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THE LARGE ASPIDORHYNCHID FISH, *RICHMONDICHTHYS SWEETI* (ETHERIDGE JNR AND SMITH WOODWARD, 1891) FROM ALBIAN MARINE DEPOSITS OF QUEENSLAND, AUSTRALIA

ALAN BARTHOLOMAI

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Material previously referred to the genera *Belonostomus* Agassiz, 1834, *Aspidorhynchus* Agassiz, 1833 and *Vinctifer* Jordan, 1919 from Lower Cretaceous (Albian) marine deposits of Queensland (Australia) is considered to be referable to *Richmondichthys* gen. nov., within the species *R. sweeti* (Etheridge Jnr & Smith Woodward, 1891). This is shown to be a very common and widespread aspidorynchid halecostome (Actinopterygii:Teleostei), the largest species within the family. *R. sweeti* differs significantly from the South American *V. comptoni* (Agassiz,1841), to which it is nonetheless closely related. Lack of teeth, elongate gill filaments, hinged cheek bones and a very deep lower jaw suggest the species was a filter feeder, possibly a gulper. ❑ *Actinopterygii, Halecostomi, Teleostei, Aspidorynchidae, Richmondichthys sweeti, Albian.*

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Aspidorhynchid fish remains comprise conspicuous and common elements of the fossil vertebrates recovered from widespread localities in the Lower Cretaceous (Albian) marine deposits of the Great Artesian Basin in central Queensland. The majority of referred material from precisely recorded localities has been derived from the shallow water, marine sediments of the Toolebuc Formation, a unit rich in invertebrate fossils and containing not only fish but also a rich suite of marine and some terrestrial reptiles. Rarer aspidorhynchid occurrences are recorded from the Allaru Mudstone, also of Lower Cretaceous (Albian) age.

The presence of ganoid fish in the Great Artesian Basin deposits was first recorded by Etheridge (1872) in a collection of fossils from 'Hughenden Station' where they were referred to *Aspidorhynchus* sp. Jack & Etheridge (1892) later referred this material to *Belonostomus sweeti*, a species that had been described by Etheridge Jnr & Smith Woodward in 1891, also based on material from Hughenden in central Queensland.

The specimens then available lacked most of the cranial elements and the neurocranium remained undescribed. Over the past century, the available sample of remains referrable to the species has expanded considerably and acetic acid preparation techniques have permitted previously unheard of detail to be revealed from the encompassing concretionary, calcilutite structures in which the fossils are usually preserved. A much more comprehensive description of the taxon is now possible, enabling better comparisons with other genera and species.

Exhaustive studies of other aspidorhynchids from elsewhere in the world have been undertaken by Brito (1992, 1997), including a very detailed study of related South and central American species of *Vinctifer*. Based upon limited material, Brito regarded the Australian material as also being referrable to *Vinctifer*, a conclusion that is not supported by the present study.

ABBREVIATIONS. Ang = Angular; acv = foramen for anterior cerebral vein; ant. my. = anterior myodome; Apto = Autopterotic; art inf = articulation for Ist infrapharyngobranchial; Aspo = Autosphenotic; Boc = Basioccipital; br = branchiostegal ray; Bsp = Basisphenoid; ci = foramen for internal carotid artery; Cl = Cleithrum; Dpt-Exsc = Dermopterotico-Extrascapular; Dsp = Dentalosplenial; Dsph = Dermosphenotic; Epo = Epiotic; Epto = Epipterotic; Exo = Exoccipital; fm = foramen magnum; Fr-Pa = Fronto-Parietal; Hymd = Hyomandibular; hymdf = hyomandibular fossa; Ic = Intercalar; ica = foramen for internal carotid artery; Io = Infraorbital; jd = jugular depression; juv = foramen for jugular vein; l.Eth = Lateral Ethmoid; mdc = mandibular canal; Mx = Maxillary; Na = Nasal; Nerves:; I = olfactory nerve; II = optic nerve; III = common occular motor nerve; IV = pathetic nerve; V = trigeminal nerve; V+VII opht = opthalmic trunks of trigeminal and facial nerves; VI = abducens nerve; VII = facial nerve; VII jugm = jugulohyomandibular trunk of facial nerve; IX = glossopharyngeal nerve; X = vagus nerve; oa = foramen for orbital artery; occa = foramen for occipital artery; Op = Operculum; Opo = Opisthotic; opp = opercular process; orb. = orbital cavity; Ors = Orbitosphenoid; Pdt = Predentary; pea = foramen for pseudo-branchial efferent artery; Pmx = Premaxillary; Po = Postorbital; Pop = Preoperculum; Post = Post-temporal; Pro = Prootic; pr psp = process of the parasphenoid; Psp = Parasphenoid; ptf = post-temporal fossa; Pts = Pterosphenoid; ptsp = pterosphenoid pedicule; Qu = Quadrate; Rart = Retroarticular; Ro = Rostral; Scl = Sclerotic Ring; Sclt = Supracleithrum; Soc = Supraoccipital; Sor = Supraorbital; Sop = Suboperculum; 1st vert. = first vertebra; Vom = Vomer.

All Queensland Museum specimens are identified with the prefix QMF. Material from other collections is identified by institution wherever they are referred to.

Class OSTEICHTHYS
Sub-class ACTINOPTERYGII
Division HALECOSTOMI (sensu Patterson, 1973)
Sub-division TELEOSTEI (sensu Patterson, 1973)
Family ASPIDORHYNCHIDAE Nicholson & Lydekker, 1889

Richmondichthys gen. nov.

DIAGNOSIS. Until further species are defined, the characters that define the species are also those that define the genus.

GENOTYPE. *Richmondichthys sweeti* (Etheridge Jnr & Smith Woodward, 1891).

Richmondichthys sweeti (Etheridge Jnr & Smith Woodward, 1891)

Richmondichthys sweeti (Etheridge Jnr & Smith Woodward, 1891) pls 1-7.
Aspidorhynchus sp. Etheridge (partim), 1872; Jack & Etheridge Jnr, (partim), 1892.
Belonostomus sweeti Etheridge Jnr & Smith Woodward, 1891; Jack & Etheridge Jnr, 1892.
Vinctifer sweeti, Brito, 1997.

HOLOTYPE. MVP (Museum of Victoria) 12988, partial skeleton including posterior of head and bulk of body, Hughenden, central Queensland.

FORMATION. Mostly from the Toolebuc Formation, of Lower Cretaceous (Albian). Also from the Allaru Mudstone, of Lower Cretaceous (Albian).

DIAGNOSIS. Very large, exceeding 1.6 metres in length. Neurocranial roof with markedly asymmetrical fronto-parietals, dermopterotico-extrascapulars and post-temporals; rostral not extending beyond maxillary; premaxillary without teeth and short, not extending anteriorly as far as the dentalosplenial; circumorbital bones are extremely well developed; maxillary without teeth, set well anterior to orbit; predentary very small, edentulate; gill filaments extremely elongated; dentalosplenial deep anteriorly and very deep posteriorly, lacking teeth; lateral line scales greatly deepened; all scales heavily covered with ganoine, raised into heavy ridges and tubercles; ornamented ganoine also covers the outer bones of the head and is present on the larger elements of the fin rays.

MATERIAL. QMF1764, scales, Hughenden, CQ; QMF1841, scales, Hughenden, CQ; QMF1842, scales, Hughenden, CQ; QMF2296, partial body, Marathon Station, E of Richmond, CQ; QMF2389, scales, Hughenden district, CQ; QMF2389, partial skeleton, no locality; QMF2390, partial skull and skeleton, Hughenden district, CQ; QMF2437, scales, nr Hughenden, CQ; QMF2582, partial skeleton, Lydia Downs Station, N of Nelia, CQ; QMF5651, partial skeleton including parts of skull and anterior of body, Dingading Station, nr McKinlay, at MR 404304 McKinlay 1:250000 sheet, NWQ; QMF5660, partial skeleton, Dunraven Station, 48km NW of Hughenden, at Pelican Bore, CQ; QMF5661, partial body, Dingading Station, nr McKinlay, at por. 4, Par. Collins, NWQ; QMF5662, vertebrae, Hughenden, CQ; QMF5663, fragment with scales, Hughenden Station, Hughenden, CQ; QMF5664, fragment with scales, Hughenden Station, Hughenden, CQ; QMF5666, partial skeleton, Boree Park Station, at MR 627413 Richmond 1:250000 sheet, CQ; QMF5667, fragment with ventral body scales, Meira Paddock, Boree Park Station, about 12km NW of Richmond, nr MR 622416 Richmond 1:250000 sheet, CQ; QMF5668, scales, Boree Park Station, at MR 627413 Richmond 1:250000 sheet, CQ; QMF5669, partial skeleton, Pub Paddock, Boree Park Station, nr MR 627413 Richmond 1:250000 sheet, CQ; QMF5670, fragment with vertebrae and scales, Pub Paddock, Boree Park Station, at MR 627413 Richmond 1:250000 sheet, CQ; QMF5671, partial skeleton, Pub Paddock, Boree Park Station, nrMR 627413 Richmond 1:250000 sheet, CQ; QMF5672, partial skeleton, Dingading Station, McKinlay, at por. 4, Par. Collins, NWQ; QMF5673, partial body, 22km N of Springvale Station, SE of Boulia, NWQ; QMF5674, partial body, 8km WSW of Marathon Station homestead, E of Richmond, CQ; QMF5675, partial skull and body, including gill filaments, Dingading Station, nr McKinlay, at MR 406306 McKinlay 1:250000 sheet, NWQ; QMF7568, partial skeleton including parts of skull and anterior of body, Marathon Station, E of Richmond, CQ; QMF7668, partial skull, no locality; QMF10608, neurocranium, Warra Station, NWQ; QMF12706, partial body, Stewart Creek, Dunraven Station, 3rd creek crossing from main road on track to Pelican Bore, CQ; QMF12856, neurocranium, no locality; QMF12904, partial body, Hughenden, CQ; QMF13412, neurocranium, Slashers Creek Station, NWQ; QMF13037, partial skeleton, Marathon Station, nr Richmond, CQ; QMF13413, neurocranium, Springvale Station, NWQ; QMF13711, partial skeleton, including partial skull and anterior of body, Dunraven Station, Stewart Creek, unnamed tributary on S side, downstream from junction with Soda Creek and upstream from Pelican Bore, NW of Hughenden, CQ; QMF13726, scales, Dunraven Station nr Hughenden, CQ; QMF13727, partial skeleton, Stewart Creek, upstream from junction with Soda Creek, Dunraven Station, nr Hughenden, CQ; QMF13728, partial skeleton, bank of unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF 13729, partial skeleton, Stewart Creek upstream from Pelican Bore, Dunraven Station, nr Hughenden, CQ; QMF13731, partial skeleton, Stewart Creek downstream from Pelican Bore, Dunraven Station, nr Hughenden, CQ; QMF13734, partial skull, unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF13744, partial skeleton, Stewart Creek, upstream from junction with Soda Creek, Dunraven Station, nr Hughenden, CQ; QMF13745, partial skull, body and scales, Stewart Creek, downstream from Pelican Bore, Dunraven Station, N of Hughenden, CQ; QMF13746, partial skeleton, Stewart Creek, upstream from Pelican Bore, Dunraven Station, nr Hughenden, CQ; QMF13747, partial skeleton, unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF13748, partial skeleton, tributary of Stewart Creek, Dunraven Station, N of Hughenden, CQ; QMF13753, partial skeleton, unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF13767, partial skeleton, tributary of Stewart Creek, Dunraven Station, N of Hughenden, CQ; QMF13771, partial skeleton, unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF13772, unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF13773, partial skeleton, unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF13774, partial skull, unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF13775, partial skeleton, unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF13776, partial skeleton, unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF13777, partial skeleton, unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF13778, partial skeleton, Dunraven Station, unnamed tributary of Stewart Creek, nr Hughenden, CQ; QMF13779, partial skeleton, unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF13780, partial skeleton, unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF13781, partial skeleton, unnamed tributary of Stewart Creek, Dunraven Station, nr Hughenden, CQ; QMF (unnumbered), partial skeleton, Rocky Waterhole, Flinders River, Julia Creek at L398 (QM collection register); QMF13787, neurocranium, Dunraven Station, N of Hughenden, CQ; QMF13788, partial skeleton and scales, Stewart Creek, downstream from Pelican Bore, Dunraven Station, N of Hughenden, CQ; QMF13789, partial skeleton and scales, tributary of Stewart Creek, Dunraven Station, N of Hughenden, CQ; QMF13790, partial skull, Stewart Creek, upstream from Pelican Bore, Dunraven Station, N of Hughenden, CQ; QMF13791, partial skeleton and scales, tributary of Stewart Creek, Dunraven Station, N of Hughenden, CQ; QMF13793, partial skeleton, tributary of Stewart Creek, Dunraven Station, N of Hughenden, CQ; QMF13794, partial skeleton, tributary of Stewart Creek, Dunraven Station, N of Hughenden, CQ; QMF13795, partial skeleton and scales, tributary of Stewart Creek, Dunraven Station, N of Hughenden, CQ; QMF13796, partial skeleton, tributary of Stewart Creek, Dunraven Station, N of Hughenden, CQ; QMF14339, partial body, Boree Park, W of Richmond, CQ; QMF18040, partial skeleton, Marathon Station, nr Richmond, CQ; QMF18115, partial skull, Flinders River crossing, W of Marathon Station homestead, Allaru Mudstone, CQ; QMF18153, body and skull fragments, 1.4km S of Jacks Bore, Canary Station, SE of Boulia, NWQ; QMF15328, skull fragment, Pelican Bore area, Dunraven Station, CQ; QMF18218, partial skull and anterior of body, NE of Canary Station homestead, SE of Boulia, NWQ; QMF18253, partial body, 2.6km S of Canary Station homestead, in lambing paddock, SE of Boulia, NWQ; QMF18295, skull and anterior of body, old Council quarry, 5km S of Flinders River, Wof Richmond, CQ; QMF18603, partial skeleton, 2km E of Jacks Bore, Canary Station, SE of Boulia, Toolebuc, NWQ; QMF18898, almost complete skull and post-cranial skeleton, 20km W of Richmond, nr Old Richmond/ Maxwelton Highway, CQ; QMF25074, partial skull, Flinders River, at QM collection locality L815, Allaru Formation, CQ; QMF25077, partial skeleton, Flinders River at QM collection locality L815, Allaru Formation, CQ; QMF25331, body scales, Canary Station, nr Boulia, NWQ; QMF41492, scales, Boree Park Station, nr Richmond, CQ; QMF41493, partial skull, Boree Park Station, nr Richmond, CQ; QMF41494, partial skull, Boree Park, nr Richmond, CQ; GSQF12904 (Geological Survey of Queensland Collection), scales, Hughenden, CQ

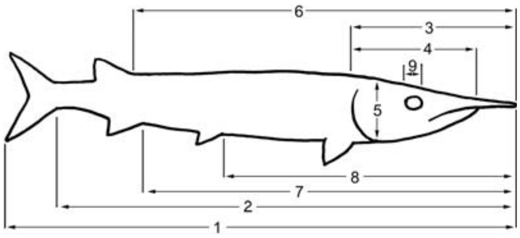

FIG. 1. Hypothetical aspidorhynchid teleost (from Brito, 1997) illustrating parameters applied in Table 1.

DESCRIPTION. *General*. General body shape is elongate and sub-cylindrical, but much deeper than broad. *Richmondichthys* was a very large fish, with preserved individuals exceeding 1.6m in length and with fragments of even larger individuals preserved. Body depth exceeded 27cm. The body is deepest just posterior to the head, gradually reducing in depth to the caudal peduncle where the depth is about 25% of maximum depth. Table 1 (linked to Fig.1), provides measurements for the most complete of the *R. sweeti* specimens (QMF18898) compared

TABLE 1. Comparative morphometric values (cm). (See Brito, 1997 for information on *V. comptoni* specimens)

	1	2	3	4	5	6	7	8	9
R. sweeti (QMF18898)	-	147.9	34.2	35.1	14.5	118.2	114.1	94.4	4.6
V. comptoni (USU 49)	75.0	70.0	19.0	13.0	8.0	55.0	54.6	47.0	1.4
V. comptoni (USU 07)	12.0	11.6	5.0	1.6	0.9	8.7	8.4	-	-
V. comptoni (FMNH PF 13486)	27.0	26.0	8.8	-	1.5	21.5	21.3	-	-

with those for specimens of *V. comptoni* provided in Brito (1997).

The head is long and narrow. Premaxillaries are extended anteriorly but do not reach as far forward as the dentalosplenials, let alone the predentary. The head represents approximately one-quarter the length of the fish. Its length is more than twice its maximum depth (Figs 2-4). The quadrato-mandibular articulation is situated anterior to the level of the front of the orbit (Fig. 3).

The scales are heavily covered with ganoine. Those along the flanks, especially anteriorly, are much deeper than dorsal and ventral scales. A total of 82 rows of scales are present in QMF18898 (Fig. 5) between the posterior border of the supracleithrum and the posterior of the caudal peduncle. As defined in the scale formula outlined by Westoll (1944) and applied by Brito (1997), the pelvic, anal, dorsal and caudal fins are located along the body as follow:

_________61______ 82

37 55 69

It is likely that the pelvic, anal and dorsal fins were reclining backwards and that the caudal fin was relatively large and forked as in other aspidorhynchids.

Cranium. The endocranium in *Richmondichthys* is well ossified in more mature individuals (Figs 6-8). It comprises a bony box with anterior and posterior moieties united by the parasphenoid below and the frontalo-parietal above, with contiguous elements firmly sutured and with such sutures variably tending to disappear with age, similar to those in other members of the Aspidorhynchidae (Brito, 1992).

The following measurements have been derived mainly from QMF7568.

Length, from the anterior of the nasal fossa to the posterior border of the post-temporal, 19.4cm; from the anterior of the nasal fossa to the posterior border of the basioccipital (lateral view), 14.3cm. Breadth, at the level of the post-orbital processes, 5.5cm. Depth, at the anterior of the basisphenoid, 3.1cm.

These measurements allow a broad comparison to be made with similar measurements in *Vinctifer comptoni* especially as these relate to proportions calculated by Brito (1992) for that species. The endocranium in *Richmondichthys* is very long, being 6.2× as long posterior to the nasal fossa as the maximum depth (c.f. 4.5× in *V. comptoni*). The nasal fossa is relatively short, representing 6% of the endocranial length in lateral view (20% in *V. comptoni*). The orbit is comparatively large (35.6% of the same measure c.f. 32% in *V. comptoni*) while the post-orbital region is very large, being 57.6% of the lateral endocranial length (48% in *V. comptoni*).

Ethmoid Region. Only the posterior of the ethmoid region is exposed in one individual, QMF568. It is well ossified and forms the floor and posterior wall of the nasal fossa. A median septum separates the fossa, while its upper extent is limited by the anterior of the frontals and the posterior of the rostral; the anterior of the nasal fossa appears to be contained by the ethmoid itself.

The posterior of the lateral ethmoid bears a large, horizontal ridge directed posteromedially towards the orbitosphenoid, above the parasphenoid, presumably supporting the olfactory nerve (I) and capping the anterior myodome. The foramen for the orbitosphenoid vein is present at the base of the large ridge and there is an articulation surface anteromedially on the ethmoid base for the palatine. Anteriorly, the ethmoid region encircles a posterior extension of the premaxillaries.

Orbito-Temporal and Otic Region. The posterior surface of the orbit is penetrated by a large number of foramina for nerves and blood vessels to the mandible and the anterior of the cranium.

The orbitosphenoid is fully ossified in those individuals in which it is visible (QMF7568 and QMF13412). It comprises the posterodorsal roof of the orbital cavity, fanning anteriorly and well separated from the posteromedial processes of the ethmoid region. It is sutured laterally to the pterosphenoids. In anterior view, the orbitosphenoid extends a medial plate anteriorly to form the base of the canal for the passage of the

FIG. 2. *Richmondichthys sweeti* (Etheridge Jnr & Smith Woodward, 1891), QMF13711, lateral view of right side of head. Scale bar = 5cm.

olfactory nerve (I) and the roof of the large opening for the optic nerves (II). There is no evidence of the presence of a foramen for the passage of the anterior cerebral vein.

The pterosphenoid forms the posterolateral part of the posterior orbital wall. It is supported dorsally by the frontal and extends to join with the autosphenotic laterally and with the base and dorsal wing of the basisphenoid. It is excluded from lateral contact with the prootic by the autosphenotic and the parasphenoid. There is a prominent bony crest forming a pterosphenoid peduncle, subparallel to the ventrolateral rim of the opening for the orbital nerve. Medially and floored by the pterosphenoid peduncle is a relatively large foramen for nerve III, close to the suture with the wing of the basisphenoid. Close to the internal border of the pterosphenoid peduncle and just above the basisphenoid suture is a foramen interpreted as that for nerve IV. This appears to be separated fairly widely from another small foramen near the lateral extent of the pterosphenoid peduncle, possibly for the anterior cerebral vein. The lateral extension of the peduncle surrounds and provides the rim of the tigeminofacial orifice and anterodorsally to this is penetrated by nerve V.

The basisphenoid has a stalk that meets the dorsal surface of the parasphenoid and slopes posterodorsally, separating the left and right moieties of the posterior myodome. The base of the basisphenoid has dorsolateral extensions that form the floor and ventrolateral walls of the large orifice for the passage of the optic nerves(II) and that meet a moderately large process of the pterosphenoid.

The autosphenotic is relatively small and triangular and caps the lateral extent of the orbitotemporal and otic regions. The dorsal face is in contact with the cranial roof in the region of the dermosphenotic but is not united with it. The anterior face is slightly curved, forming the posterodorsal extent of the orbit with both the pterosphenoid and the lateral process of the parasphenoid. Posterolaterally, the autosphenotic

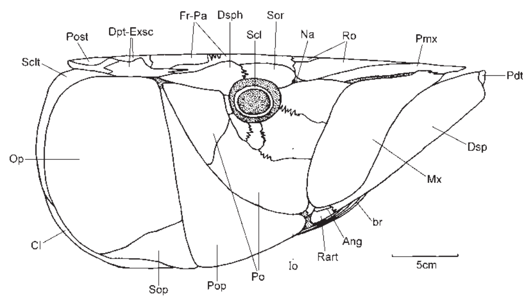

FIG. 3. *Richmondichthys sweeti* (Etheridge Jnr & Smith Woodward, 1891): Reconstruction of the head in lateral view, based primarily on QMF13711 and QMF18898. Scale bar represents 5cm.

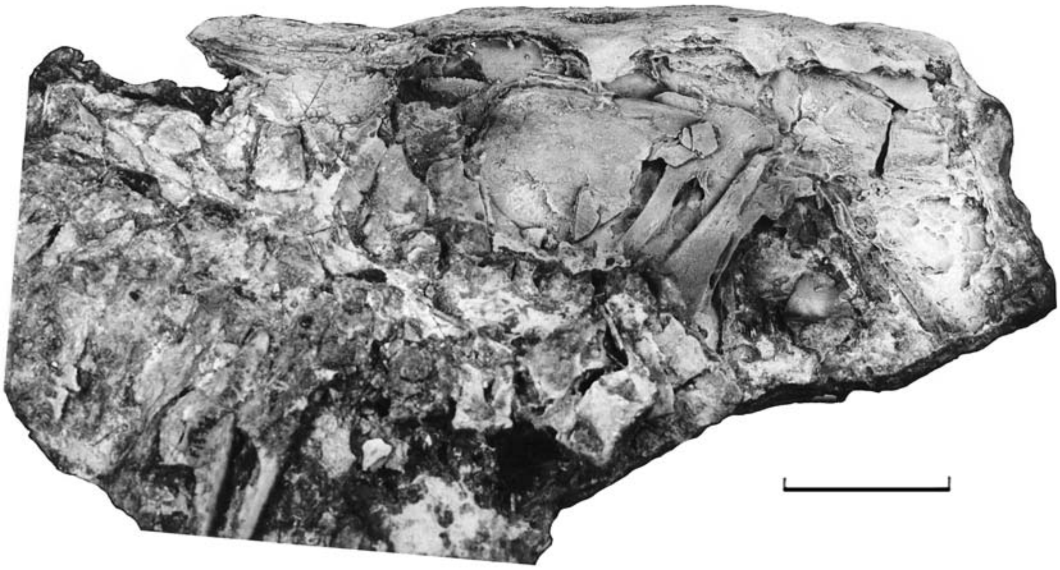

FIG. 4. *Richmondichthys sweeti* (Etheridge Jnr & Smith Woodward, 1891), QMF13711, lateral view of left side of head. Scale bar = 5cm.

meets the prootic and bears a large depression that represents the anterior extent of the articular fossa for the hyomandibular.

The prootic is a large, complex bone that forms the bulk of the floor and walls of the neurocranium, reaching from the back of the postorbital processes to the cranial roof and the lateral walls and back of the posterior myodome. In lateral view, the prootic extends to meet the basioccipital, the suture with which is sometimes partially or completely obscured and difficult to identify. Similarly, the suture separating the prootic and opisthotic is not able to be identified in available specimens.

In lateral view, the otic region carries the bulk of the large, horizontal, hyomandibular fossa, which extends from the back of the postorbital process below the cranial roof to the abutment of the autopterotic. The fossa is slightly hour-glass shaped. Immediately below the hyomandibular fossa are several well developed and large foramina – the large opening for the passage of the jugular vein into the trigemino-facial chamber; the foramen for the jugulohyomandibular trunk of the facial nerve, midway along the prootic; the slightly smaller foramen for the glossopharyngeal nerve (IX), situated near the basioccipital suture within the jugular depression; and the larger foramen for the passage of the vagus nerve (X), opening at the dorsal end of the otico-occipital suture. The depression for the jugular vein is very distinct, especially in the area of the foramen for the jugulohyomandibular trunk of nerve VII. The extracranial trigemino-facial chamber opens backwards through the large oriface or the passage of the jugular vein. The space also appears to provide a communication with the cranial cavity for the profundus, trigeminal (V) and facial (VII) nerves. The orbital opening of the trigemino-facial chamber is divided by the pedicule of the pterosphenoid with the median opening accommodating the ophthalmic rami of the trigeminal and facial nerves (V + VII opht) and a lateral opening possibly for the trigeminal and facial nerves and for the jugular vein and orbital artery. The profundus nerve appears to proceed through a foramen more anterodorsally, near the suture between the pterosphenoid and the orbitosphenoid, close to a foramen believed for the median cerebral vein. The ventral border of the prootic, immediately behind the parasphenoid process contributes to the articulation for the first infrapharyngobrachial, although the bulk of the articulation is on the parasphenoid process itself. The articulation of the infrapharyngobrachial has not been observed in any specimen.

The opisthotic is generally fused to the prootic and the suture is not easily observed. It extends backwards from behind and above the large

FIG. 5. *Richmondichthys sweeti* (Etheridge Jnr & Smith Woodward, 1891), QMF18898, almost complete skeleton from right side. Scale bar = 10cm.

foramen for the glossopharyngial nerve (IX) and just reaches that for the vagus nerve (X). The bone was much smaller than the prootic.

The autopterotic is very small, developed above the back of the opisthotic and lateral to the even smaller epipterotic. It has a well defined and robust process directed posteriorly to be sutured with the intercalar process. The autosphenotic is totally independent of the dermal bones of the cranium.

The intercalar is prominent, extending posteriorly as a large, flattened and vertically expanding process from the junction of the opisthotic and autosphenotic. It is fused laterally to the process of the autosphenotic and extends well beyond the vertebra fused to the basioccipital. It is partially covered by the extrascapular and the post-temporal and bears a large foramen anteriorly, above the suture with the autopterotic.

Occipital Region. The bony mass of the occipital region is limited anteriorly by the suture with the prootic (the otico-occipital fissure), to include the whole of the foramen for nerve X and posteriorly by the fusion of the basioccipital and the first vertebra.

The basioccipital is defined laterally by well defined sutures. It comprises the ventral and lateral margins of the occipital region. The ventral margin extends slightly anterior to the foramen for the glossopharyngeal nerve (IX). It is united with the prootic and opisthotic by an oblique suture. The basioccipital has not, as yet, been exposed in posterior view. Posterodorsally, it meets the exoccipital. Occasionally, a small foramen is present above and towards the back of the parasphenoid for the passage of the occipital artery. The first vertebra is firmly fused to the basioccipital and forms part of the endocranium.

The exoccipital contributes to the dorsolateral part of the occipital region and to the posterior surface. It extends from just above and behind the foramen for the vagus nerve (X) and is sutured deeply with the basioccipital anteroventrally and posteriorly fused with the first vertebra. Each exoccipital is extended posterodorsally into an arch, comparable with that of the first vertebra and deeply sutured to it.

The epiotic forms the posterior margins of the post-temporal fossa. It is positioned between the exoccipital and the posterior process of the intercalar and contributes to the posterodorsal border of the endocranial roof. It is deeply sutured to the exoccipital posterodorsally and is penetrated by a number of foramina, the largest of which is interpreted to be for the posterior cerebral vein.

The supraoccipital is largely hidden by the extrascapular in most specimens. It is a small bone, firmly fused with the epiotic and has a pair of posterodorsal processes that overlap the arch structure of the exoccipitals.

Dermal Bones of the Anterior Aspect of the Endocranium. The parasphenoid comprises a narrow veneer of bone under the neurocranium. It is very long anteroposteriorly, extending from near the front of the ethmoid region to just posterior to the level of the foramen for the vagus nerve (X). It appears to contribute medially to the posterior of the rostral tubes and is anteriorly broadened and flattened between the ethmoids. It does not appear to bifurcate in this region to envelop the vomer and its relationship with the vomer has not been observed. The parasphenoid is slender below the orbit, flattened laterally and

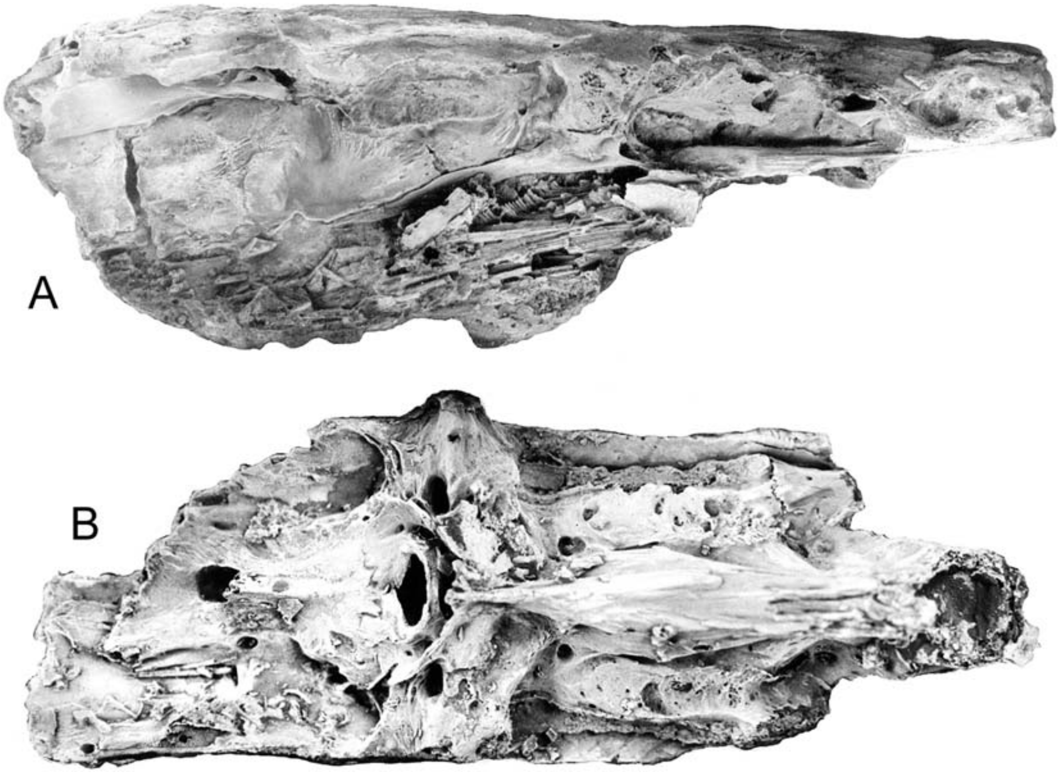

FIG. 6. *Richmondichthys sweeti* (Etheridge Jnr & Smith Woodward, 1891) neurocranium. A, lateral view of right side, QMF7568, × 0.65; B, ventral view, QMF13412, × 1.75.

dorsally crested. It then presents a concavity towards the back of the orbital cavity that curves dorsally to about the level of the postorbital processes before extending posteriorly and flattening dorsoventrally below the otico-occipital region.

A wing-like process is developed on each side of the parasphenoid below the postorbital processes. These are directed ventrolaterally to below the autosphenotics, with the anterior margin of the parasphenoid process forming the border of the posterior myodome and the posterior margin scalloped out to contribute to the foramen for the passage of the internal carotid artery. Another foramen is present in each wing, well beyond the midline and these are believed for the pseudobranchial efferent artery.

The parasphenoid is totally devoid of teeth and lacks any trace of a basipterygoid process.

The vomer has not been observed in any specimen yet found. It is possible that it is present within the anterior broadening of the parasphenoid in F7568. However, no sutures are evident and there is no evidence for any vomerine teeth.

Rostral Region. The premaxillaries comprise the major elements of the anterior of the rostral region. They are ornamented with fine, longitudinal striae, where exposed. Posteriorly, the bone is inserted deeply below other dermal bones and forms the rostral tube that is fitted into the endocranial ethmoid region. Anteriorly, the premaxillaries are not greatly tapered and terminate posterior to the junction of the dentalosplenial and the predentary. Ventrally, it is believed that the premaxillaries are underlain by the parasphenoid and possibly the vomer; posteriorly, each is encased by the rostral above and the dorsal margin of the maxillary. Contact with the nasal does not appear to occur. The premaxillaries are edentulate where they have been observed.

The rostral is a large bone, transversely convex and much longer than wide, covering the posterior of the premaxillaries and overlapping the frontals. It is ornamented by ridges of ganoine.

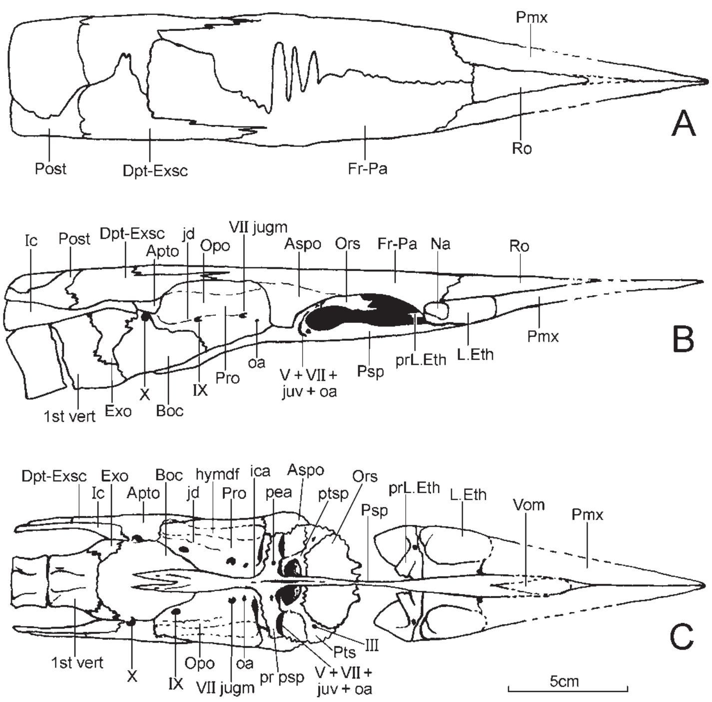

FIG. 7. *Richmondichthys sweeti* (Etheridge Jnr & Smith Woodward, 1891): Reconstructed neurocranium based primarily on QMF7568, QMF13711 and QMF13412. A, dorsal view; B, lateral view; and C, ventral view. Scale bar = 5cm.

The nasal is a small bone, limited dorsally by the rostral and appears to be limited anteriorly and posteroventrally by the first infraorbital and posterodorsally by the supraorbital. Association of the infraorbital canal with the nasal has not been observed in any of the available specimens. The anterior of the supraorbital canal traverses the nasal.

Cranial Roof. Apart from the rostral region, the cranial roof comprises a series of bones identified as the fronto-parietals, dermopterotico-extrascapulars and the post-temporals.

The fronto-parietals comprise the largest bones of the cranial roof. They extend from the rostrals to the dermosphenotico-extrascapulars, just above the front of the opercular. In dorsal view, the width is almost constant from front to back, although there is a slight broadening above the rear of the orbit. The bones are markedly asymmetrical, with the mediodorsal suture deeply interdigitated and set mainly to the left but occasionally to the right of the midline. The frontals have usually been firmly welded to the parietals but sutures with the latter are sometimes visible. The surfaces are heavily ornamented with ridges and tubercles of dentine, generally radiating anteriorly, posteriorly and medially from points on the frontals, above the autosphenotics. Laterally, the fronto-parietals are shallowly grooved to accommodate the upper margins of the uppermost postorbital and the supraorbitals.

The dermopterotico-extrascapulars comprise a pair of gently arched bones that, like the fronto-parietals are markedly asymmetrical and that have a well-defined mediodorsal suture. Variable ridges and tubercles of ganoine radiate on the surface from anterolateral loci. Lateral grooves accommodate the upper margin of part of the dermosphenotic.

The post-temporals are similar to the dermopterotico-extrascapulars and comprise a pair of markedly asymmetrical, gently arched bones that are anteriorly overlain by the extrascapulars and that meet one another along a deeply overlapping and broadly undulating mediodorsal suture. Ornamentation is of strong ridges and tubercles of ganoine radiating from loci mid-way along the lateral margins.

Cheek. The orbit is surrounded by the infraorbital series and by the dermosphenotic and supraorbital. Two large postorbital plates and the preoperculum complete the cheek bones. The cheek bones are largely unornamented by ridges and tubercles of ganoine except for the supraorbital and dermosphenotic where coarse ornamentation is present in rows paralleling the dorsal margins. The sclerotic ring appears to comprise no more than two plates.

The dorsal margins of the cheek bones fit into a groove along the dorsolateral margin of the neurocranium, forming a hinge along which the cheek bones can be rotated outwards.

The infraorbital series comprises five bones, generally increasing in size from a small rectangular element posterior to the orbit, around the ventral and anterior rim of the orbit. The large,

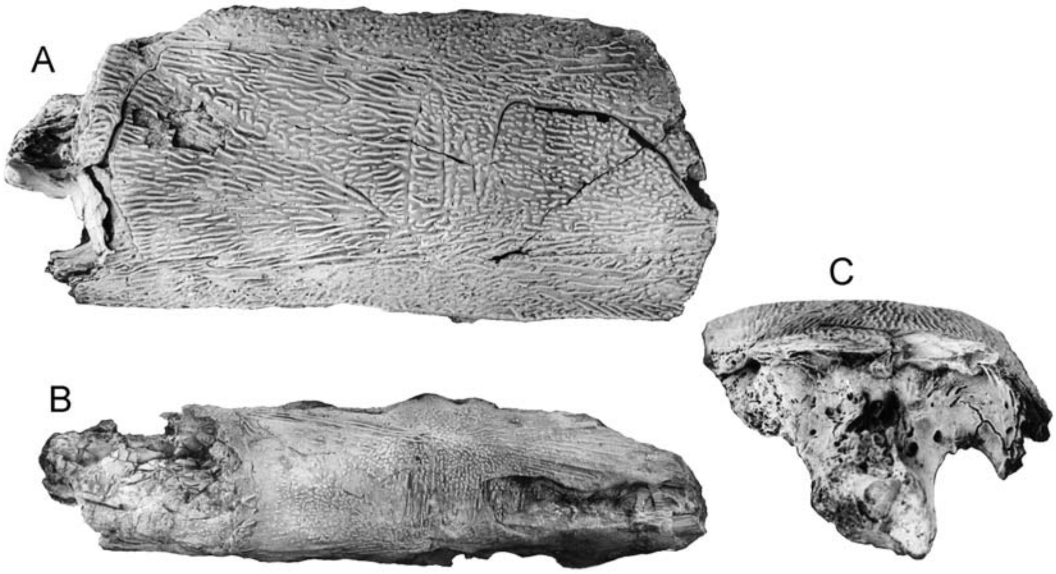

FIG. 8. *Richmondichthys sweeti* (Etheridge Jnr & Smith Woodward, 1891) neurocranium. A,C, dorsal and posterior views of QMF10608, × 1.4; B, dorsal view of QMF7568, × 0.45.

uppermost anterior element reaches well in front of the nasal and has broad contact with the maxillary. The second infraorbital is equally large and also has broad contact with the maxillary. Remaining infraorbitals (Io 3-5) complete the ventral and posterior margins of the orbit and broadly contact the postorbitals.

The supraorbital is a robust element approximately twice as long as it is high. It forms the anterodorsal margin of the orbit and abuts the frontal, reaching anteriorly to the nasal and the rostral.

The dermosphenotic is very long and robust, extending posteriorly from its suture with the supraorbital above the middle of the orbit to a point above the dorsal extremity of the preoperculum. It has a long abutment with the frontal and the dermopterotic.

The postorbitals comprise two very large elements that cover the anterior margin of the preoperculum. The ventral element makes broad contact with the maxillary and meets Io 2-4.

The preoperculum is an extremely large, triangular bone with the posteroventral angle approximately 90º. The preopercular canal has not been observed in any specimen.

Opercular Series. No interoperculum is present.

The operculum is a large, heavy element, subovate in outline with a slightly indented ventral margin, a straight anterior margin and near right angled anteroventrally. The facet for the articulation with the hyomandibular is situated anterodorsally. The surface is heavily ornamented with numerous, irregular and concentric ganoine ridges and tubercle rows, centred approximately above the hyomandibular facet.

The suboperculum is a moderately large bone, filling the space between the preoperculum and the operculum and ventral to the latter. It is quadrant-shaped and its surface is heavily ornamented with low, irregular, concentric ganoine ridges and tubercles around a centre near the anterodorsal extremity. Areas overlapped by other bones lack ganoine.

Some 13 branchiostegal rays are present below the posteroventral angle of the mandible.

No gular plate is present.

Upper Jaw. The maxillary is a large, boomerang-shaped bone that is much more developed in its posterior part than anteriorly. It is positioned considerably in advance of the orbit with the posteroventral margin remaining well anterior to the anterior of the orbit and not extending to the preoperculum. The posterior portion is thin and broadly covers the posterodorsal area of the mandible. The anterior presents a weak dorsal process that articulates with the premaxillary. No teeth are present. The bone is coated with largely featureless ganoine extending backwards and dorsally from the oral margin.

No supramaxillary is present.

Lower Jaw. A predentary is present as a medial element at the extreme anterior of the mandibles. It is edentate and is a tiny bone deeper than long. The oral border is much shorter than the depth of the bone.

The mandible has a relatively elevated and very deep symphysis, united in its upper moiety with the predentary by a near vertical suture. The coronoid process is virtually non-existent and is covered by the maxillary in most specimens. The lateral face is largely formed by the dentalo-splenial. The angular is relatively large but is almost completely covered by the posterior of the maxillary. The articular facet for the quadrate is formed at the base of the coronoid process by the angular and retroarticular on the upper surface of the mandible, at the base of the coronoid process. A short posterior process present behind the articular facet is formed by the articular and the retroarticular. The dentalosplenial and the angular are crossed longitudinally by the mandibular canal which has surface expression on the dentalosplenial as a shallow groove towards the ventrolateral margin. Ventrolaterally and around the anterior border, the mandible is heavily ornamented with ganoine ridges and tubercles, generally arranged longitudinally. The remainder of the lateral surface is coated with smooth ganoine.

The mandible is edentate.

Hyoid Arch Area. The mandibular-neurocranial connection is through the hyomandibular and the quadrate There is no evidence for the presence of a symplectic.

The hyomandibular is upright with the articular facet for the junction with the neurocranium elongate and near horizontal and with its distal extremity slightly curved anteriorly. The lateral surface is strengthened by a prominent ridge that separates a deep anterior portion that appears to abut the metapterygoid. The posterior border carries a prominent opercular process towards its top. The body of the bone is penetrated by the large foramen providing passage for the hyomandibular trunk of the facial nerve. The distal extremity has not been well exposed in any specimen but apparently provides broad contact with the quadrate anteroventrally and with the proximal ceratohyal towards the back. There is no evidence for the presence of an interhyal and the distal ceratohyal, hypohyal and basihyal have not been exposed in any of the available specimens.

The quadrate is a large, triangular bone but the dorsal extremity is not exposed in any of the available material. Anterodorsally, the quadrate overlies the ectopterygoid and is assumed to contact the metapterygoid dorsally. It also has broad contact with the hyomandibular dorsally. The articular condyle is oriented ventrally and anteriorly.

The autopalatine is almost completely obscured in all specimens, as are the metapterygoid and entopterygoid. The ectopterygoid is visible only posteriorly, where its ventral border is almost horizontal and the whole bone is essentially straight and tapering anteriorly. The bone is edentate.

The branchial arch is imperfectly preserved. Each element of the gill arches bears very numerous, extremely elongated gill filaments directed away from the arch (Fig. 9). Slightly more robust and elongated gill rakers occur anteromesially.

Postcranial Skeleton. The vertebral column has not been completely exposed in any specimen, making it impossible to indicate the number of individual vertebrae. Each centrum is amphicoelous and ovate in anterior view, being slightly higher than long. Each bears a small central foramen, the remnant of the notochord. The centrum is otherwise entirely ossified and only very slightly constricted longitudinally. Length of each centrum is about equal to the width. The lateral surface is smooth (Fig. 9). In section, the centrum possesses very fine radiating laminae of bone, separated by unossified areas. Neural arches are attached and bear prezygopophyses and postzygopophyses and support elongate, posteriorly directed neural spines, at least anteriorly in the body. In this area, such spines consist of separate lateral elements. Anterior neural arches are very elongate, occupying the entire length of each centrum , with the spines emerging above the middle of the centrum. Very short epineural spines are present anteriorly, fused firmly at the base of each neural spine. Anterior parapophyses are fused to the centra ventrolaterally. In more posterior vertebrae, haemal arches appear slender and at least in some individuals, both these and the neural arches are not fused to the centrum. The ventral surface of anterior vertebrae bears a median, longitudinal ridge separated from the parapophyses by shallow depressions.

The pectoral girdle is only partially exposed in all specimens. The supracleithrum extends from

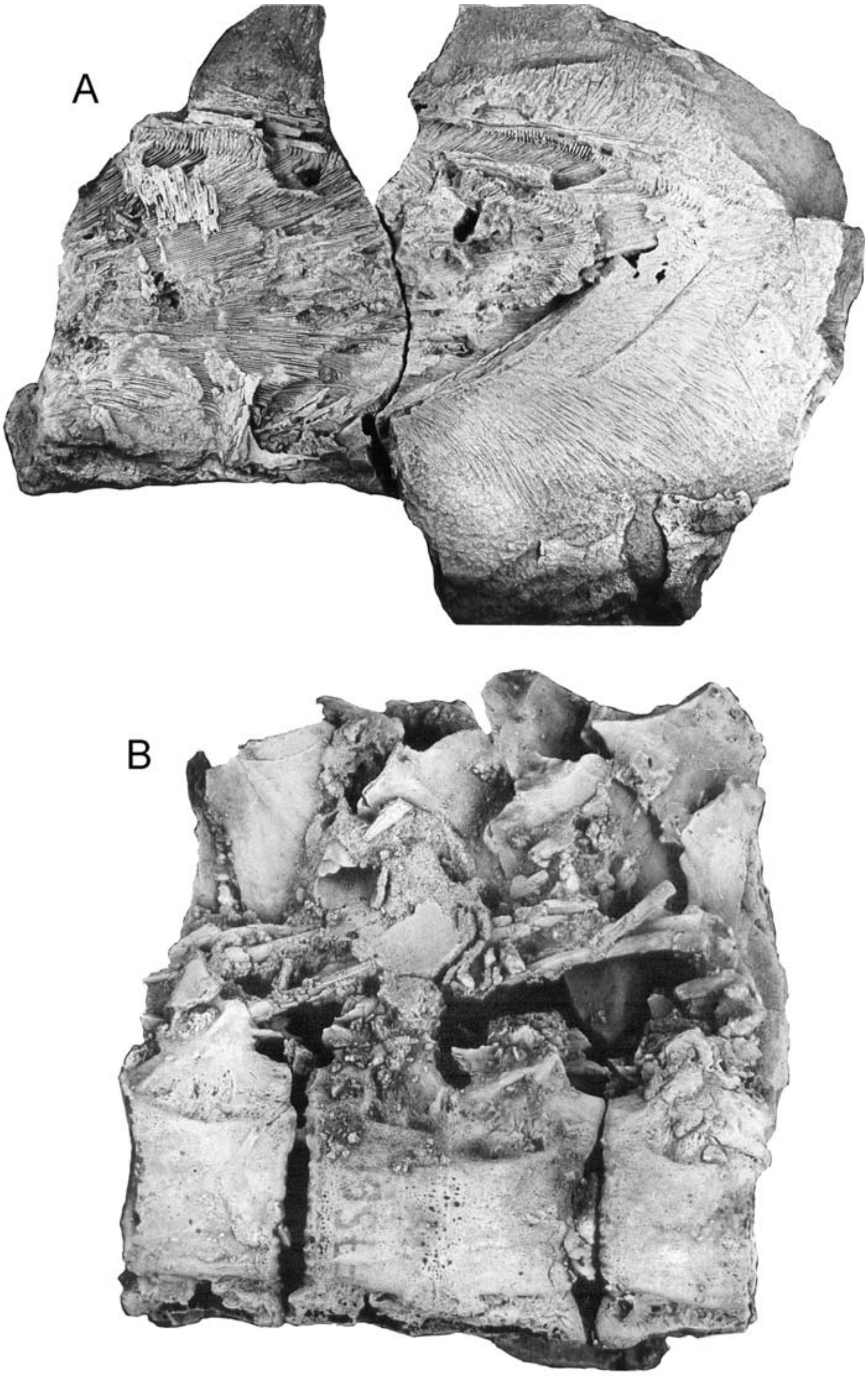

FIG. 9. *Richmondichthys sweeti* (Etheridge Jnr & Smith Woodward, 1891). A, gill elements, QMF5675, × 0.7; B, portion of vertebral column, QMF7568, × 1.6.

near the dorsal limit of the convex upper margin of the operculum ventrally to about one-half way down its posterior margin. Exposed portions are ornamented with irregular ridges and tubercles of ganoine, arranged parallel to the dorsoventral axis of the bone. The cleithrum is a much larger element, overlapped dorsally by the supra-cleithrum and extending around and under the posteroventral and ventral margins of the operculum and suboperculum. It is markedly concave anteriorly and exposed portions are ornamented with ganoine. The scapula and coracoid are almost completely obscured but the former is facetted to carry the pectoral fin. Other bones of the pectoral girdle are unknown.

Remains of the bases of all fins are preserved in only one specimen, QMF18898, and the formula for the fin positions above have been based upon this. Some exposed basal elements of all fins appear to have been coated with ganoine.

The pectoral fin appears to have seven rays, with the first smaller than the second, the latter being the largest ray in the series. At least proximally, the rays bear ornamentation of ganoine. As the rays broaden distally, the longitudinally orientated ganoine ridges are increased by insertion of additional ridges. The fin is moderately long, at least equal to two-thirds the depth of the anterior expanded flank scales. The pelvic, anal, dorsal and caudal fins are known from only remains of their bases.

Scales. The scales are heavy, strong and conspicuous and are the most commonly preserved parts of the skeleton (Figs 5,10). They are thickly ornamented with ganoine pits, low ridges and tubercles. Anterior and mid-body scales of the median flank series are very large. Individual lateral line scales in large specimens are up to 14.5cm deep and 2.3cm long. Table 2 details the depths of flank scales along the body in QMF18898.

TABLE 2. Depth of flank scales (cm) where: A measures scale immediately ventral to lateral line scale; B measures lateral line scale; and C measures maximum observed body depth.

Character	Near Head (Row 4)	Above Pelvic Fin	Above Anal Fin	Front of Caudal Fin
A	5.0	2.7	1.0	0.8
B	10.6	11.6	7.9	5.6
C	21.4	22.1	16.6	10.1

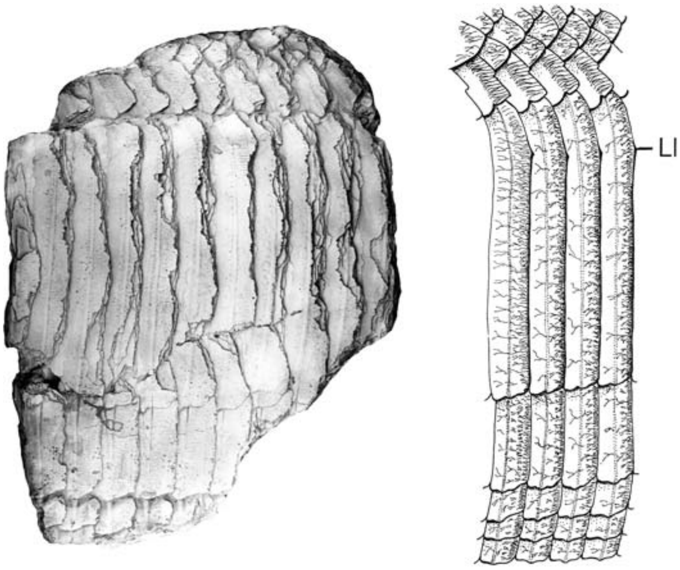

FIG. 10. *Richmondichthys sweeti* (Etheridge Jnr & Smith Woodward, 1891) mid-body scales with dorsal wall uppermost. A, GSQF12904; B, reconstruction (by T. Lees); both × 0.3.

Each median flank scale is slightly laterally convex with the convexity increasing dorsally. The posteroventral border is rounded. The ventral border, while generally convex, has a broad mesial process. The posterior margin is finely and irregularly serrate where the low ridges of ganoine project. The upper margin is pointed, with the apex posterior to the apex of the scale. The leading edge is smooth. A heavy ganoine ridge runs down the axis of the scale and this is usually paralleled by a second, less well defined ridge, just anterior to it.

The major ridge is often ornamented with tubercles, while the other ridge sometimes degenerates to a series of tubercles only. The anterior ganoine is smooth or only very slightly pitted or tuberculate. Posterior to the main ridge, irregular ganoine ridges run generally antero-posteriorly, often bifurcating or reuniting but give a general impression of subparallel, longitudinal ornamentation. Ornamentation is heavier dorsally. The lateral line is marked by a heavier, longitudinal plication, close to the dorsal limit of the scale.

TABLE 3. Comparison of Aspidorhynchid genera. Information on *Vinctifer*, *Belonostomus* and *Aspidorhynchus* is based on revised diagnoses and descriptions in Brito (1997).

Characters	*Richmondichthys*	*Vinctifer*	*Belonostomus*	*Aspidorhynchus*
Premaxillary teeth	Absent	Absent	Present	Well developed
Maxillary teeth	Absent	Present	Present	Present
Supramaxillary	Absent	Absent	Present	Present
Maxillary	Very expanded	Large	Slender	Slender
Premaxillary	Short	Attenuated	Very attenuated	Attenuated
Neurocranium	Fused	Fused	Fused	Unfused
Parasphenoid	Edentulate	Edentulate	Toothed	Toothed
Anterior infraorbitals	Much expanded	Unexpanded	Unexpanded	Unexpanded
Predentary	Minute	Small	Very attenuated	Small
Lateral line scales	Very deep	Deep	Somewhat deep	Shallow
Scale ganoine	Very ornamented	Unornamented	Unornamented	Absent

Ventral to the main flank scales are at least four and possibly up to six rows of progressively smaller scales. In large individuals, anteriorly the uppermost are up to 5cm deep. The next scales row are up to 1.8cm deep, those in the third row are up to 1.5cm deep, while in the fourth row they approach 1cm deep. The uppermost of these ventral scales has very similar structure and ornamentation to the main flank scales. Lower scales generally have little or no ornamentation, other than traces of the median ridge and are subovate in shape but have a distinct peg arranged axially along the dorsal margin.

Dorsal scales above the main flank scales also appear to be in no less than four rows anteriorly. Unlike the ventral series where scales are arranged in near vertical rows, those above the main flank scales are angled anteriorly. In outline, scales of the first row are similar to the main flank scales but have a ventral emargination rather than a peg. The median ridge is less strongly defined but minor ornamentation is similar. In large specimens, the lowermost dorsal scale is up to 2.8cm deep. Scales above this row are inserted to leave a broadly convex posterior margin but are otherwise rhomboidal in shape. Little trace remains of a median ridge and ornamentation consists of anteroposteriorly arranged , irregular ganoine ridges. Occasional heavy tubercles are present. In depth, the dorsal scales decrease in size dorsally and in large individuals measure up to 2cm, 1.9cm and 1.7cm within each row.

More posteriorly along the body, depth of the large flank scales gradually decreases and near the base of the caudal fin, all scales are of a similar size, are rhomboidal and are arranged in an imbricated pattern. Ornamentation has been reduced to a posterior, longitudinal keel with subparallel minor ridges. Up to 82 rows of scales are present in the flank series.

DISCUSSION

Brito (1997) has undertaken a major revision of the Family Aspidorhynchidae and referred the Australian material, previously ascribed to *Belonostomus sweeti*, to the genus *Vinctifer*. Fragmentary aspidorhynchid remains from Cretaceous sediments at Hughenden Station in central western Queensland and referred by Etheridge (1872) to *Aspidorhynchus* sp. included parts of large body scales that are ornamented with ridges and tubercles of ganoine. This material was referred to the species *Belonostomus sweeti* by Jack and Etheridge Jnr (1892). Clearly, this material is not referable to *Aspidorhynchus*, which is shown by Brito (1997) to lack ganoine on its scales. Similarly, it is not referable to either *Belonostomus* or *Vinctifer* both of which have unornamented ganoine on their principal and other body scales. However, rugosity may be present on the scales in some *V. comptoni*, as described by Jordan (1921). The Hughenden material is here referred to the new genus, *Richmondichthys*, although non-diagnostic specimens can only be regarded more generally as undetermined aspidorhynchids. Table 3 provides a comparison of major morphological characters within the genera of the family, based on those features that are present in all of them. Figure 11 compares the heads of the aspidorhynchids.

In many of the earlier reconstructions of *V. comptoni*, the extent of the premaxillary spine was not recognized e.g., in that illustrated in Jordan (1921). The retracted nature of this feature in R.*sweeti* might thus be supposed to reflect a similar accident of preservation, with an attenuated spine broken off and lost during preservation. Close examination of the tips of the premaxillaries in QMF18898 shows that this specimen presents the entire extent of the spine and that the termination of this structure is posterior to the anterior extent of the lower jaw.

In ascribing *B. sweeti* to *Vinctifer*, Brito (1997) believed the species to be close to but much larger than the type species, *V. comptoni* from the Albian Santana Formation, Jardim, Ceara, Brasil. Temporal and geographical distribution of *V. comptoni* is recorded by Brito (1997) as also being from the Santana of the Araripe Basin, the Aptian/Albian Codo Formation of the Parnaiba Basin, the Aptian Muribeca and Albian Riachuelo Formations of the Sergipe and Alagoas Basins and in the Aptian Apon Formation of Venezuela and the Albian Morelos Formation of Tepexi de Rodriguez, Puebla, Mexico.

Apart from *V. comptoni*, to which Brito (1997) referred the recently described *V. punctatus* Santos,1985 from the Aptian/Albian Muribeca Formation in the State of Alagoas, Brasil, a number of other species of *Vinctifer* have been recognised, namely *V. longirostris* Santos, 1990 and *V. araripensis* Santos, 1994 from the Brasilian Aptian Marizal Formation in the Tucano Basin and the Albian Santana Formation in the Araripe Basin respectively. Like *V. comptoni*, these species are quite distinct from the Australian material here referred to the new genus *Richmondichthys*.

A heavily ossified and fused neurocranium from the late Campanian of Patagonia, illustrated by Brito (1997) could relate to either *V. comptoni* or *R. sweeti* but is too incomplete to enable its specific identity to be resolved with any certainty. Predentaries and isolated scales that are much deeper than long are recorded from the Barremian Missao Velha Formation of the Chapada do Araripe and identified as *Vinctifer* by Brito et al.(1994). This material appears to lack close affinity with *Richmondichthys*.

Taverne (1969) referred the partial posterior of a body of an aspidorhynchid from the Cretaceous of Equatorial Guinea to *Belonostomus*; this material has very deep lateral line scales compared with those immediately above and below them, suggesting to Brito (1997) the material is more likely to be referable to *Vinctifer*, supporting a view taken earlier by Maisey (1991). It is unlikely this material is more closely related to *R. sweeti*. Similarly, the specimen from the Jurassic of Antarctica, illustrated by Brito (1997, fig. 28) appears to be more appropriately assigned to *Vinctifer* as suggested by him. It had been identified previously as *Aspidorhynchus* by Richter & Thomson (1989).

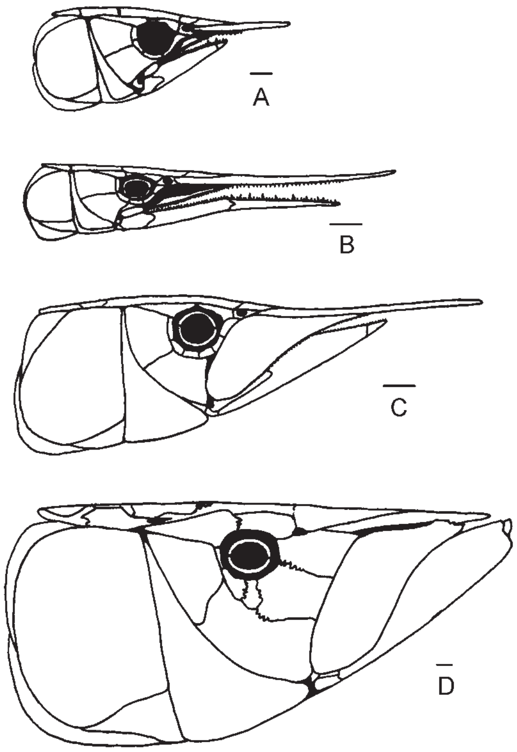

FIG. 11. Comparison of reconstructed heads of aspidorhynchids. A, *Aspidorhynchus* acutirostris (Blainville, 1818); B, *Belonostomus* tenuirostris (Agassiz, 1833); C, *Vinctifer comptoni* (Agassiz, 1841); and D, *Richmondichthys sweeti* (Etheridge Jnr & Smith Woodward, 1891). A,B and C from Brito (1997). Scale bars = 1cm.

It thus appears that *Richmondichthys* is known only with certainty from the Albian of north central Queensland, Australia. On the other hand, *Vinctifer* probably existed widely throughout Gondwanaland from South America, Africa and Antarctica but, as yet, has not been recorded from Australia.

Day et al. (1983) indicate that, during the Albian, deposition in the northern part of the Eromanga Basin in central Queensland took place in restricted marine and lagoonal environments, with limited communication with the sea in the Carpentaria Basin to the north. The northern seaway reestablished across the Euroka Arch in late Albian times and was marked by the deposition of the interbedded black shale and limestone of the Toolebuc Formation. Oil shale deposits of this formation indicate specialised environmental conditions which favoured the growth and preservation of organic remains. These conditions were terminated by continued transgression and the succeeding Allaru Mudstone represents normal marine deposition. Sedimentation in the Eromanga Basin ended with the regressive cycle in late Albian time as the sea withdrew into the Carpentaria Basin.

Richmondichthys was well equipped through the defensive nature of its heavily armoured scales and dermal bones to co-exist with a range of predatory reptilian, teleost and selachian contemporaries. Lack of teeth and the weight of the skeletal elements point to an incapacity to move quickly either to capture food or to escape predators. The organisation of the cheek bones and their 'hinging' along the length of the neurocranium, together with the extreme length of the gill rakers support the view that *R. sweeti* was a filter feeder, either gulping to ingest food or widely opening its jaws and ballooning its cheeks whilst moving slowly through plankton swarms. Large specimens predominate amongst those preserved and the species was one of the most common in Queensland's Lower Cretaceous.

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LITERATURE CITED

AGASSIZ, L. 1833-44. Recherchessur les Poissons fossiles. Neuchatel. 5 vols. 1420 pp., with supplement.

BRITO, P.M. 1992. L'endocrane et le moulage endocranien de *Vinctifer comptoni* (Actinoptrtygii, Aspidorhynchiformes) du Cretace inferieur du Bresil. Annals of Paleontology (Vertebrate - Invertebrate) 78(3): 129-57.

1997. Revision des Aspidorhynchidae (Pisces, Actinopterygii) du Mesozoique: osteologie, relations phylogenetiques, donnees environmentaleset biogeographiques. Geodiversitas 19(4): 681-772.

DAY, R.W., WHITAKER, W.G., MURRAY, C.G., WILSON, I.H. & GRIMES, K.G. 1983. Queensland geology – a companion volume to the 1:250000 scale geological map (1975). Publications of the Geological Survey of Queensland 383: 1-194.

ETHERIDGE, R. 1872. Description of Palaeozoic and Mesozoic fossils of Queensland. Quarterly Journal of the Geological Society of London 28: 317.

ETHERIDGE, R. JNR & SMITH WOODWARD, A. 1891. On the occurrence of the genus *Belonostomus* in the Rolling Downs Formation (Cretaceous) of Central Queensland. Transactions of the Royal Society of Victoria 2(2): 1-7.

JACK, R.L. & ETHERIDGE, R. JNR 1892. The geology and palaeontology of Queensland and New Guinea. Publications of the Geological Survey of Queensland 92(1): 504.

JORDAN, D.S. 1919. New genera of fossil fishes from Brazil. Proceedings of the Academy of Natural Science of Philladelphia 71: 208-10.

1921. Piexes cretaceos do Ceara e Piauhy. Monografias. Servico Geologico e Mineralogico do Brasil 3: 101.

MAISEY, J.G. 1991. *Vinctifer*. Pp 170-89. In Maisey, J.G. (ed.) Santana Fossils. (TFP: New York).

NICHOLSON, H.A. & LYDEKKER, R. 1889. A manual of palaeontology. Edit. 2. (Edinburgh and London).

PATTERSON, C. 1973. Interrelationships of holosteans. Pp 233-305. In Greenwood, P.M., Wiles, R.S. & Patterson, C. (eds) Interrelationships of fishes. (Academic Press: London).

RICHTER, M. & THOMSON, MRA. 1989. First Aspidorhynchidae (Pisces: *Teleostei*) from Antarctica. Antarctic Science 1(1): 57-64.

SANTOS, R. da S. 1985. Sobre a presenca de *Vinctifer* Jordan (Pisces, Aspidorhynchidiformes) na Formacao Muribeca, Estada de Algoas. Pp. 47-50. In Coletania de trabelhos paleontologicos. (Departmento Nacional da Prodção Mineral: Brasilia).

1990. *Vinctifer longirostris*, do Cretaceo inferior da formacao Marizal, Estata da Bahia, Brasil. Anais de Academia Brasileira de Ciencias 62 (3): 251-60.

1994. *Vinctifer araripensis* sp. nov. da Formacao Santana. Bacia do Araripe, NE do Brasil. Anais de Academia Brasileira de Ciencias 66(1): 85-94.

TAVERNE, L. 1969. Sur la presence d'un Aspidorhynchidae (Pisces Holosteen, Order Aspidorhynchidiformes) dans les terrains eocretaciques de la Guinee Equatoriale. Revue de zoologie et de botanique africaines 79(3/4): 261-4.

WESTOLL, T.S., 1944. The Haplolepidae, a new family of late Carboniferous bony fishes. Bulletin of the American Museum of Natural History 83: 1-34.