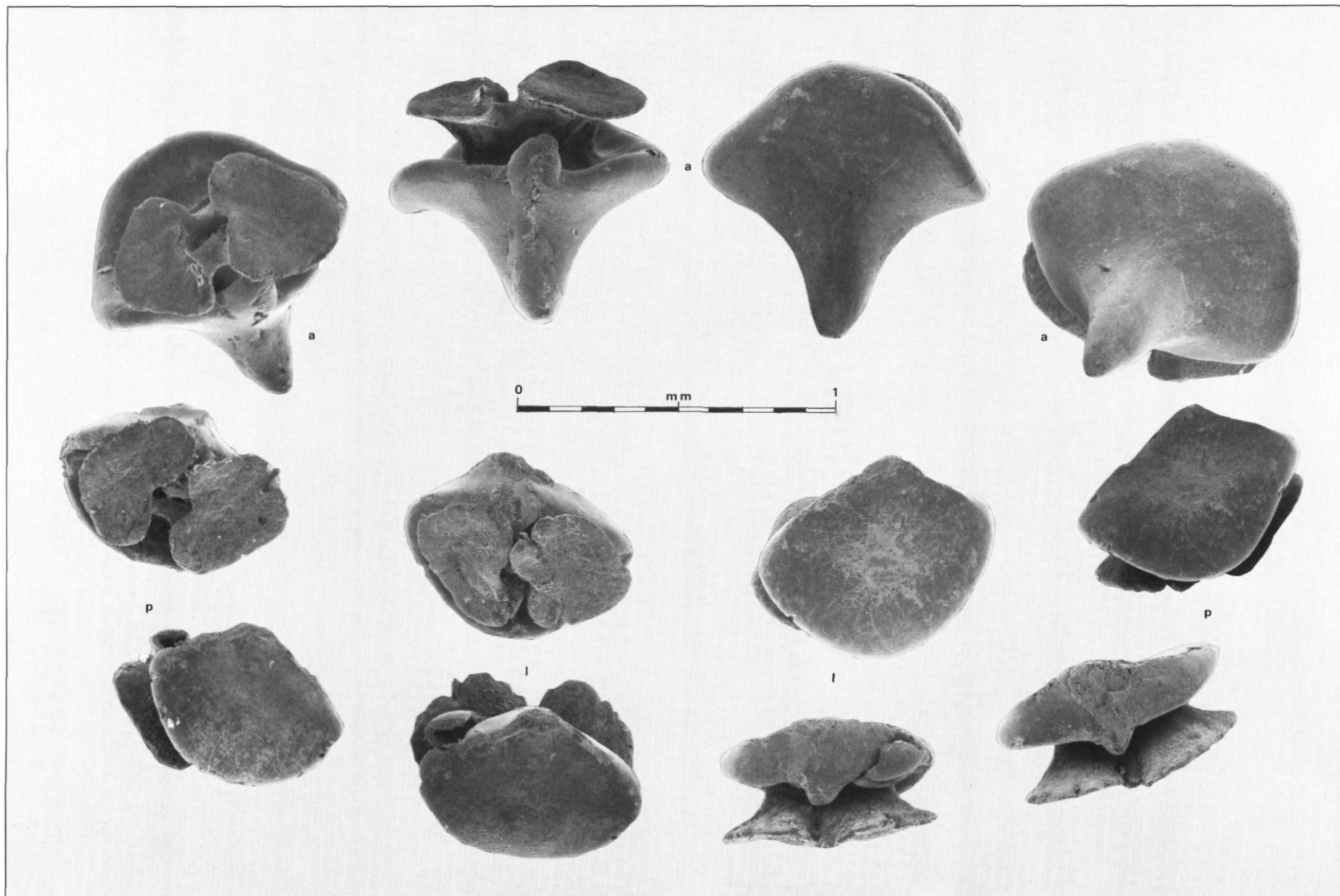


Plate 17. – *Raja* (*Amblyraja*) *radiata* DONOVAN, 1808. Male 29,5 cm (t.l.), North Atlantic, East Greenland. Upper and lower teeth.

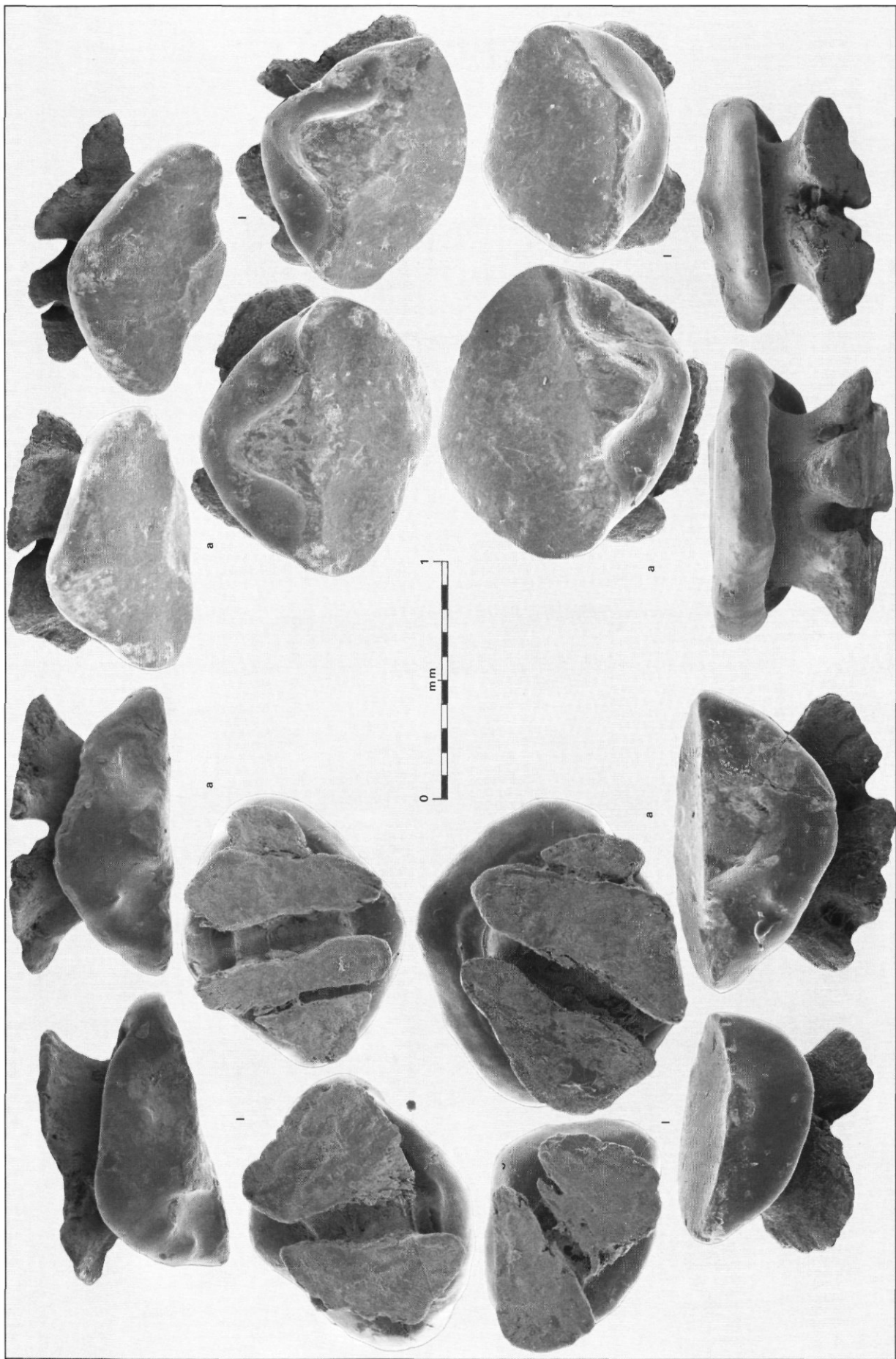


Plate 18. - Raja (Dipturus) batis LINNAEUS, 1758. Female 60 cm (l.l.), North-East Atlantic, West Scotland. Upper and lower teeth.

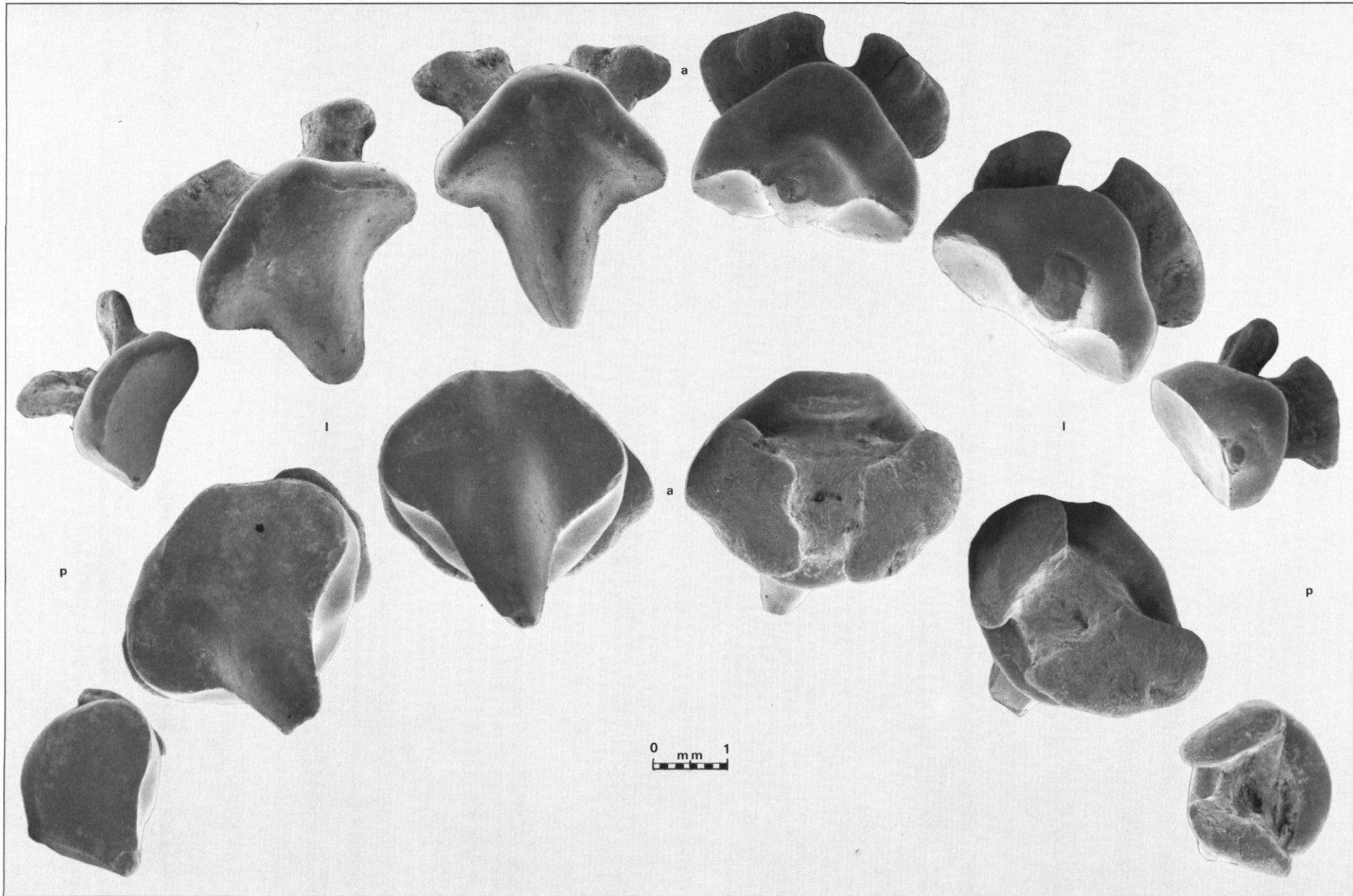


Plate 19. – *Raja (Dipturus) batis* LINNAEUS, 1758. Male 120 cm disc width, North-East Atlantic. Upper teeth.

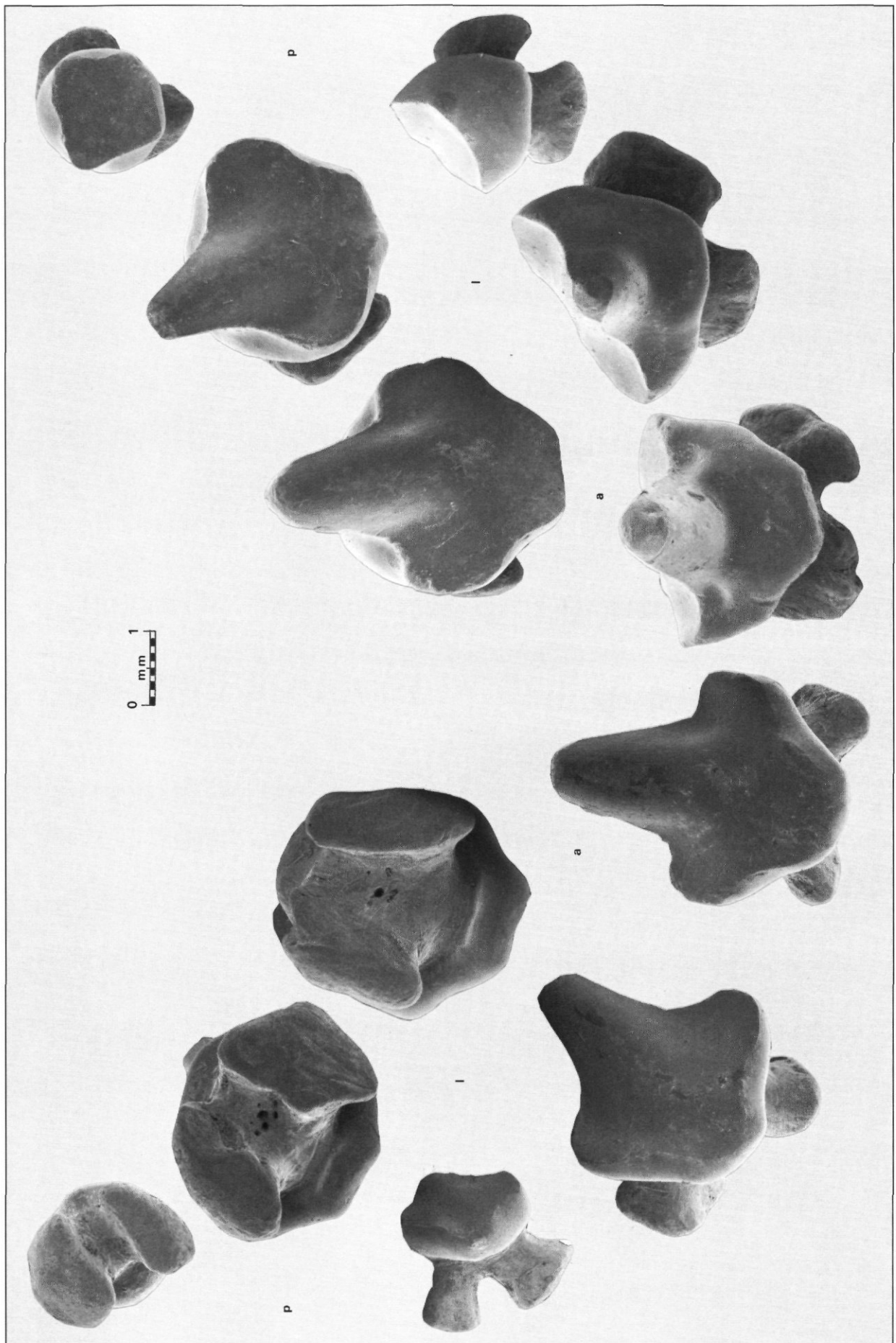


Plate 20. - Raja (Dipturus) batis LINNAEUS, 1758. Male 120 cm disc width, North-East Atlantic. Lower teeth.

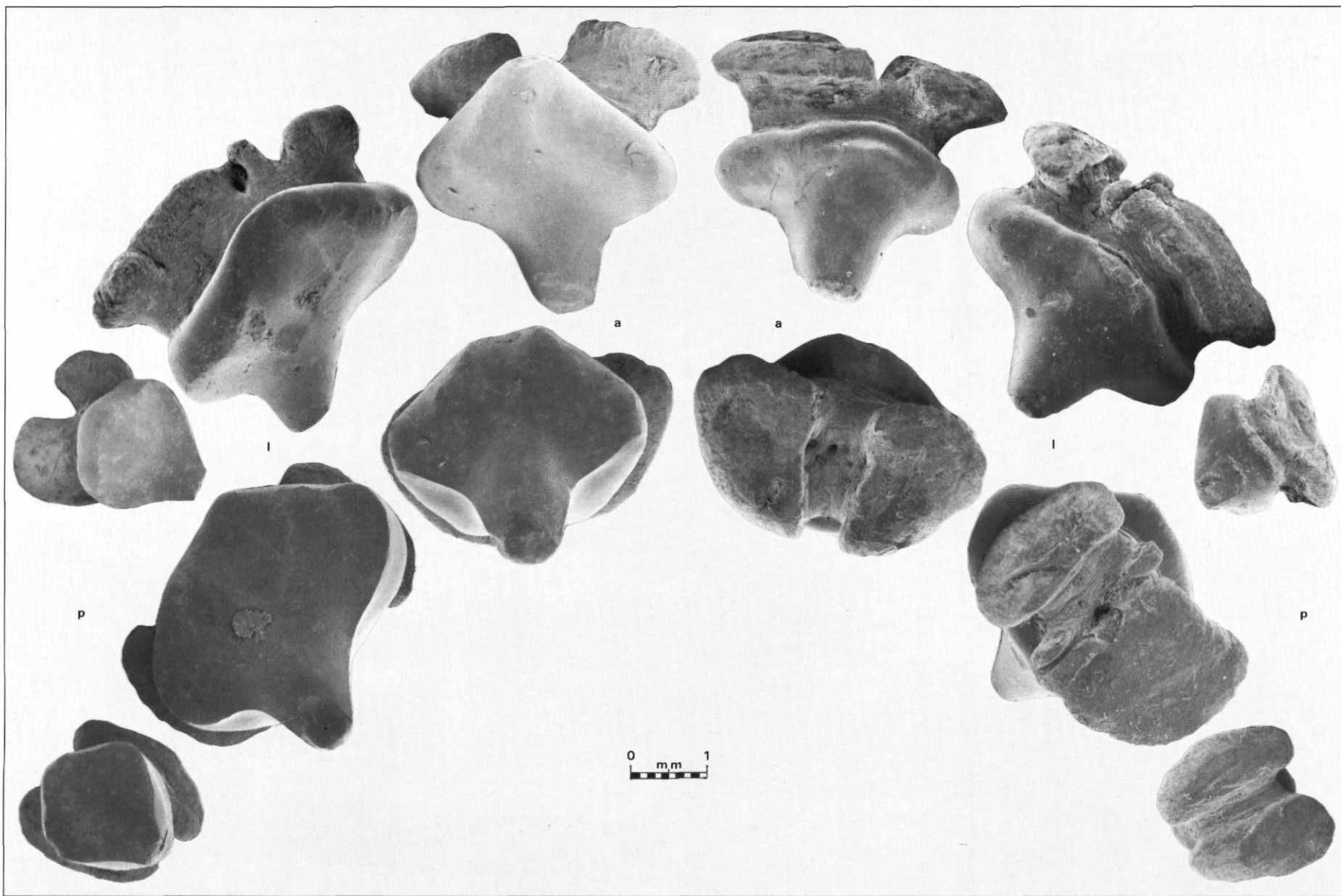


Plate 21. – *Raja (Dipturus) batis* LINNAEUS, 1758. Female 150 cm disc width, North-East Atlantic. Upper teeth.

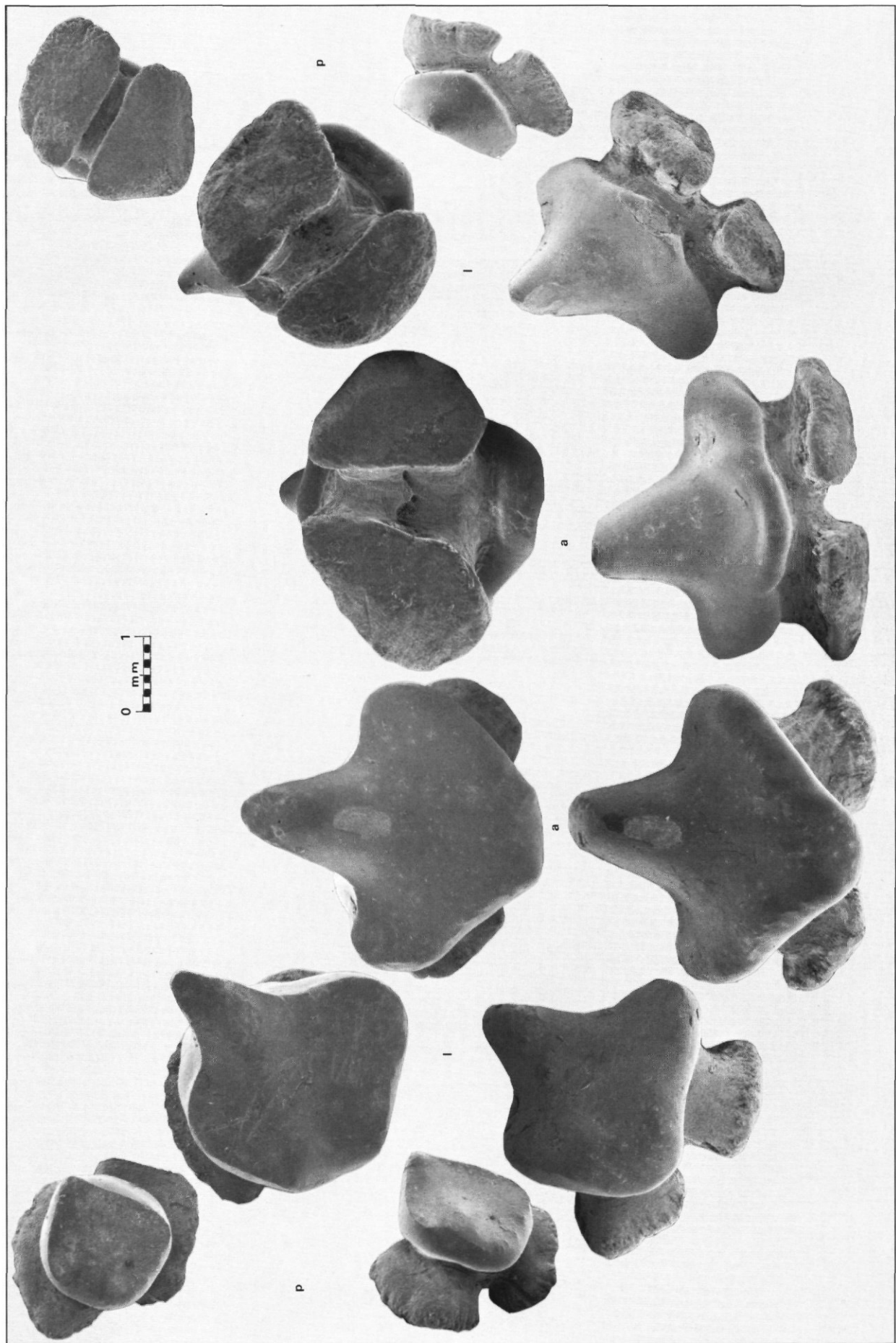


Plate 22. — Raja (Dipturus) batis LINNAEUS, 1758. Female 150 cm disc width, North-East Atlantic. Lower teeth.

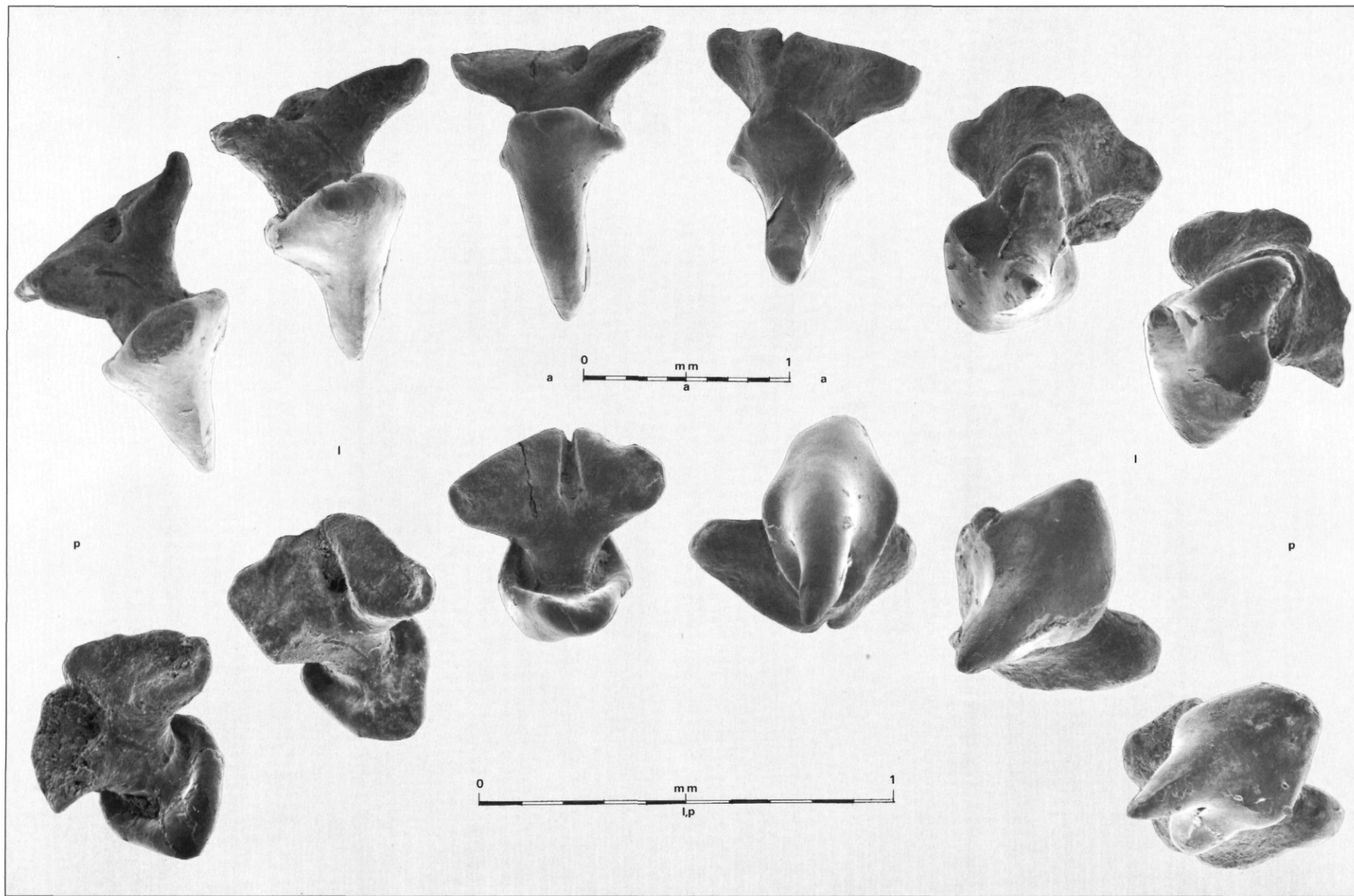


Plate 23. – *Raja* (*Leucoraja*) *naevus* MÜLLER & HENLE, 1841. Male 48 cm (t.l.), North-East Atlantic, West Ireland. Upper teeth.

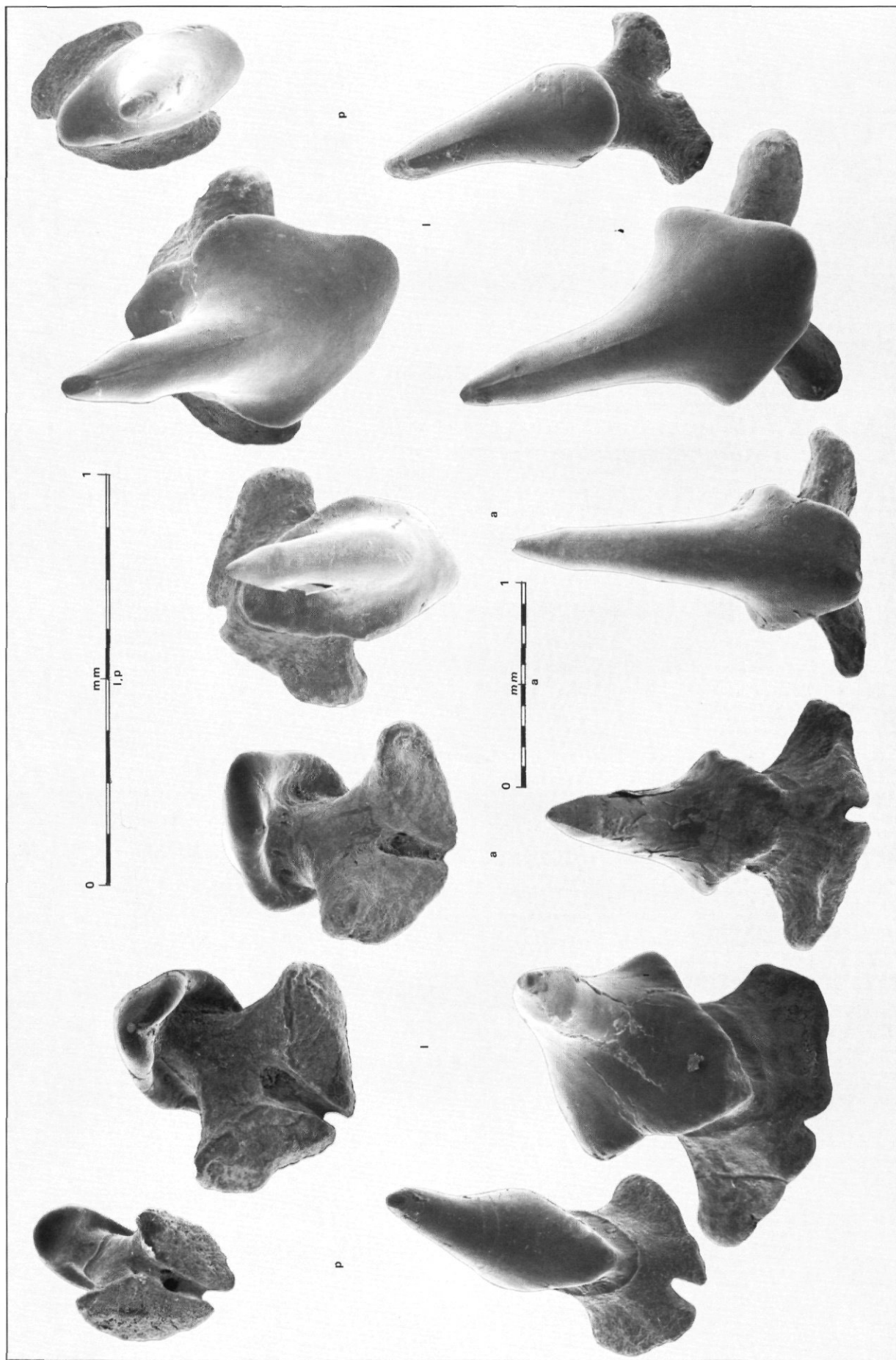


Plate 24. - Raja (Leucoraja) naevus MÜLLER & HENLE, 1841. Male 48 cm (t.l.), North-East Atlantic, West Ireland. Lower teeth.

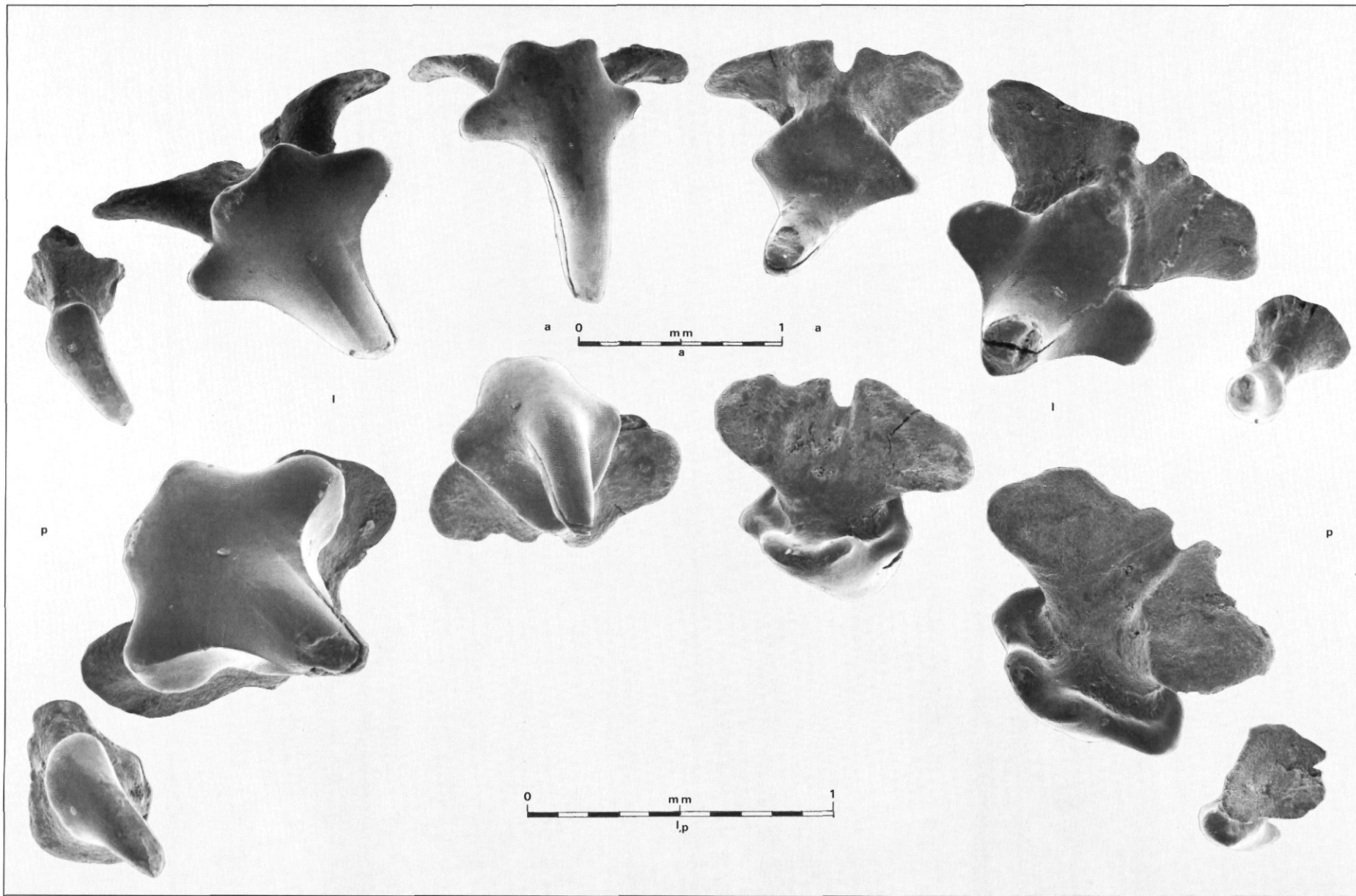


Plate 25. – *Raja* (*Leucoraja*) *naevus* MÜLLER & HENLE, 1841. Female 42 cm disc width, North-East Atlantic. Upper teeth.



Plate 26. - Raja (Leucoraja) naevus MÜLLER & HENLE, 1841. Female 42 cm disc width, North-East Atlantic. Lower teeth.

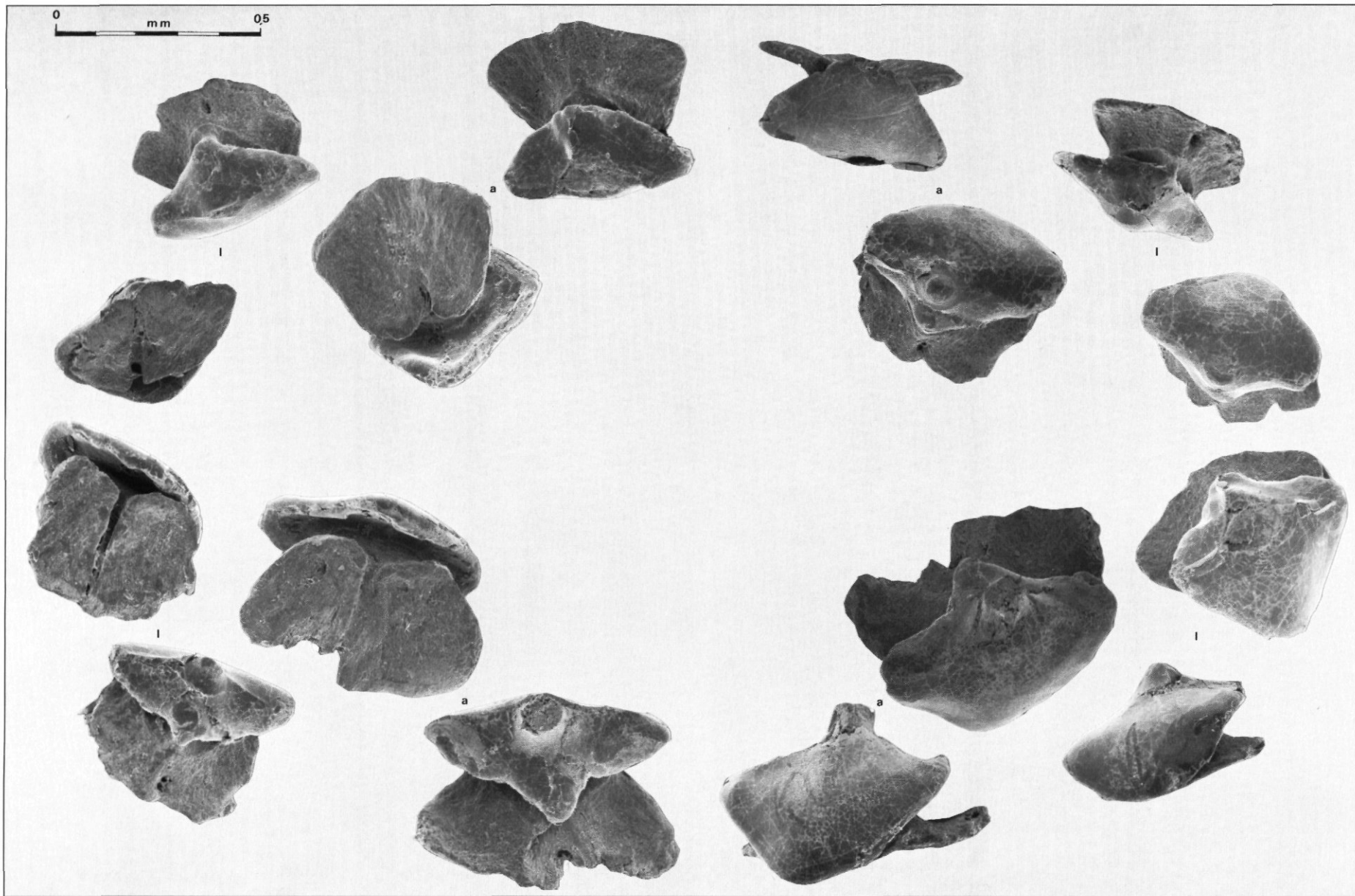


Plate 27. – *Raja* (*Leucoraja*) *naevus* MÜLLER & HENLE, 1841. Male 31 cm (t.l.), North-East Atlantic. Upper and lower teeth.

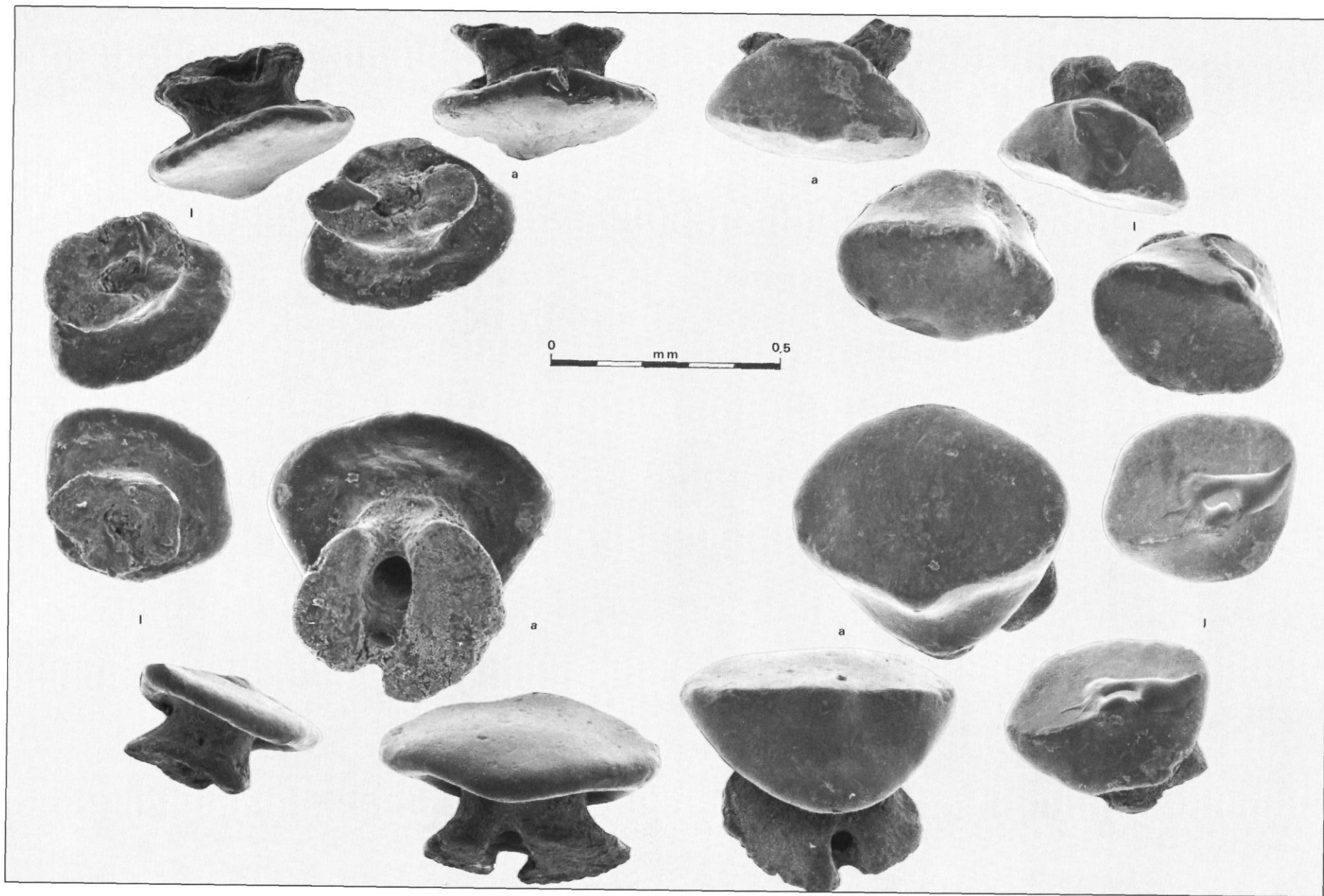


Plate 28. - Raja (Raja) clavata LINNAEUS, 1758. Female 28 cm (t.l.), North-East Atlantic, Irish Sea. Upper and lower teeth.

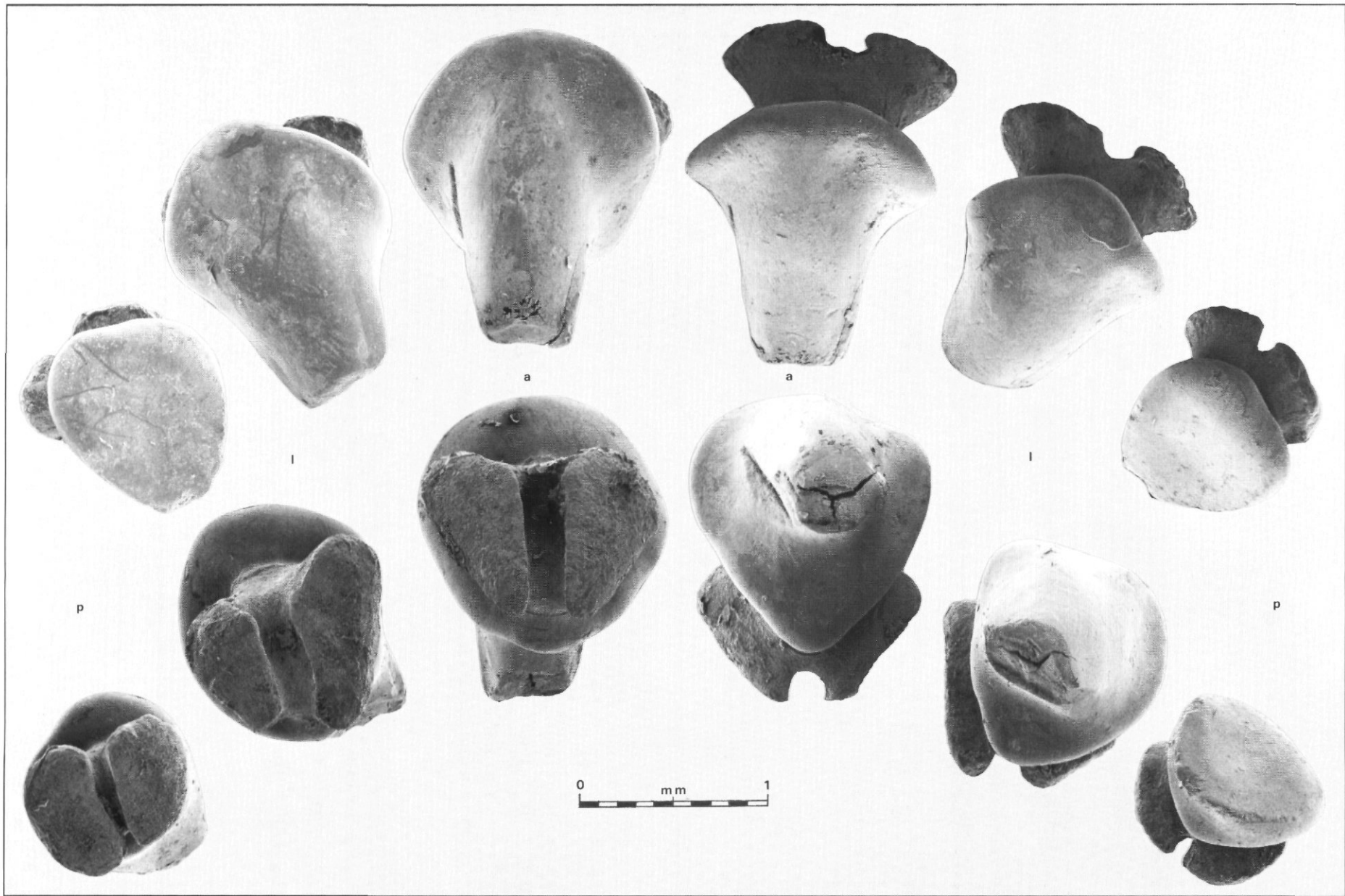


Plate 29. – *Raja (Raja) clavata* LINNAEUS, 1758. Male 77 cm (t.l.), North-East Atlantic, North Sea. Upper teeth.

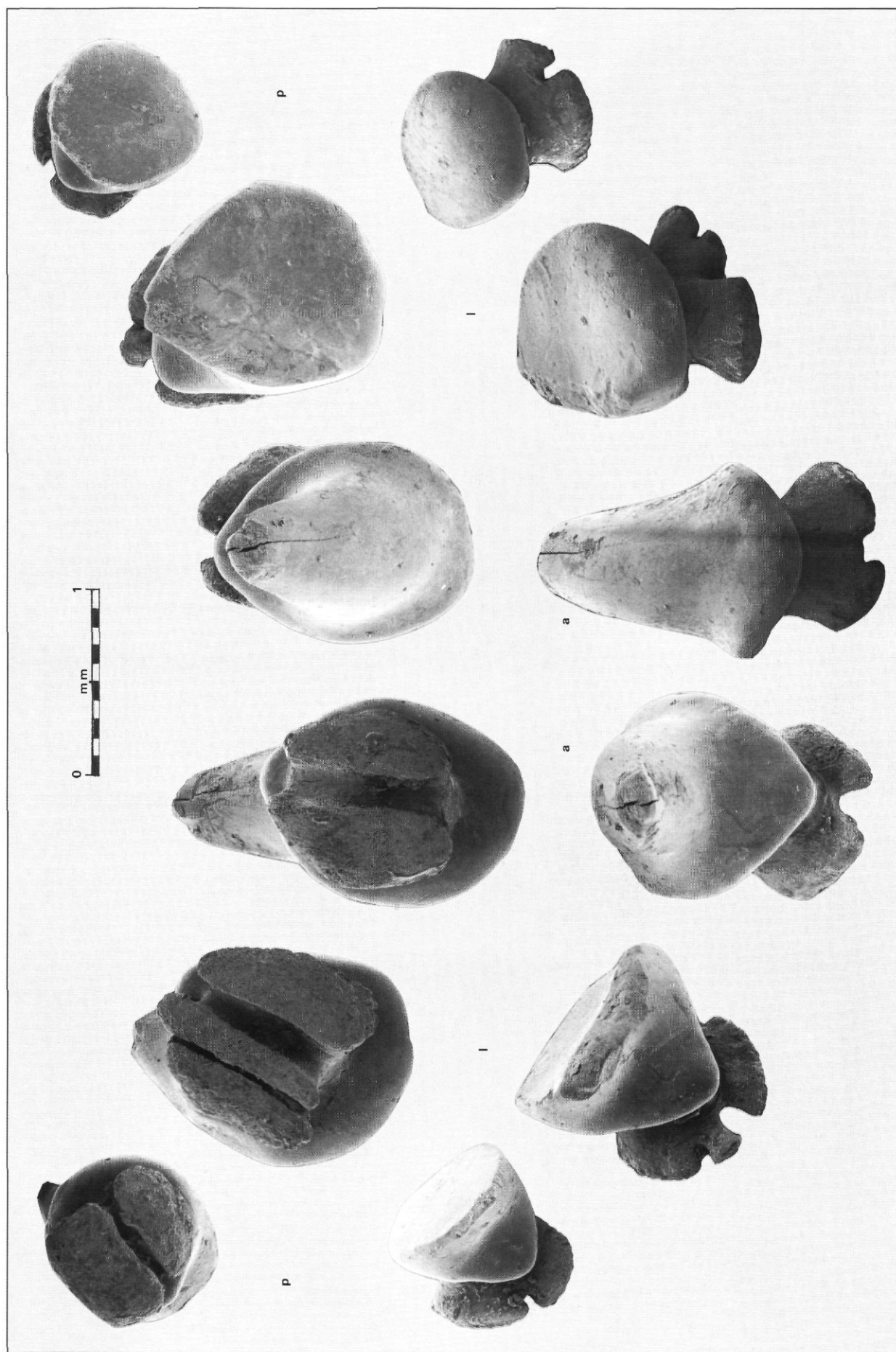


Plate 30. — Raja (Raja) clavata LINNAEUS, 1758. Male 77 cm (t.l.), North-East Atlantic, North Sea. Lower teeth.

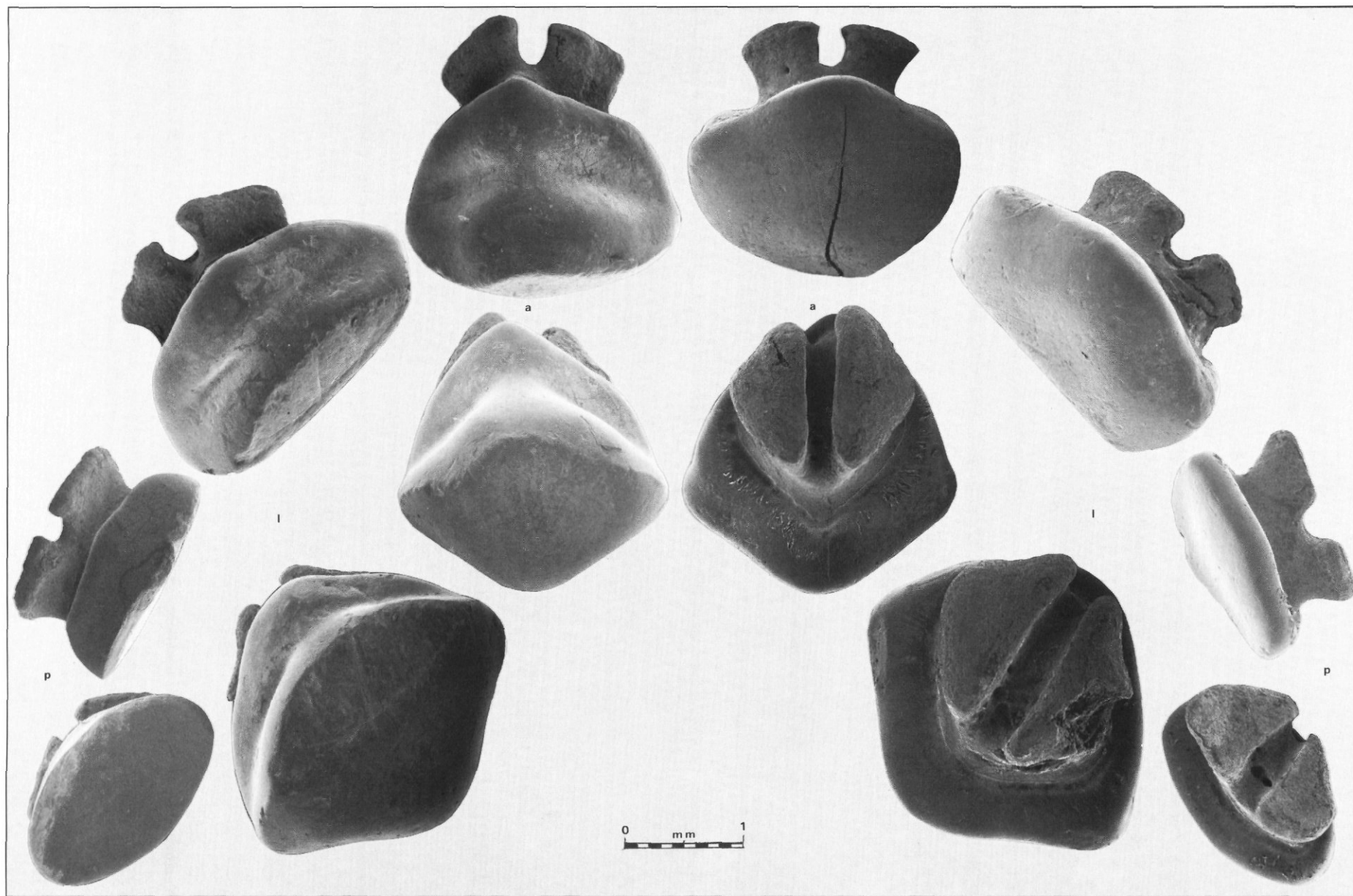


Plate 31. – Raja (Raja) clavata LINNAEUS, 1758. Female 88 cm (t.l.), North-East Atlantic, off Ireland. Upper teeth.

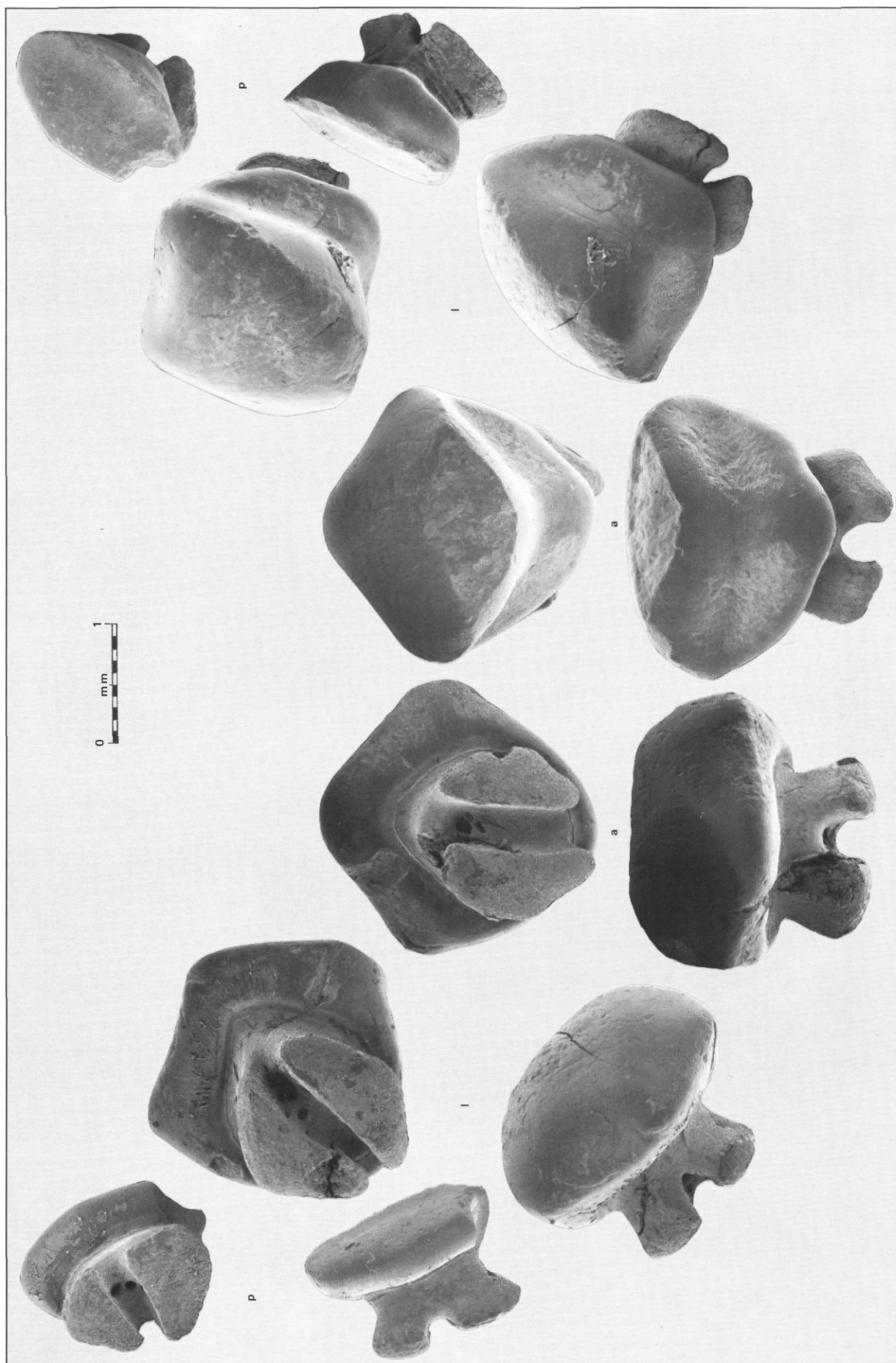


Plate 32. - Raja (Raja) clavata LINNAEUS, 1758. Female 88 cm (t.l.), North-East Atlantic, off Ireland. Lower teeth.



Plate 33. — *Raja (Rajella) bathyphila* HOLT & BYRNE, 1908. Male 88 cm (t.l.), North-East Atlantic, off Scotland. Upper and lower teeth.

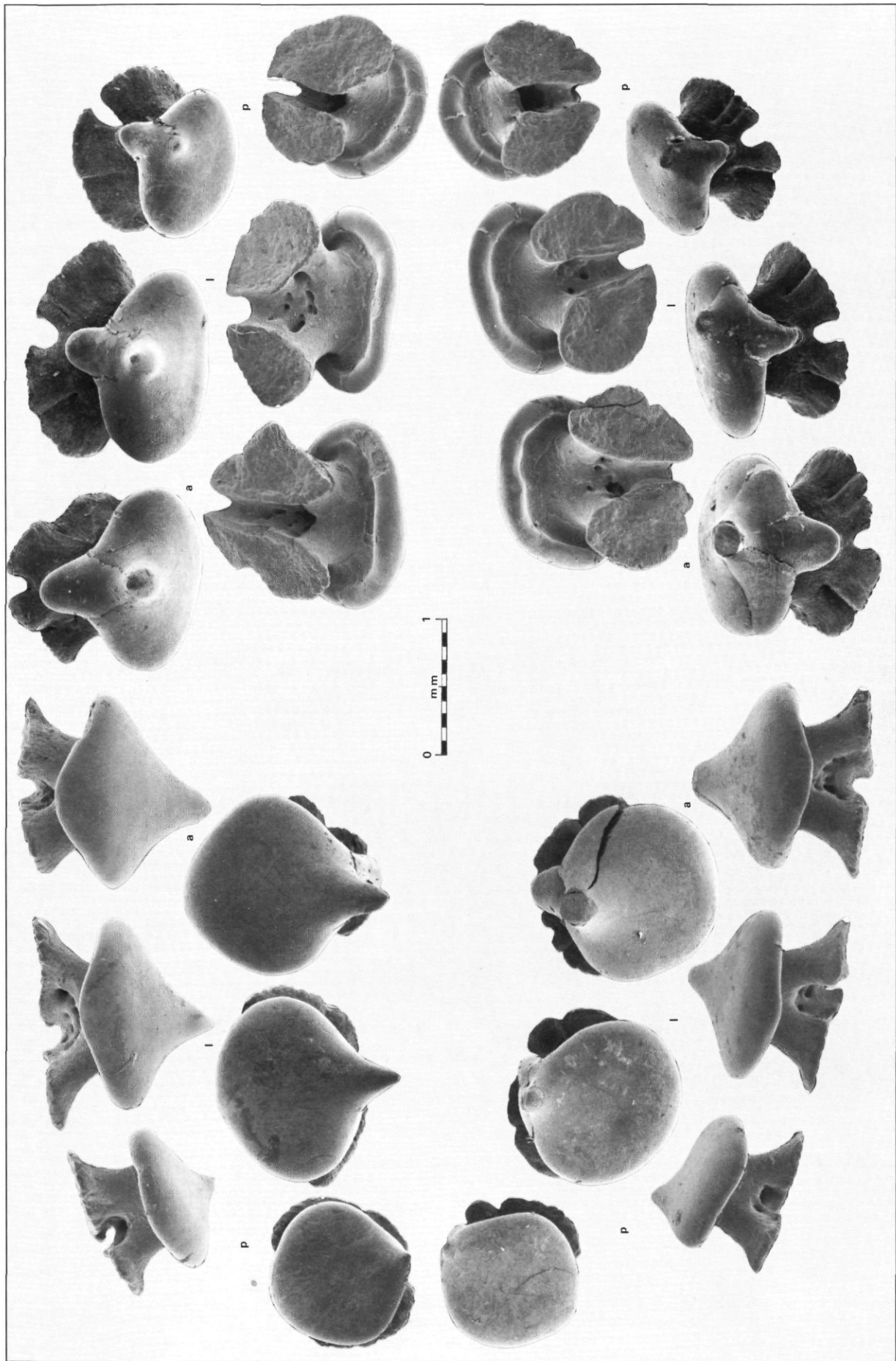


Plate 34. - Raja (Rajella) bathyphila HOLT & BYRNE, 1908. Female 77 cm (l.l.), North-East Atlantic, off Scotland. Upper and lower teeth.



Plate 35. – *Raja (Rajella) bathyphila* HOLT & BYRNE, 1908. Male 32,5 cm (t.l.), North-East Atlantic, Denmark Strait. Upper and lower teeth.

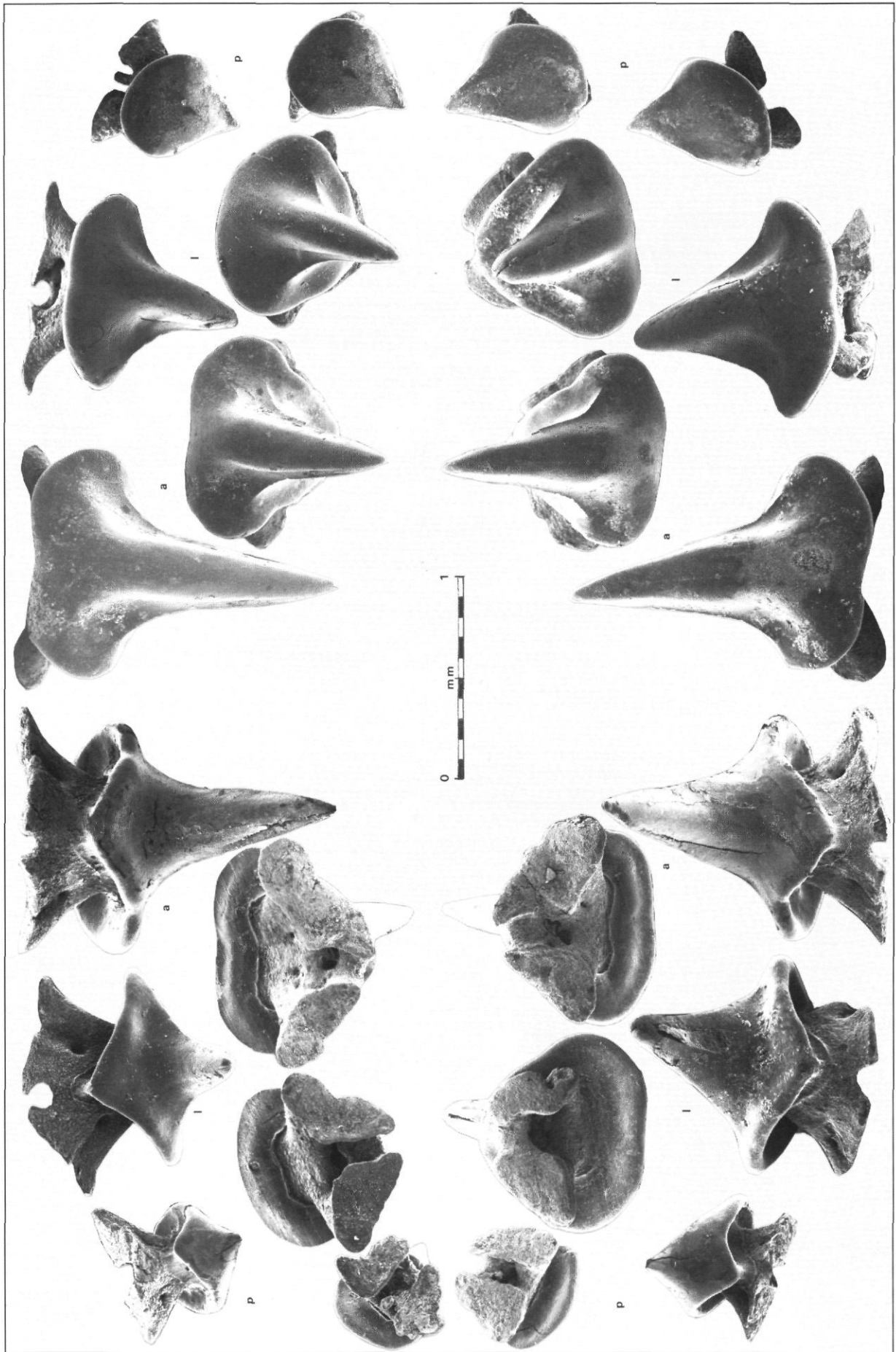


Plate 36. - Raja (Rajella) fyllae LÜTKEN, 1888. Male 28 cm disc width, North-East Atlantic, North Ireland. Upper and lower teeth.

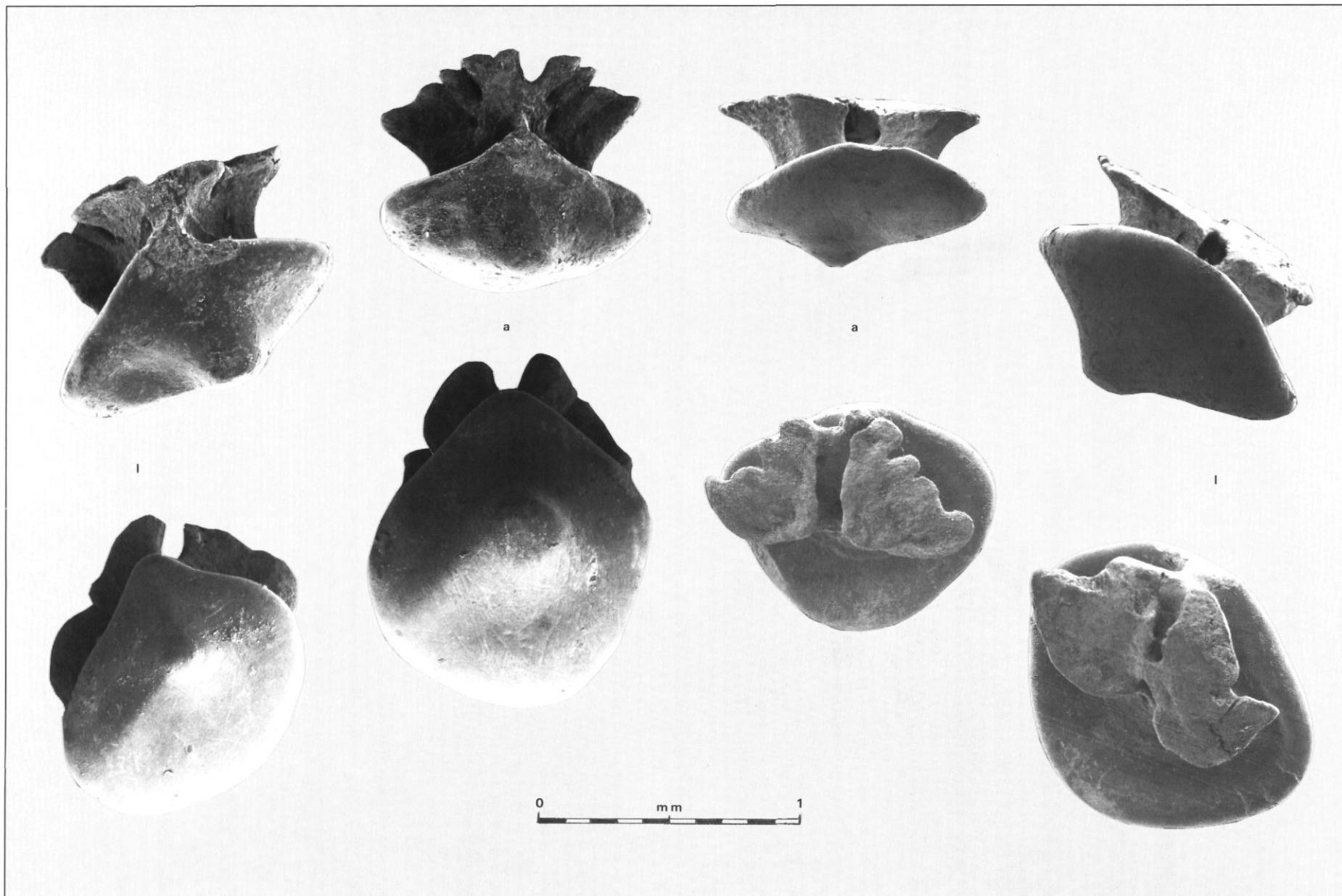


Plate 37. – *Raja (Rajella) fyllae* LÜTKEN, 1888. Male 27 cm (t.l.), North-East Atlantic, North Ireland. Upper teeth.

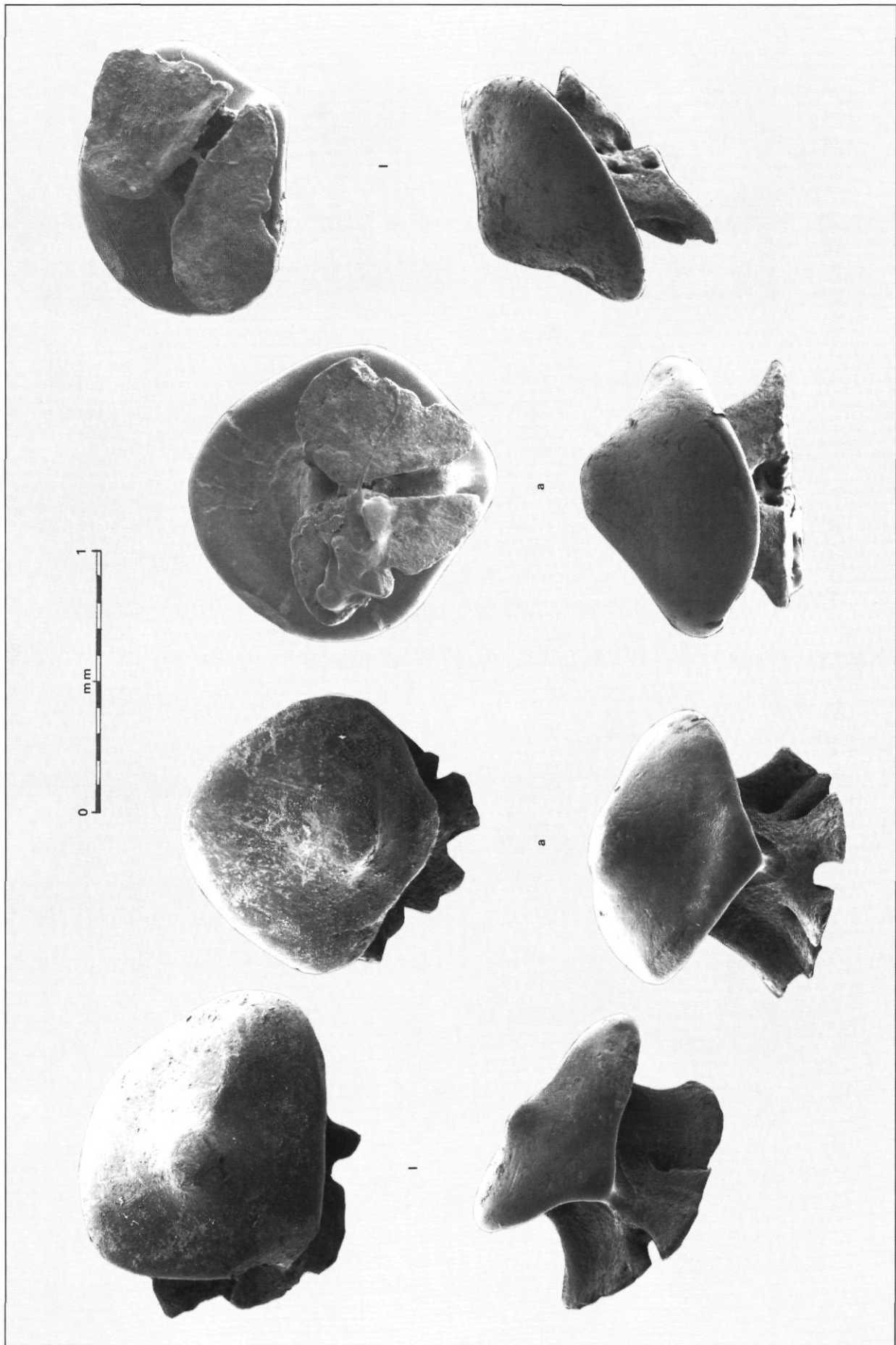


Plate 38. — Raja (Rajella) fyllae LÜTKEN, 1888. Male 27 cm (t.l.), North-East Atlantic, North-Ireland. Lower teeth.

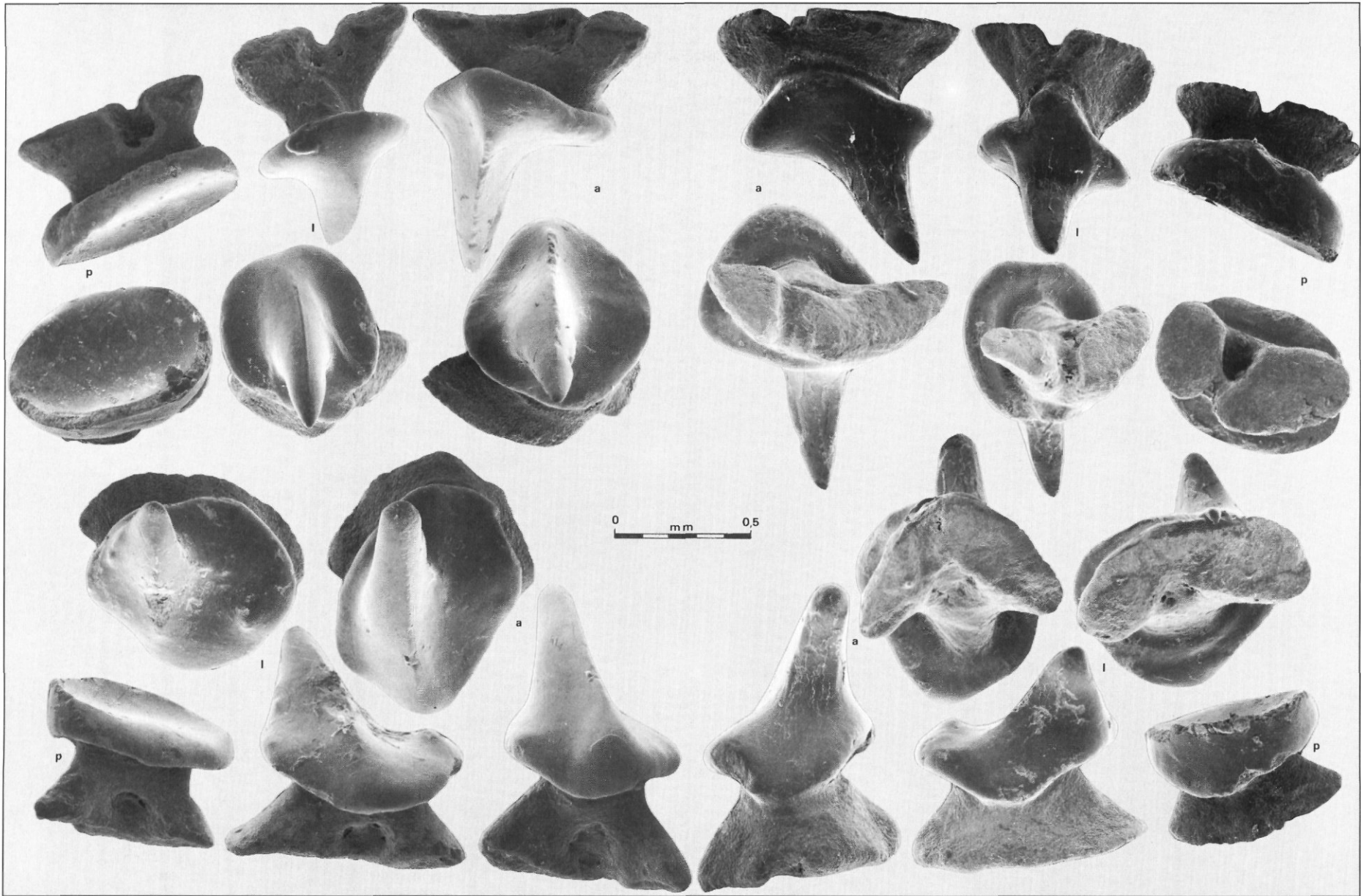


Plate 39. – *Raja* (*Rioraja*) *agassizi* (MÜLLER & HENLE, 1841). Male 48 cm (t.l.) South Atlantic, Rio de la Plata. Upper and lower teeth.

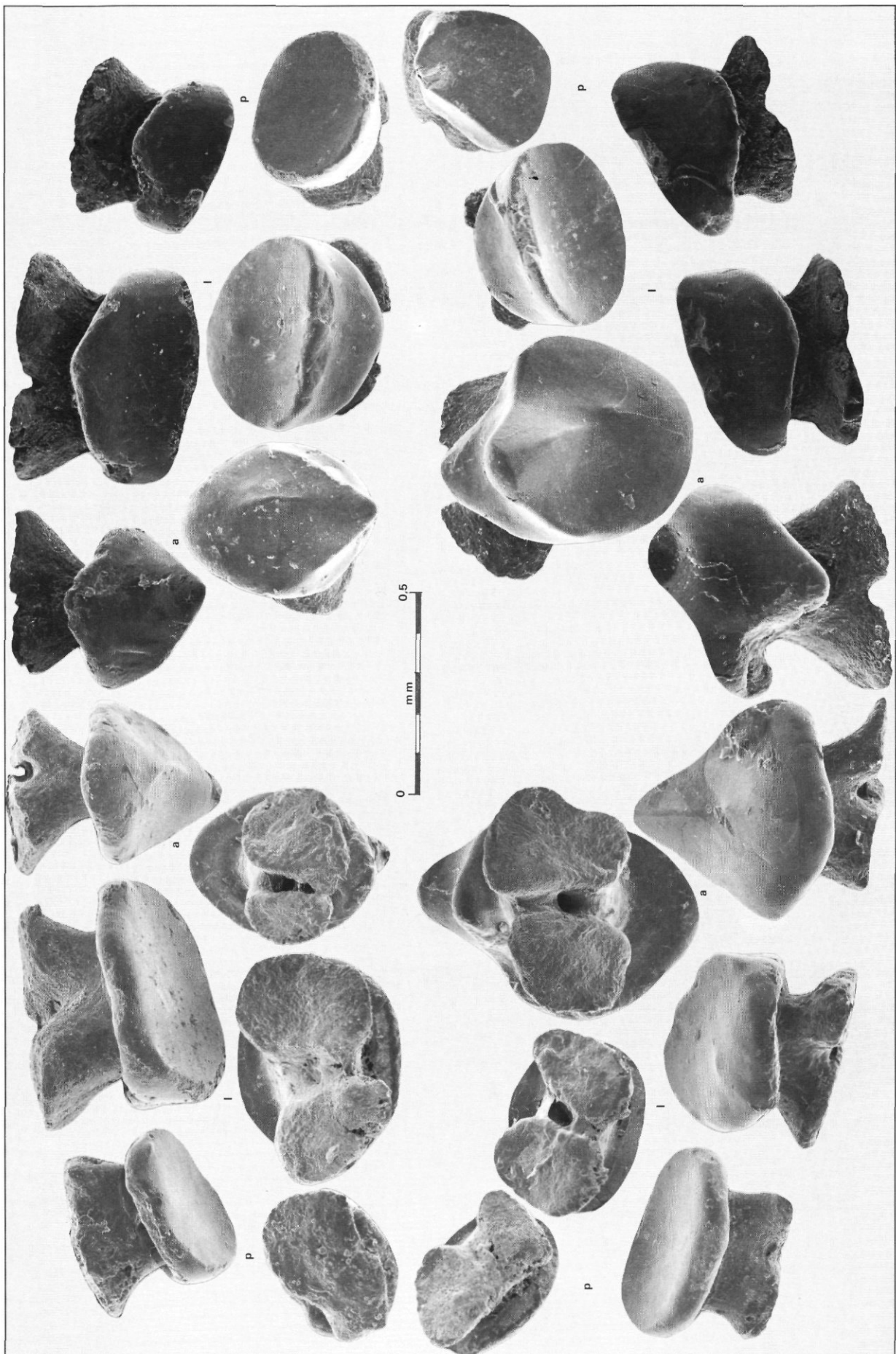


Plate 40. - Raja (Rioraja) agassizi (MÜLLER & HENLE, 1841). Female 42 cm (t.l.), South Atlantic, Rio de la Plata. Upper and lower teeth.

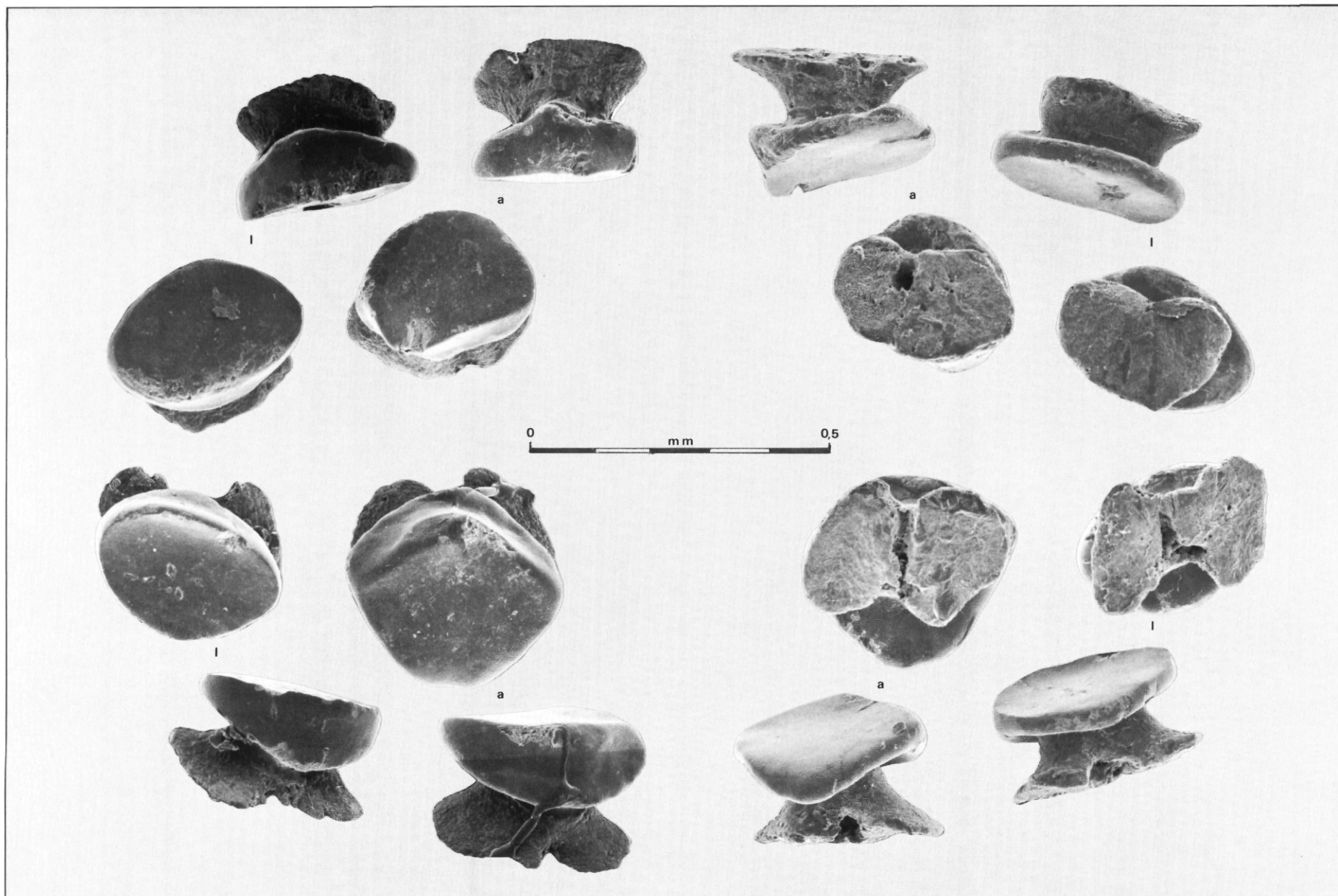


Plate 41. – *Raja* (*Rioraja*) *agassizi* (MÜLLER & HENLE, 1841). Male 27 cm (t.l.), South Atlantic, Rio de la Plata. Upper and lower teeth.

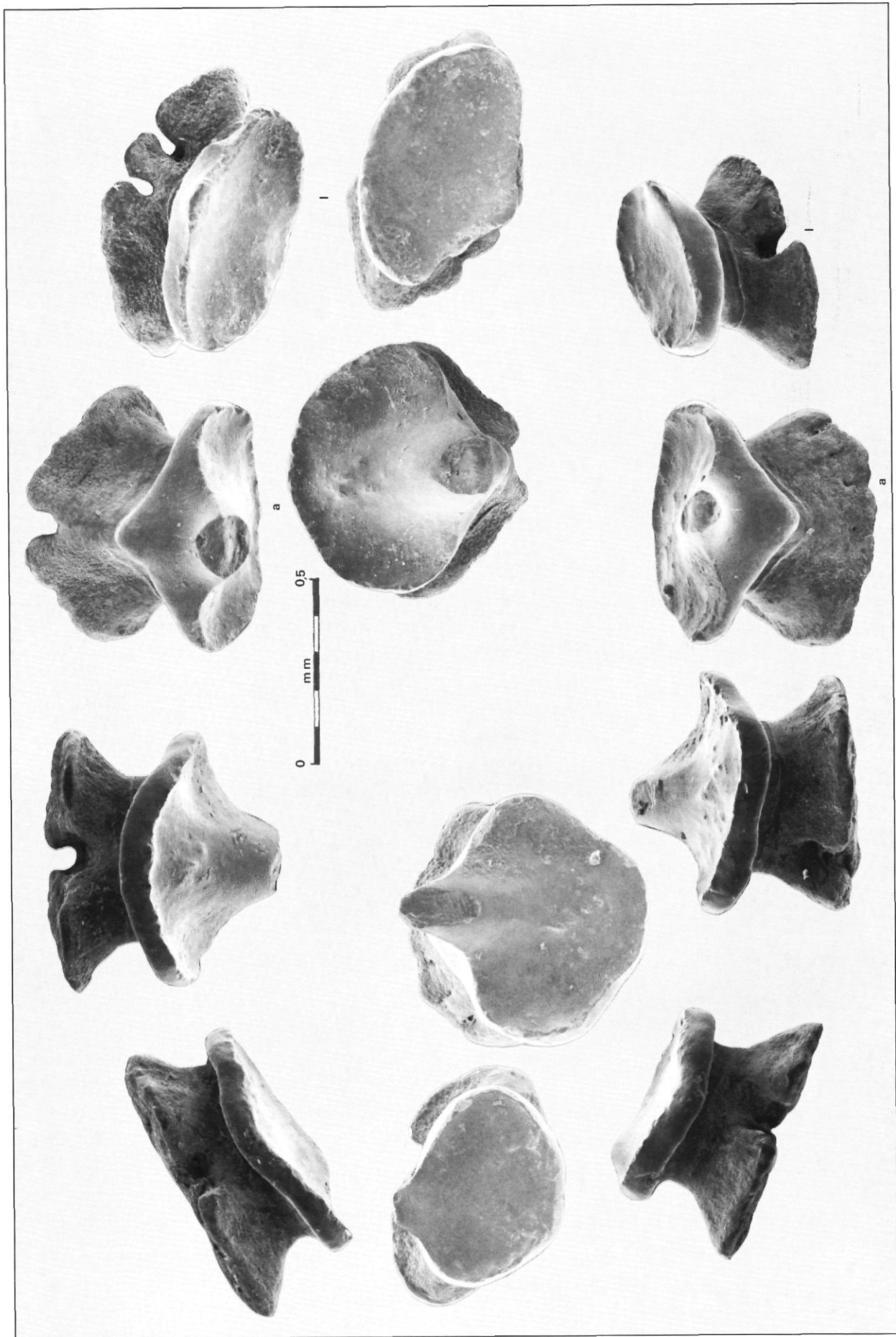


Plate 42. - Raja (Rostroraja) alba LACEPEDE, 1803. Male 41 cm (I.L.), South Atlantic, Mouth of Zaïre River. Upper and lower teeth.



Plate 43. – *Raja (Rostroraja) alba* LACEPEDE, 1803. Male 187 cm (t.l.), South Africa, Western Cape. Upper teeth.

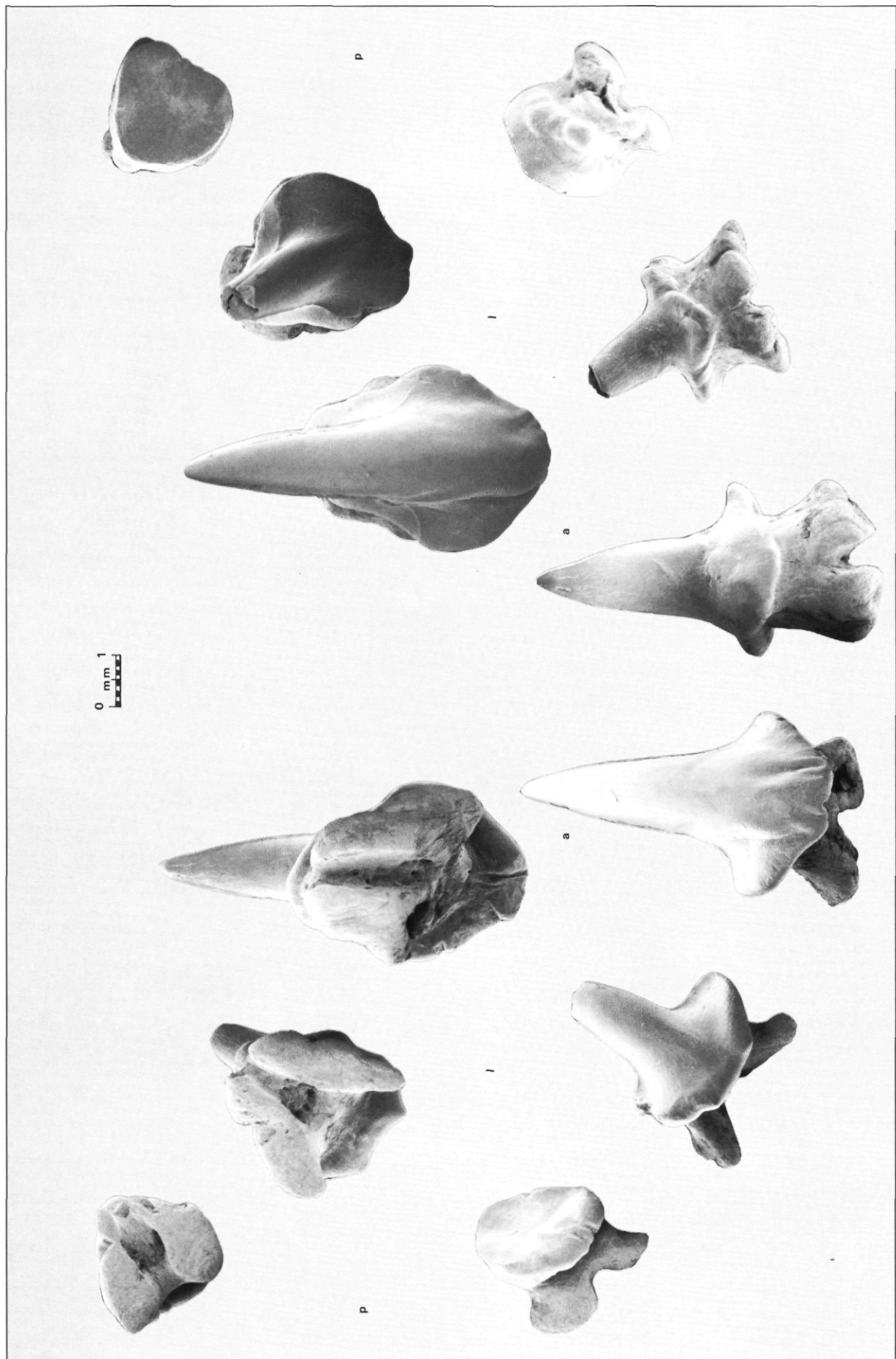


Plate 44. - Raja (Rostroraja) alba LACEPEDE, 1803. Male 187 cm (t.l.). South Africa, Western Cape. Lower teeth.

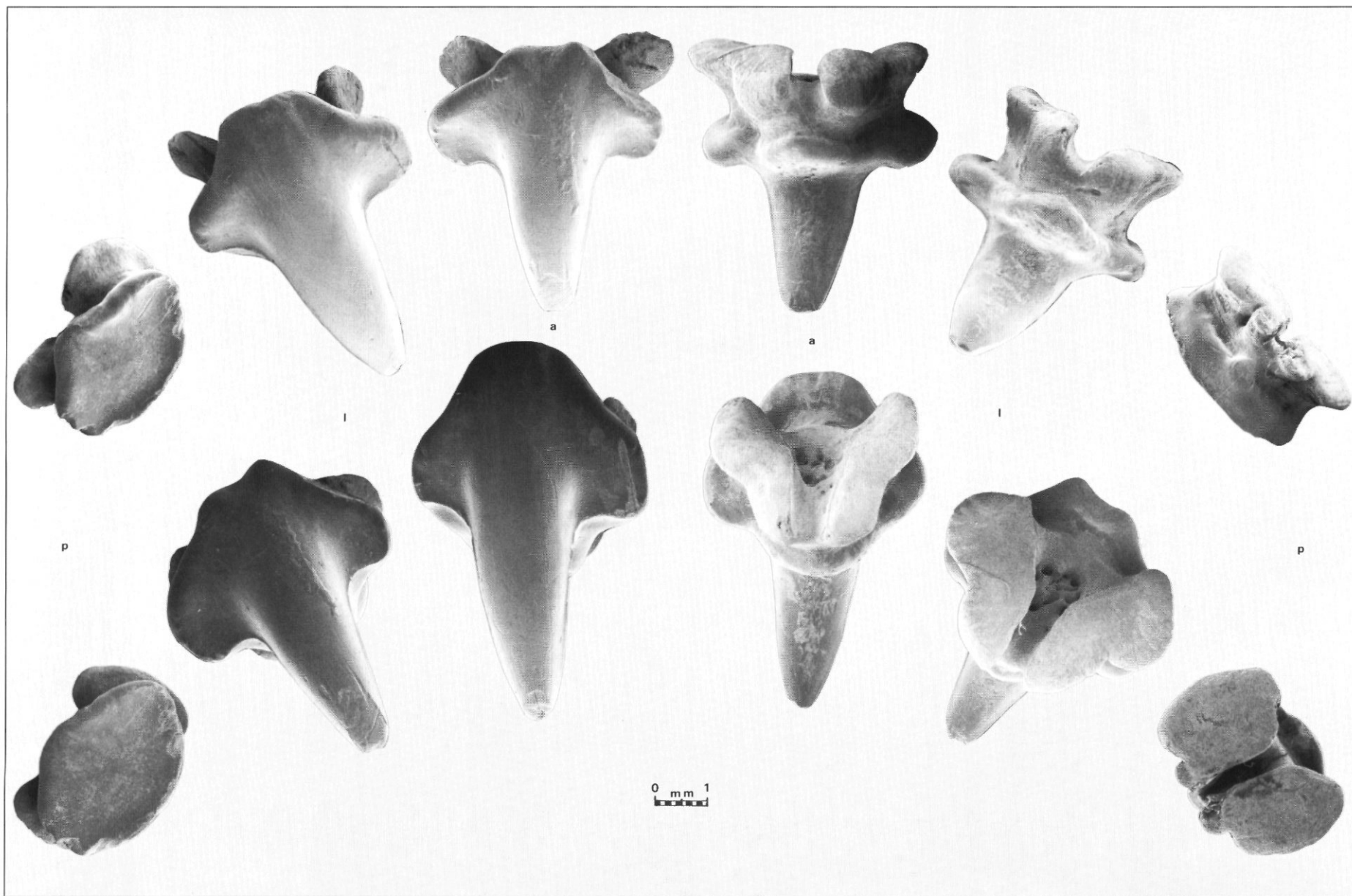


Plate 45. – Raja (Rostroraja) alba LACEPEDE, 1803. Female 215 cm (t.l.), South Africa, Western Cape. Upper teeth.

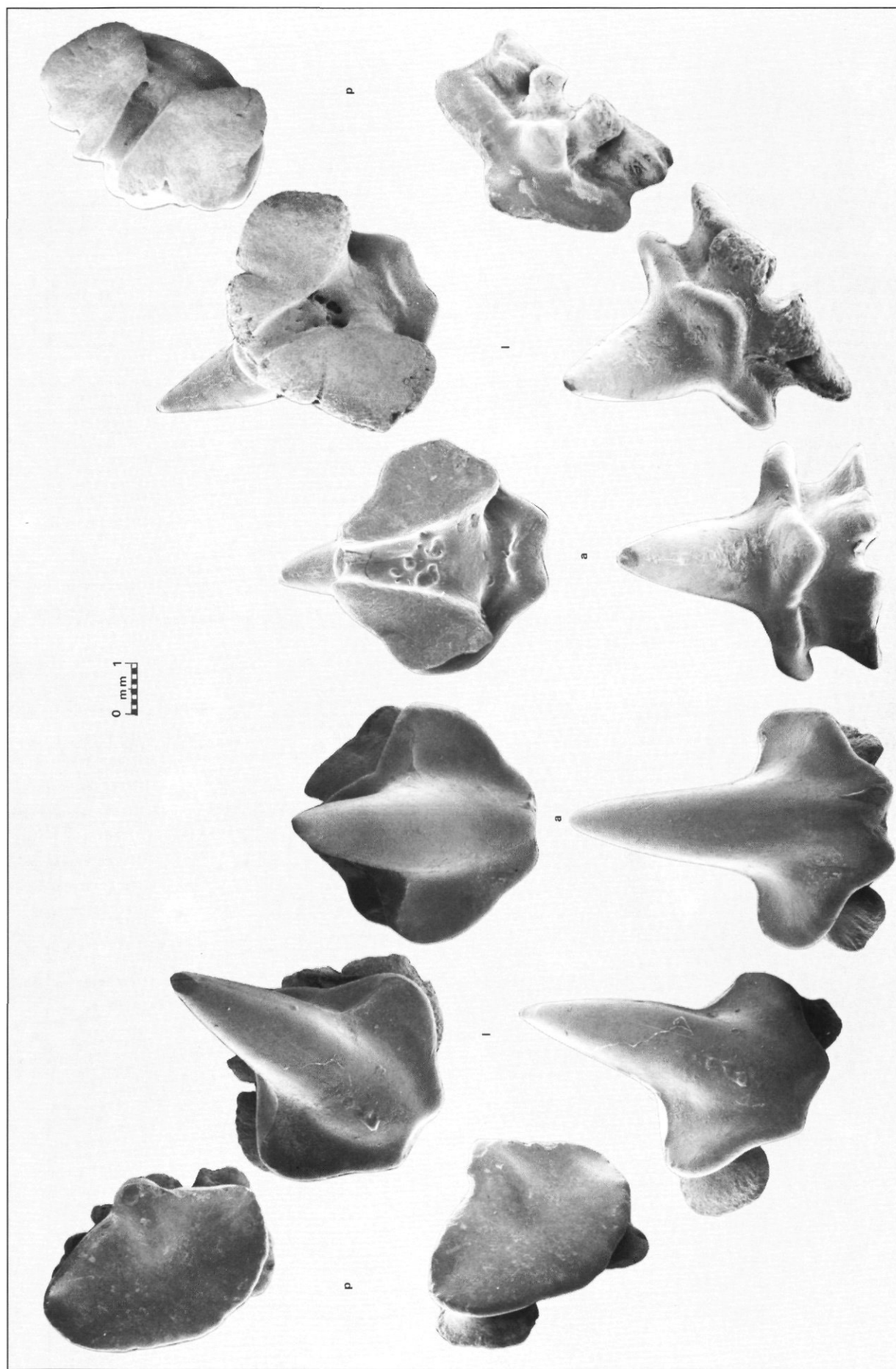


Plate 46. - Raja (Rostroraja) alba LACEPEDE, 1803. Female 215 cm (t.l.), South Africa, Western Cape. Lower teeth.

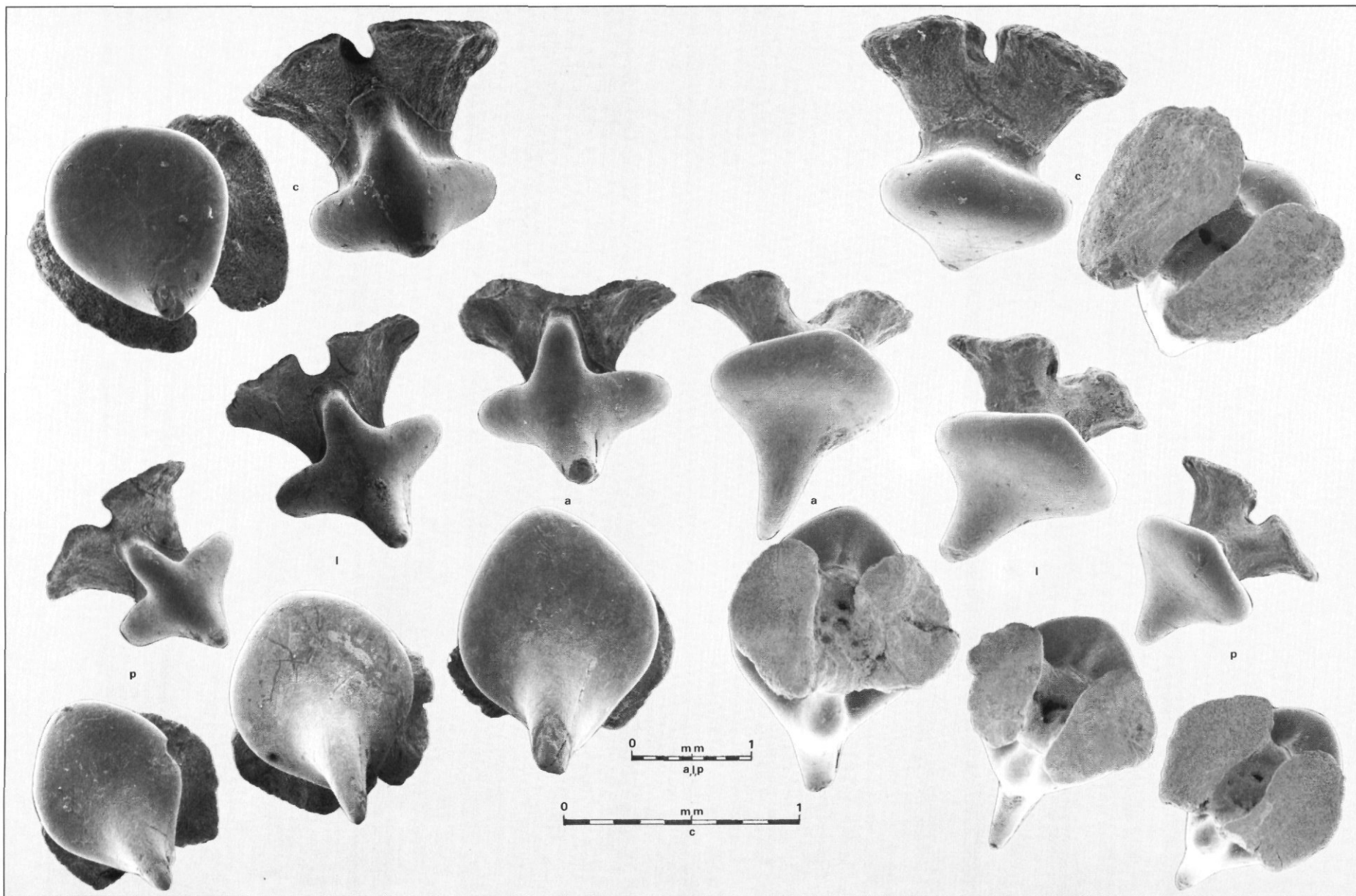


Plate 47. — *Raja lintea* FRIES, 1838. Male 95 cm (t.l.), North Atlantic. Upper teeth.

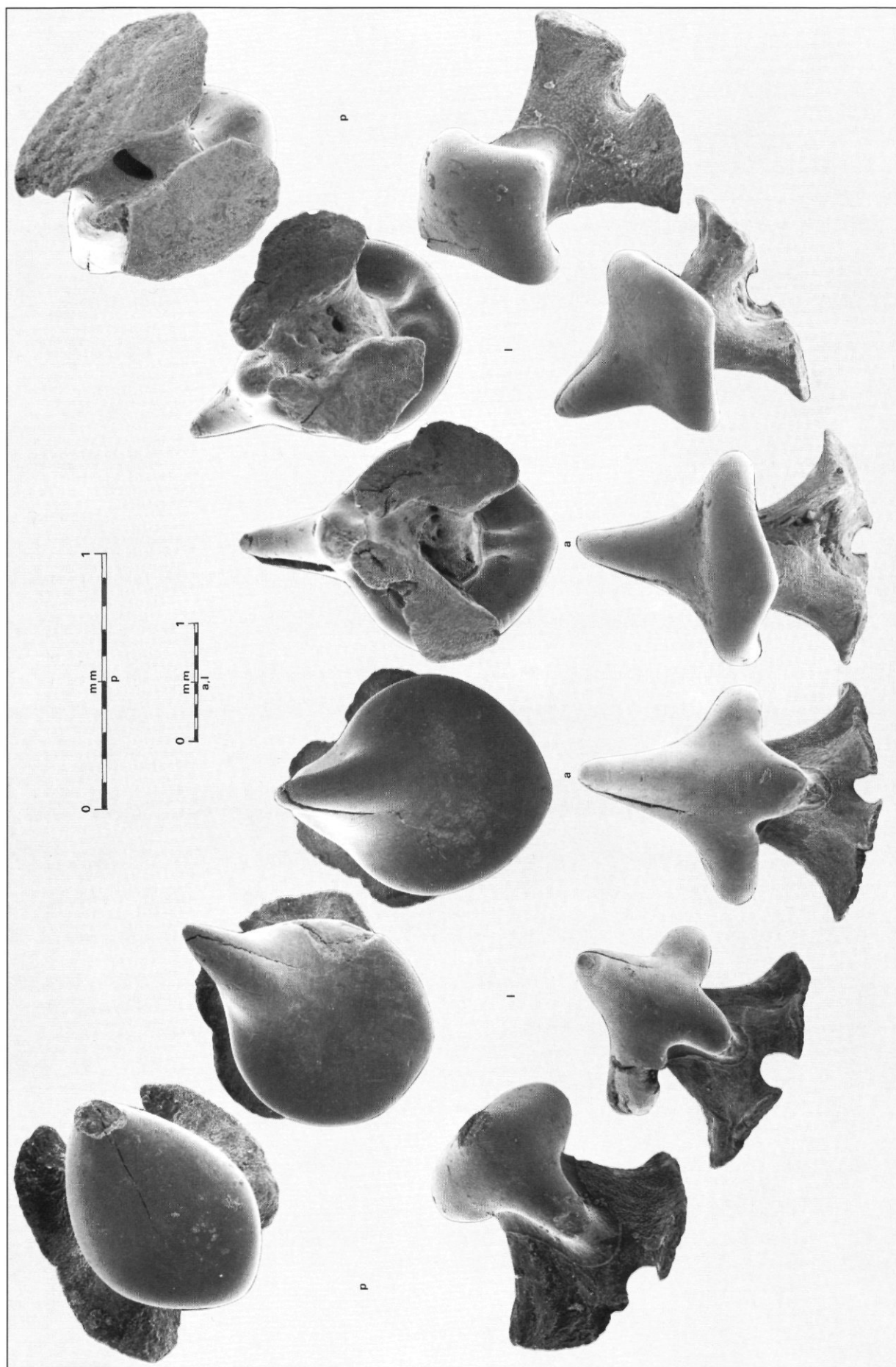


Plate 48. — *Raja lintea* FRIES, 1838. Male 95 cm (t.l.), North Atlantic. Lower teeth.

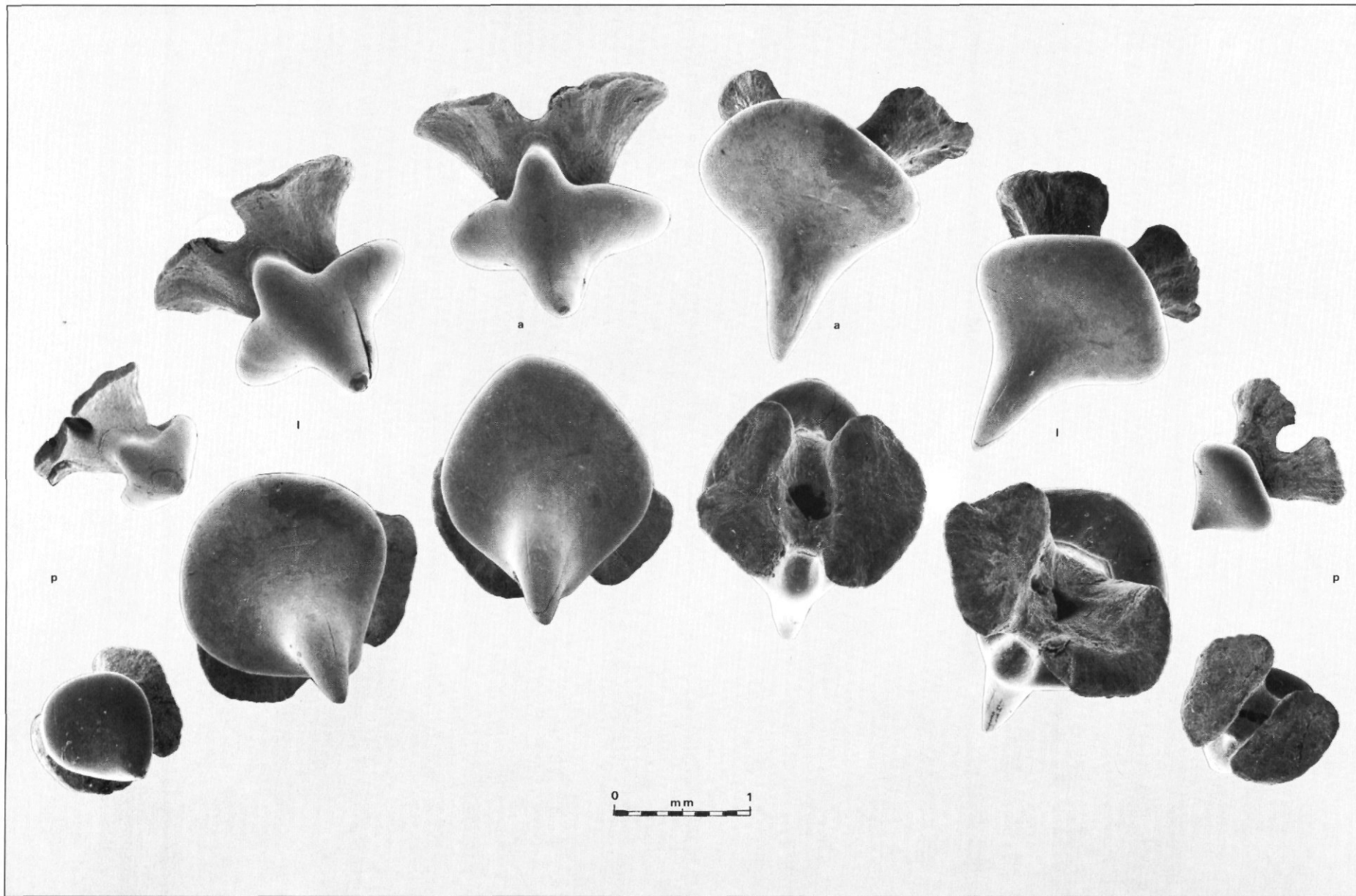


Plate 49. — *Raja lintea* FRIES, 1838. Female 110 cm (t.l.), North Atlantic. Upper teeth.

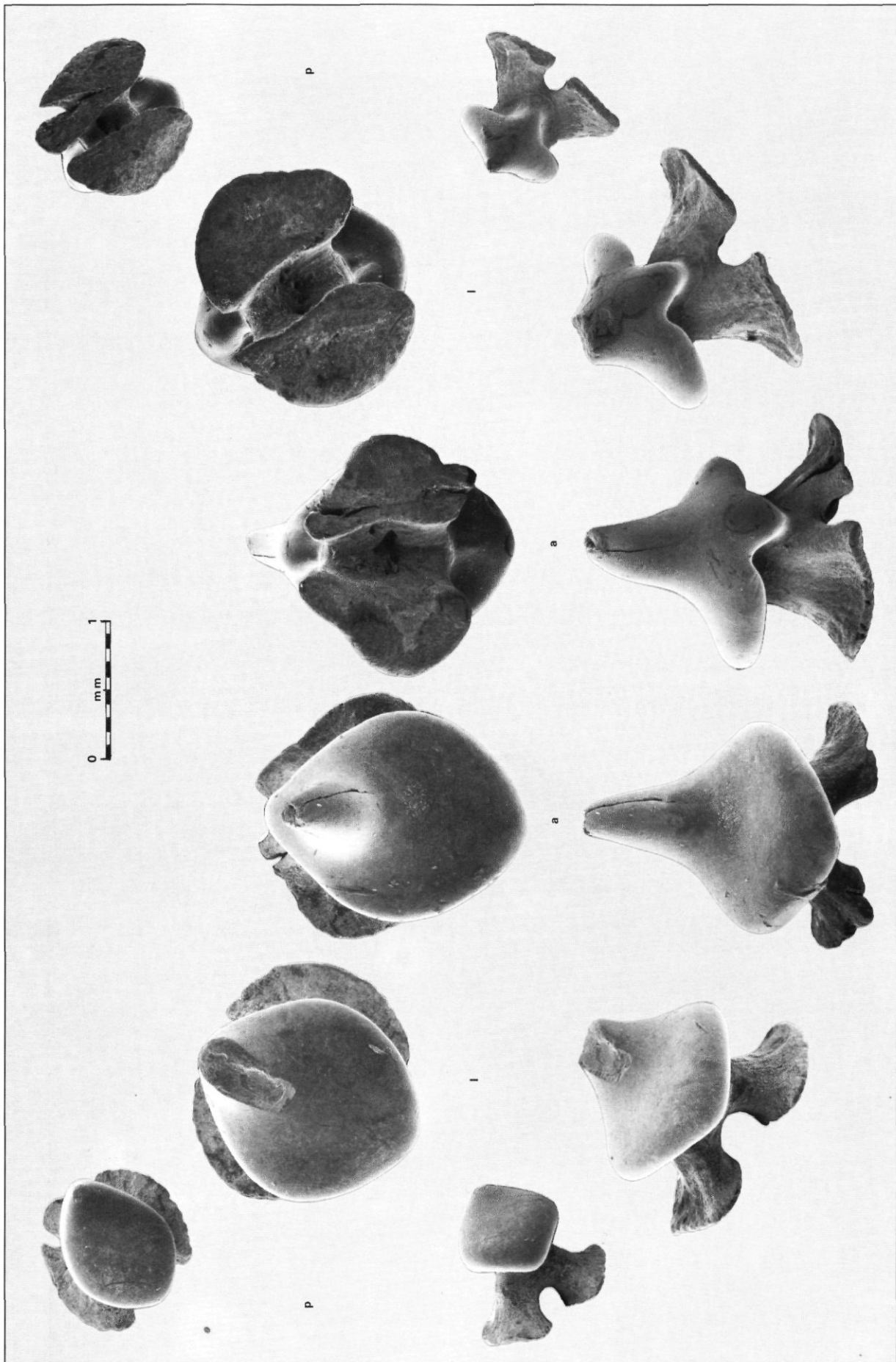


Plate 50. - *Raja lintea* FRIES, 1838. Female 110 cm (t.l.), North Atlantic. Lower teeth.

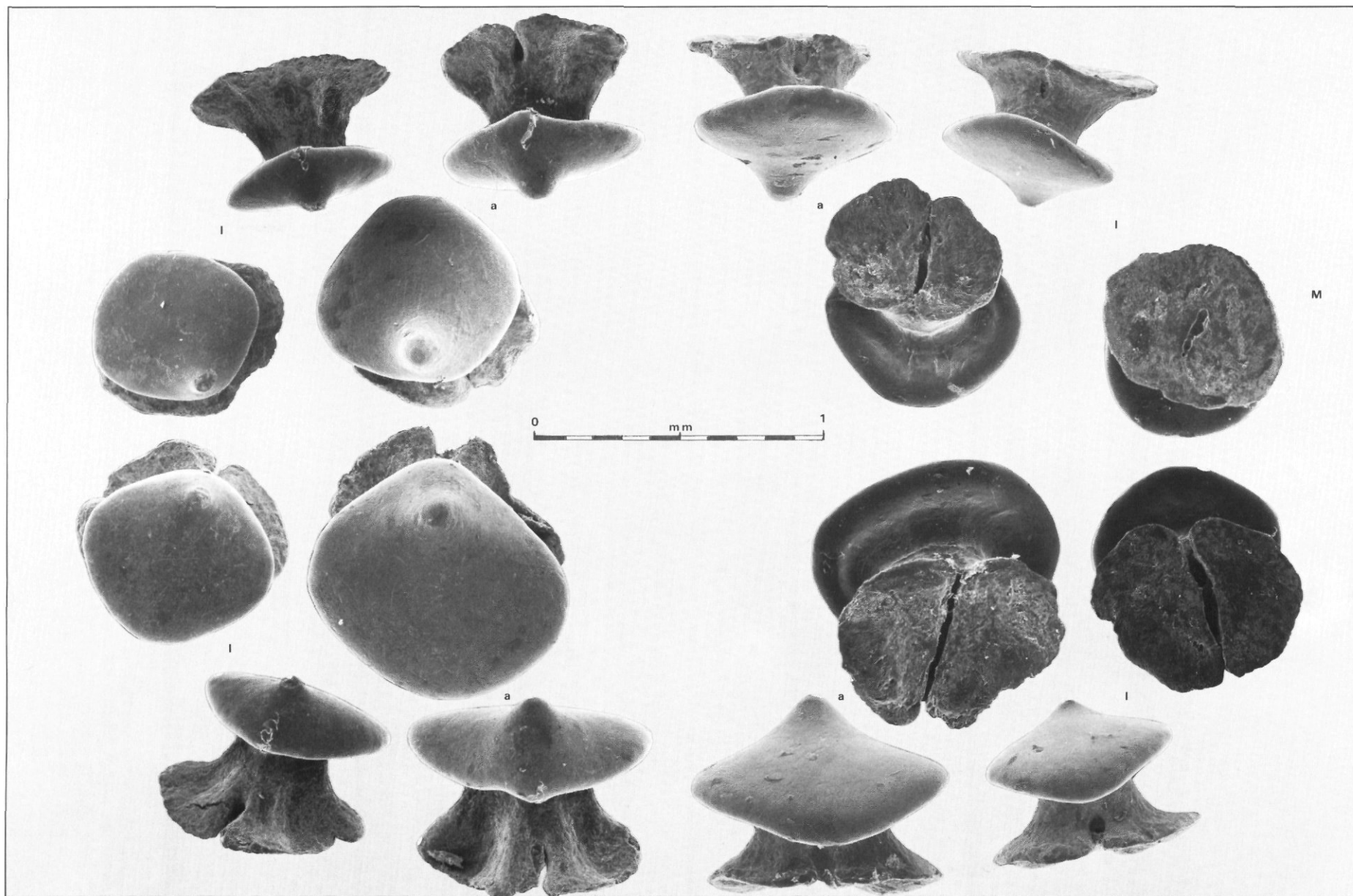


Plate 51. – *Raja lintea* FRIES, 1838. Male 47,5 cm (t.l.), North-West Atlantic, West Greenland. Upper and Lower teeth.

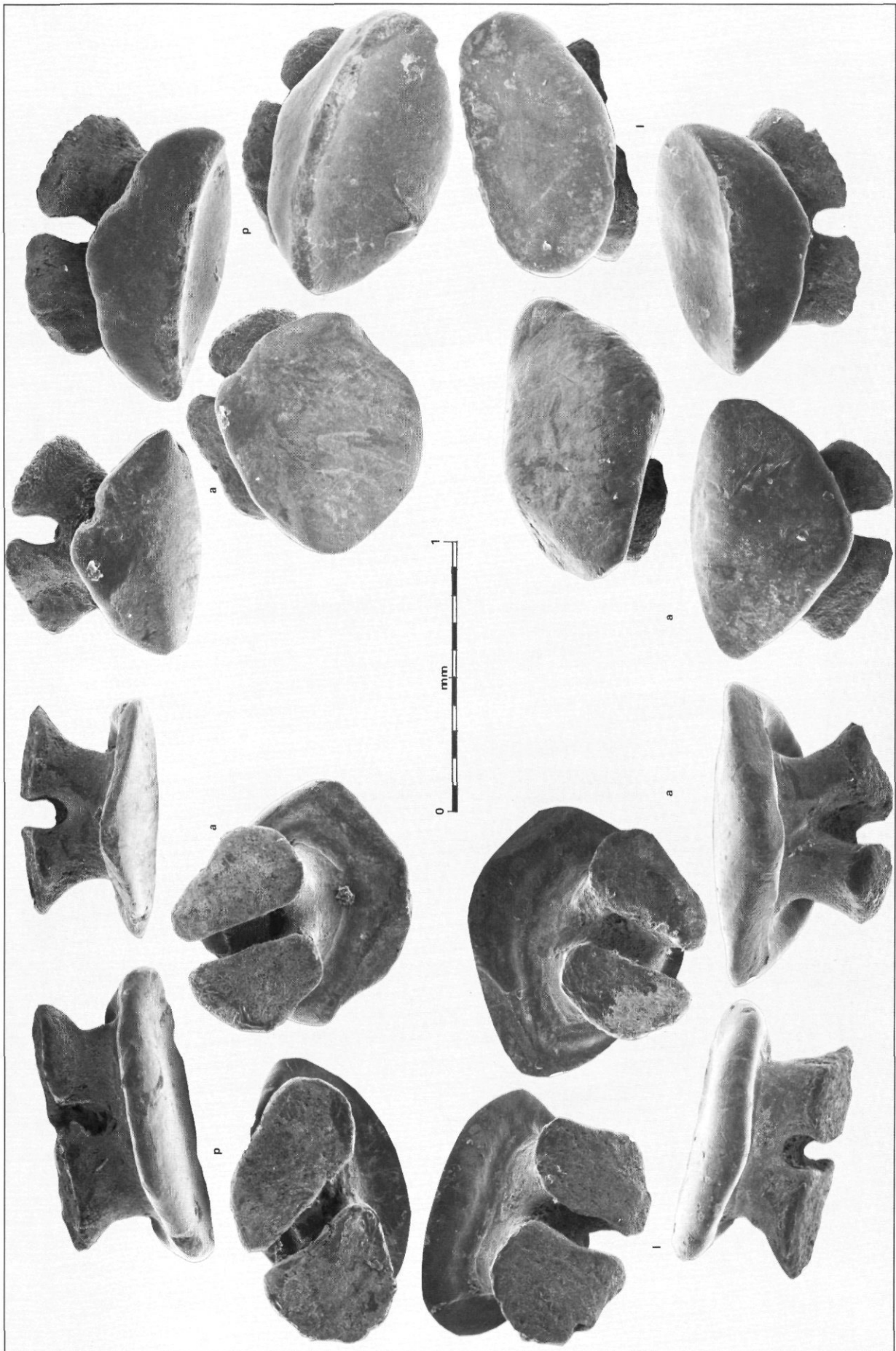


Plate 52. - *Sympterygia bonapartei* MÜLLER & HENLE, 1841. Male 43 cm (l.l.), South Atlantic, North Argentina. Upper and Lower teeth.

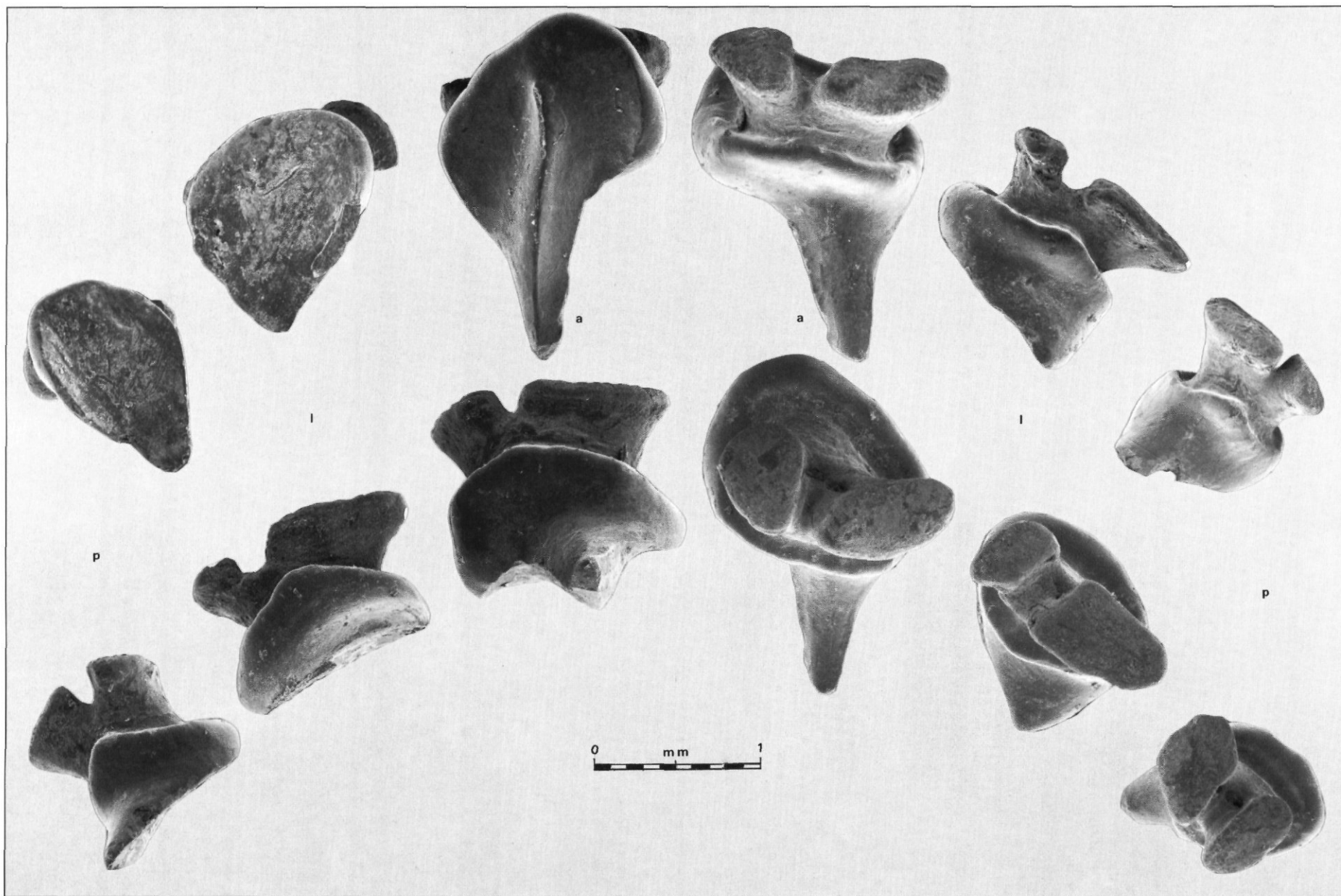


Plate 53. – *Sympterygia bonapartei* MÜLLER & HENLE, 1841. Male 57 cm (t.l.), South Atlantic, North Argentina. Upper teeth.

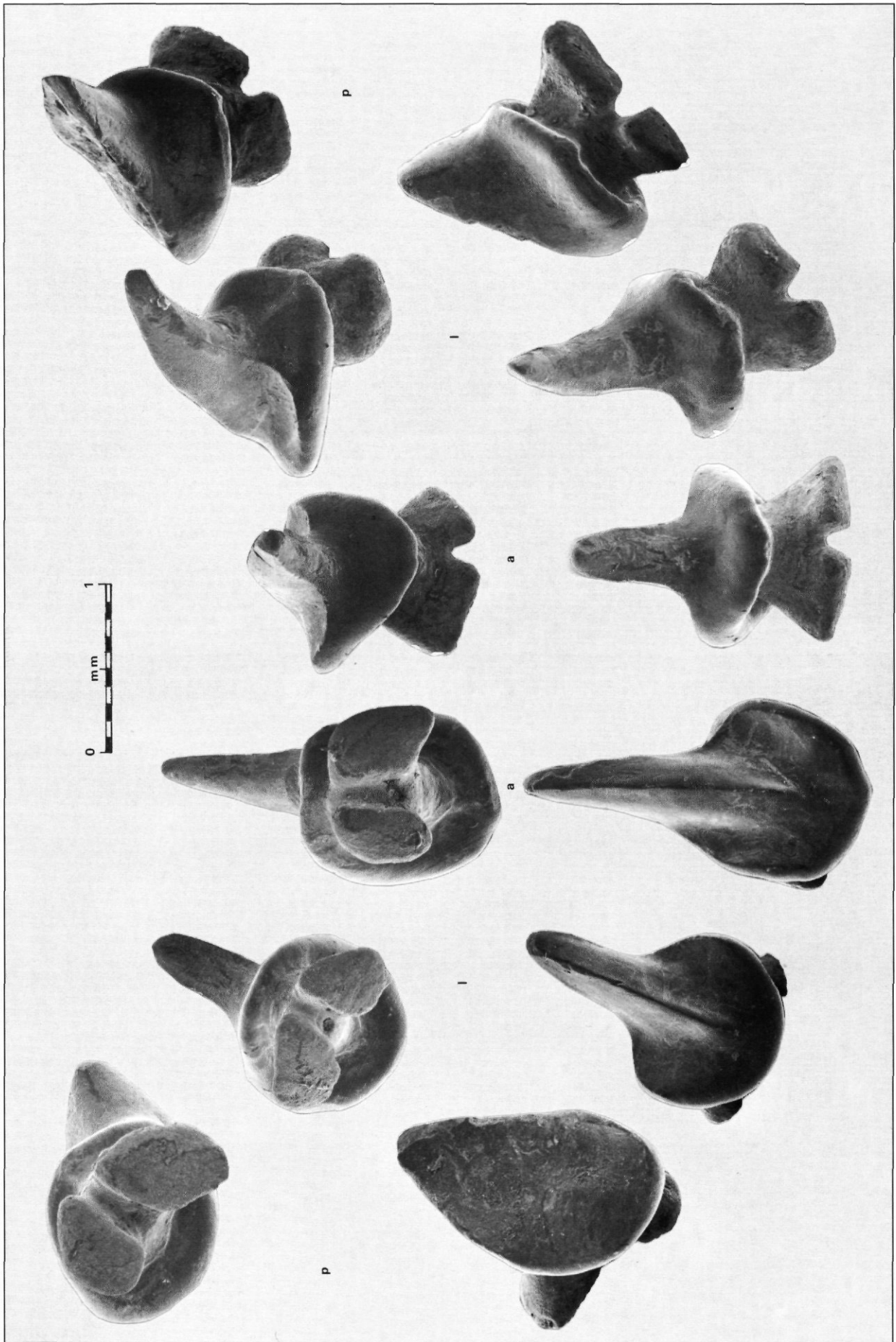


Plate 54. - *Sympterygia bonapartei* MÜLLER & HENLE, 1841. Male 57 cm (l.l.), South Atlantic, North Argentina. Lower teeth.

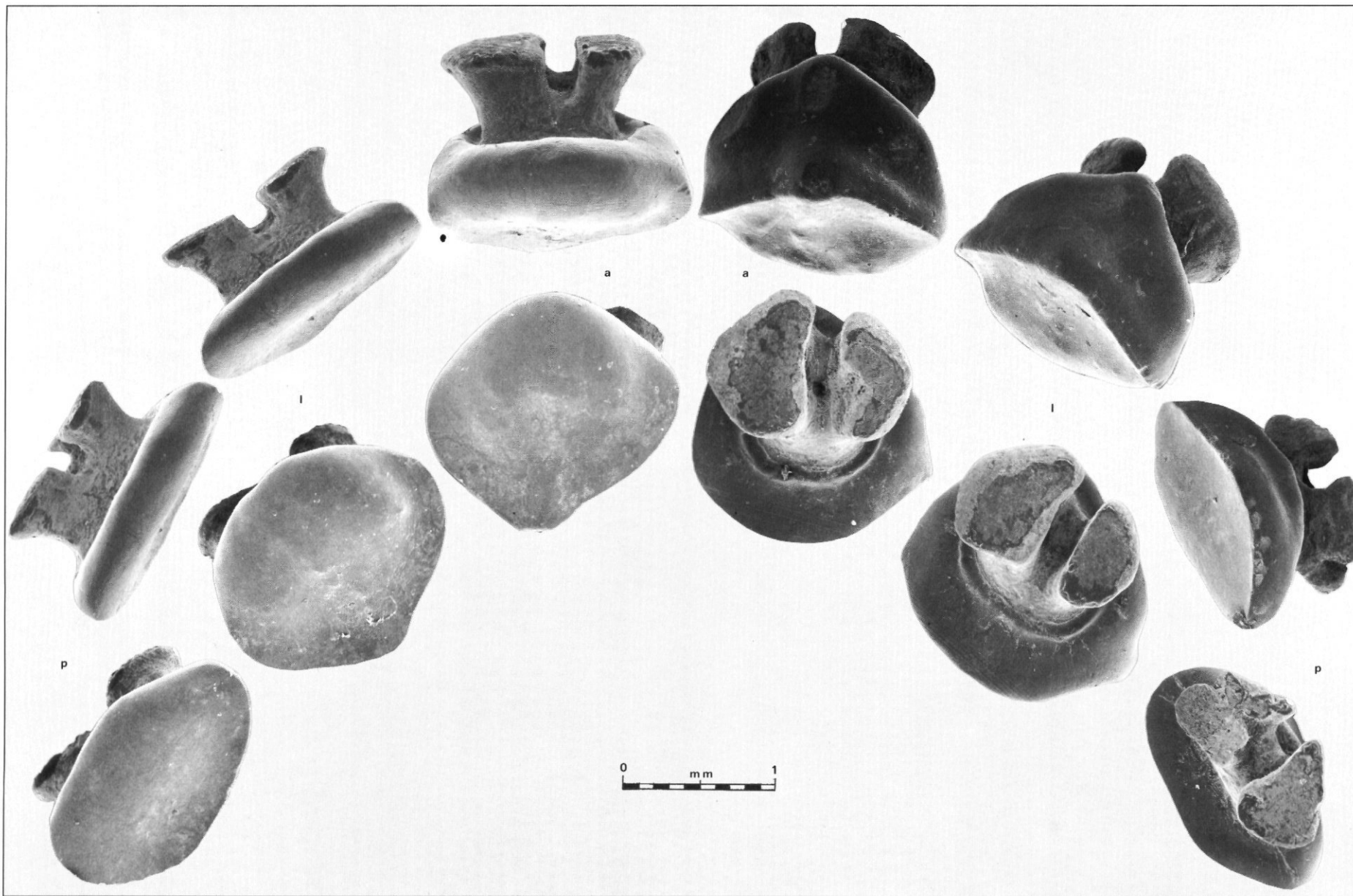


Plate 55. — *Sympterygia bonapartei* MÜLLER & HENLE, 1841. Female 67 cm (i.l.), South Atlantic, North Argentina. Upper teeth.

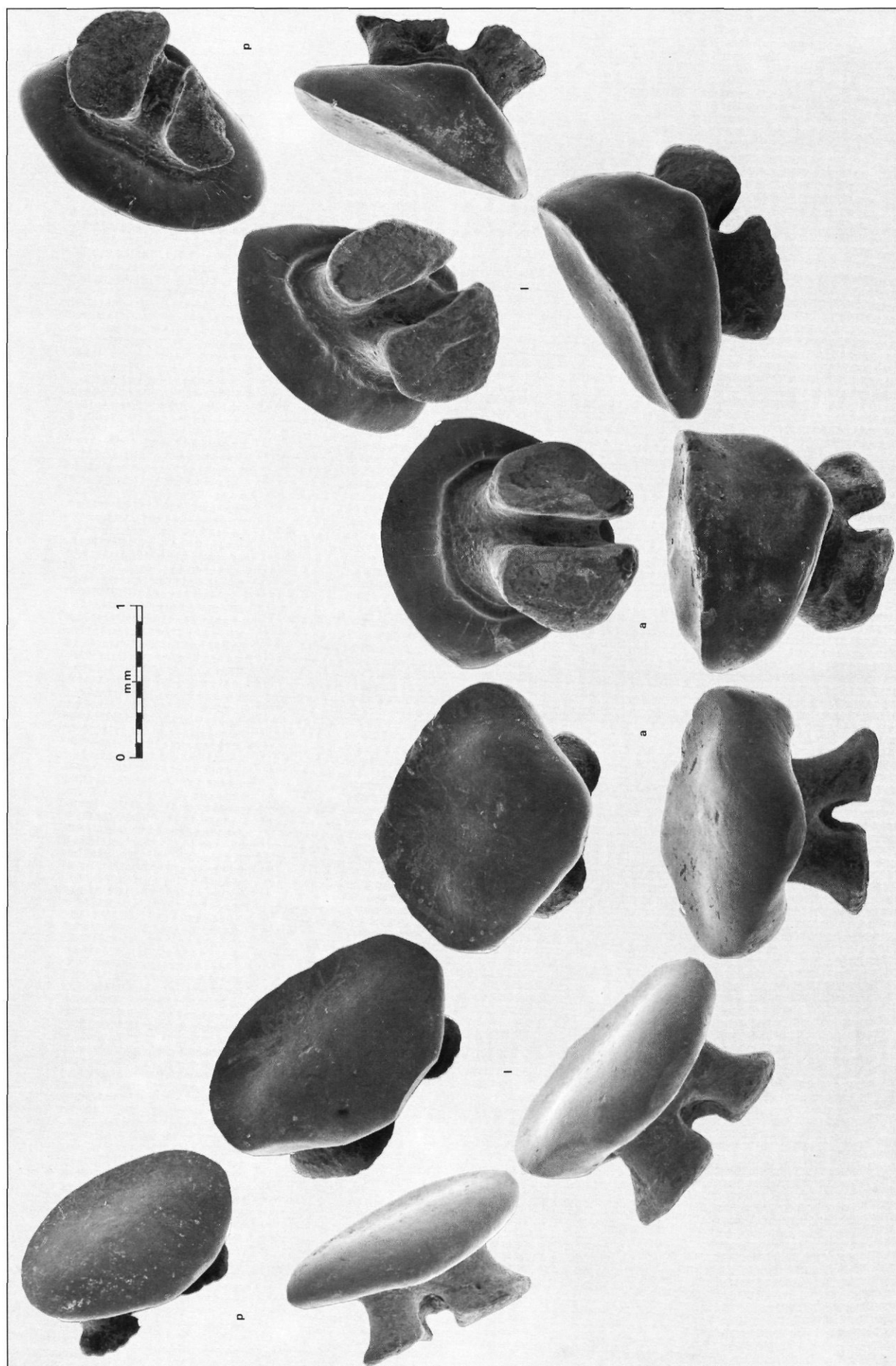


Plate 56. — *Sympterygia bonapartei* MÜLLER & HENLE, 1841. Female 67 cm (t.l.), South Atlantic, North Argentina. Lower teeth.

