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ICHTHYOSAURS FROM CRETACEOUS MULLAMAN BEDS NEAR DARWIN, NORTHERN TERRITORY

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ABSTRACT

Few Australian ichthyosaur remains have been found outside the Queensland Artesian Basin. Near Darwin, N.T. poorly preserved *in situ* ichthyosaur fossils are relatively common in Upper Albian Beds of shore line character, often in association with fragments of petrified wood. One specimen of ichthyosaur, recovered from a thin, shaley bed outcropping at the mouth of Rapid Creek near Nightcliff is complete enough to record some overall structural and proportional details, but no taxonomically diagnostic elements were present. The indeterminate ichthyosaur material, resembling *Platypterygius australis* in general proportions and vertebral morphology is presented as *gen. et sp. indet.*

KEYWORDS: Cretaceous, ichthyosaur, Darwin area, Mullaman Beds, phosphorites, Albian shoreline, fossil wood.

INTRODUCTION

A fragmentary *in situ* ichthyosaur fossil consisting of a series of articulated vertebrae and isolated finds of ichthyosaur vertebral centra and other elements collected from marine outcroppings of the Mullaman Beds along the northeastern shoreline of the Darwin area in 1982-1983 indicate a relative abundance and wide distribution of material little known in Australia outside of the Albian — aged Artesian Basin sediments of Queensland (Wade 1984).

Northern Territory ichthyosaur fossils were first discovered by workmen in 1915, near Fannie Bay, Darwin. That material now resides in the Australian Museum (Anonymous 1924). The discovery of new fossils from other localities in the area indicates a promising source of new ichthyosaur material that may eventually contribute to our now less than satisfactory understanding of the distribution and marine palaeoecology of the group.

DARWIN AREA ICHTHYOSAUR LOCALITIES

Several fragments of ichthyosaur vertebrae recovered from a reef exposed only on spring tides were taken to the museum for identification by Gregg Timms in 1982. I accompanied Mr Timms to the locality, near Casuarina Beach but we were unable to relocate the original source. However, when we examined other sections of the reef, new specimens of ichthyosaur material were found (Figs 1,10). A second ichthyosaur locality was discovered by Ron and Keith Docking of the Nightcliff suburb of Darwin in October, 1983. The Dockings left the fossil *in situ* and reported it to the Northern Territory Museum. This fossil differed from the isolated finds at Casuarina Beach in being an articulated series of vertebral centra consisting primarily of moulds and partially silicified, deeply weathered bone fragments. The Fannie Bay ichthyosaur is also an associated assemblage of centra, though disarticulated and scattered. The bone appears to be well preserved whereas the Causarina Beach material is composed primarily of siltstone casts retaining little of the original bone structure. Each of the localities have a somewhat different geological setting and depositional history.

Nightcliff Locality

The more recently discovered articulated vertebral series was located at longitude 130°51.1′E., latitude 12°22.5′S

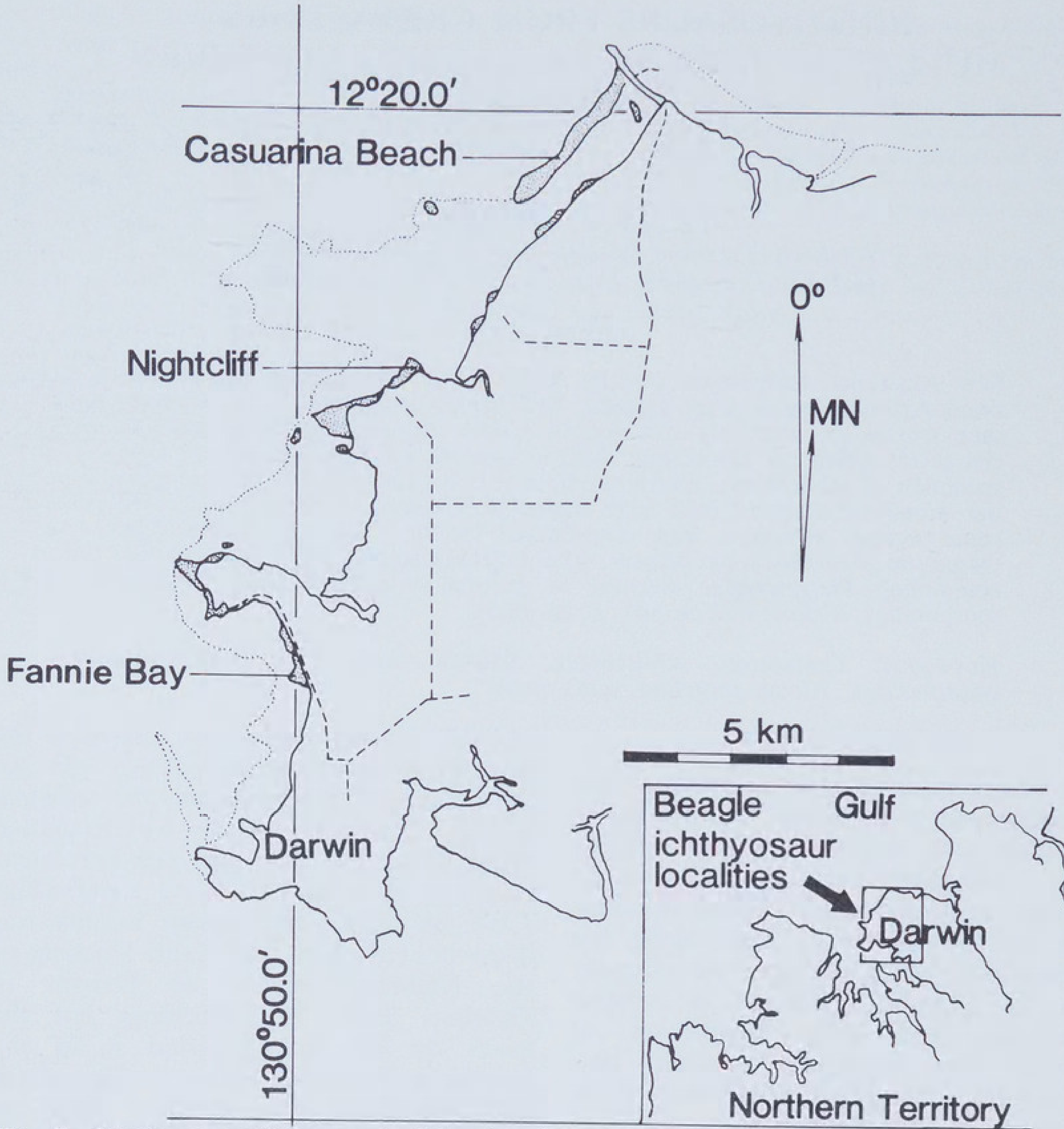

Fig. 1. Darwin area ichthyosaur localities; location of reefs and outcroppings based on Australian hydrographic Service, R.A.N. chart 1980, Aus 27.

near the Darwin suburb of Nightcliff in a deeply weathered, variegated light grey to white, shaley siltstone outcropping about 50 metres from the grassy verge of an adjacent foreshore park on a bearing of 340° (Fig. 1). The outcrop consists of several beds discernable on the basis of texture, colour and locally well defined bedding planes (Fig. 2). The ichthyosaur is embedded in a thin (4.0cm-6.0cm thick) stratum of jointed, fossiliferous, shaley siltstone overlain by 20-30cm of reddish brown to dark brown, lateritized fine sandstone containing infilled structures resembling burrows. Traces and moulds of invertebrate fossils present in the immediate vicinity of the ichthyosaur remains include two or more kinds of poorly defined pelecypod moulds, internal casts of a burrowing mollusc, either *Teredo* sp. or a closely related form and belemnites, probably *Dimitobelus* sp. (Fig. 4). The ichthyosaur stratum has a patchy distribution having been largely eroded away by wave action and tidal currents that occur with each espisode of spring tides. The entire outcrop dips gently to the north. Careful examination of the remaining fossiliferous stratum located two more isolated but well preserved ichthyosaur vertebrae belonging to a second and possibly a third individual (Fig. 8). Numerous indistinct infillings and nodular phosphoritic structures, some of undoubted organic origin,

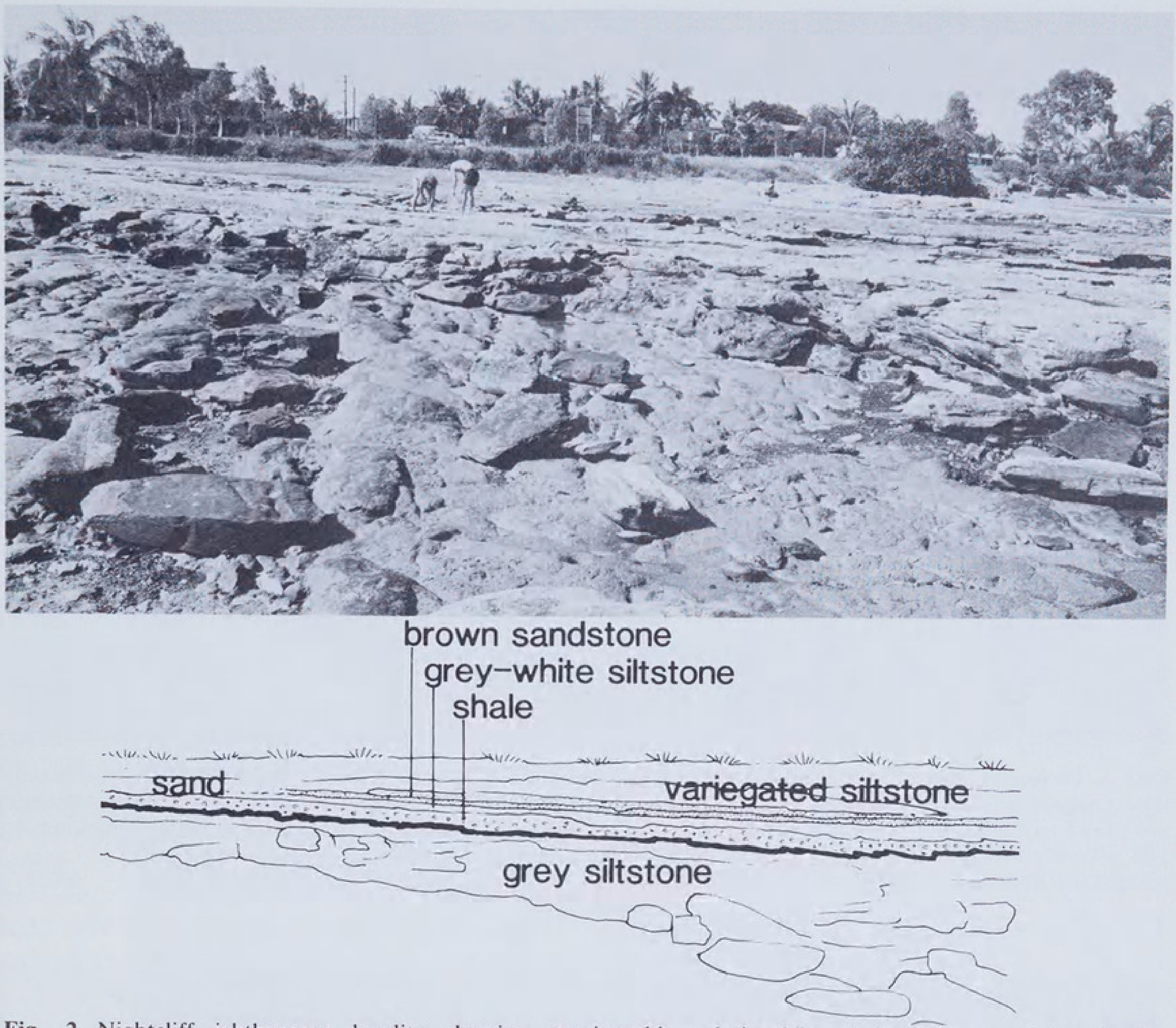

Fig. 2. Nightcliff ichthyosaur locality showing stratigraphic relationship of fossiliferous shale clearly visible as a thin band directly beneath the two figures (excavating the ichthyosaur fossil). Weathered and jointed blocks of greyish white siltstone, capped by reddish sandstone (the darker band) can be seen in superposition. The shale lies thinly bedded over a massive jointed bed of greyish white siltstone 0.5 to 0.75 metre thickness.

are scattered throughout the shale along with fragments and casts of wood or roots, some of which contain *Teredo* like borings (Fig. 3).

Casuarina Locality

The Casuarina Beach locality, approximately 5.0km NNE of the mouth of Rapid Creek, Nightcliff, outcrops in the area of longitude, 130°52.5′E latitude 12°20.6′S. It is composed of a series of irregular, usually submerged siltstone reefs. The top of the reefs generally project less than 1.0 metre above the adjacent and surrounding sandy beach and are accessible only at low water on spring tides.

Access to the locality is by road to the "Casuarina Free Beach". Most of the surface of the dark grey, massively bedded siltstone outcrop is obscured by thick marine growth. The fossil material is composed primarily of casts of ichthyosaur vertebral centra that have partially weathered out from the bedrock by wave action. Some specimens show traces of internal structure but the majority of them are siltstone infillings with no internal detail (Fig. 10). Of some interest here, are large, well preserved fragments of fossilized wood, the gross internal structure of which may yield an identification of its taxonomic relationships.

The extensive Casuarina siltstone outcrop (approximately 0.3km wide by 3.0km long) has had less than 5% of its surface examined for fossils. Nearly all of the

Fig. 3. Photograph showing approximately 0.5 metre of the eroded surface of the Nightcliff shale band taken approximately 7 metres away from the ichthyosaur fossil. The phosphatic nodules being more durable, are proud to the matrix; note silicious pisolites exposed in some examples. The thin bed is extensively jointed and severely eroded. Approximately half of the areal extent of the exposure is gone. In the Darwin area, phosphatic beds are confined to a horizon 18.3 metres above the base of the Cretaceous (Kemezys 1968).

fossils were found on the seaward margin of the reef where wave impact combined with the scouring action of beach sand has kept a 1 metre wide strip free of marine encrustations. The siltstone also contains uncommon poorly formed pelecypod casts and belemnites.

Fannie Bay Locality

The exact provenience of the Fannie Bay ichthyosaur fossil does not appear to have been recorded. The most likely outcrop in the area that fits the description on a beach near Fannie Bay, Darwin is in the proximity of longitude 130°49.9′E latitude 12°25.5′S (Fig. 1). The Fannie Bay Mullaman Beds in that area generally resemble the exposure near Nightcliff in gross lithology and stratigraphic position. The Fannie Bay ichthyosaur appears to be the best preserved material from the Darwin area and consists of more than 50 vertebral centra embedded in fine light coloured siltstone of approximately 10.0cm-15.0cm thickness.

The Fannie Bay fossil (Fig. 11g) has a unique history in having been discovered twice. Following its initial discovery by workmen, the large slab containing the fossil was removed with the aid of a gang of prisoners from the Fannie Bay Goal by Dr H.I. Jensen, at that time Director of Mines, Northern Territory. Unable to send the ichthyosaur to Sydney as he had intended, Dr Jensen left the bulky specimen at the nearby Darwin Botanical Gardens. In 1923, the apparently forgotten fossil was brought to the attention of Surgeon Lieutenant W.E.J. Paradice, R.A.N. by Dr Allen, then Director of the Botanical Gardens, who apparently rediscovered it in the park grounds. Dr Paradice recognized the fossil as an ichthyosaur and arranged to have it shipped to Sydney aboard the H.M.S. *Geranium*, a survey ship to which he was commissioned as ship's Doctor. The Fannie Bay ichthyosaur raised considerable interest in the Sydney press in 1923-24 when, among other things, it was described as one of the major discoveries of the *Geranium's* expedition. In spite of all the publicity, the specimen failed to arouse sufficent interest among palaeontologists to initiate even the briefest formal description of it, their colourful remarks being confined to newspaper quotes. The fossil continues to reside in overflow storage at the Australian Museum (Alex Ritchie, pers. comm.; *Sydney Evening News*, 8 December 1923; *Sydney Sunday News*, 9 December 1923; *Sydney Morning Herald*, 13 December 1923; *The Daily Telegraph*, 12 December 1923; *Sydney Morning Herald*, 3 January 1924).

AGE

The Darwin area Mullaman Beds containing ichthyosaur remains are considered to be late Albian equivalent (Day 1969; Skwarko 1966; Skwarko 1968). The nearly horizontal Darwin area Mullaman Beds overlie PreCambrian rocks, usually commencing as a basal gravel or conglomerate, superposed by a deeply weathered quartz sandstone and succeeded by silicified fossiliferous clay or siltstone having persistant bands but poorly developed bedding planes. The beds dip gently to the north. The fossiliferous bands containing ichthyosaur material at about 18 metres above the base of the Cretaceous, may have originally been deposited in a silty mud in which formed or were embedded, numerous phosphatic nodules before the bed underwent diagenic conversion to shale and subsequent partial silicification (Kemezys 1968). The extent of silicification of the beds varies locally and indeed, the condition of the embedded materials ranges from leached chalky infillings of pelecypod and belemnite moulds to hard, irregular clastic nodules with a core of siliceous pisolites.

DESCRIPTION

Nightcliff Ichthyosaur

The Nightcliff ichthyosaur specimen is a partially preserved articulated vertebral array embedded *in situ* (Fig. 5). The vertebral centra are in various but generally poor states of preservation ranging from half moulds, casts and partially silicified fragments of bone showing a coarse, open-work structure. All elements are compressed and slightly warped. The articulated vertebrae lie in four consecutive closely approximated segments, suggesting that the fossil was embedded at a relatively late stage in

Fig. 4. Casts of belemnites, probably *Dimitobelus* sp. No internal structure is present in the casts; their composition appears to be identical to the phosphatic nodules lying adjacent to them.

the decomposition of the connective tissues supporting the vertebral column.

The vertebral array tapers in both directions but the less tapered anterior end is delineated by the presence of a fragment of the pectoral girdle and the posterior portion by the tapering of the vertebrae to a very small diameter. Because of the poor state of preservation of the specimen, the location of other elements were determined with the aid of a scaled restoration, based on the Telemon *Platypterygius* (QM. F 2453) that was superimposed on a photographic tracing of the Nightcliff ichthyosaur. This resulted in the discovery of a scapula, a possible hind paddle trace and a fragment of the cranium after the actual proportions of the specimen were realized. Inspite of the sequential vertebral preservation, the angle of deflection of the tail fin vertebrae could not be discerned. This is unfortunate because Broili (1907) used a downturn of 50° from another genus for his restoration of *Platypterygius*.

Sixty of the vertebral centra are clear enough to make a positive identification of them as such. The rest are represented by traces and aligned, amorphous lumps.

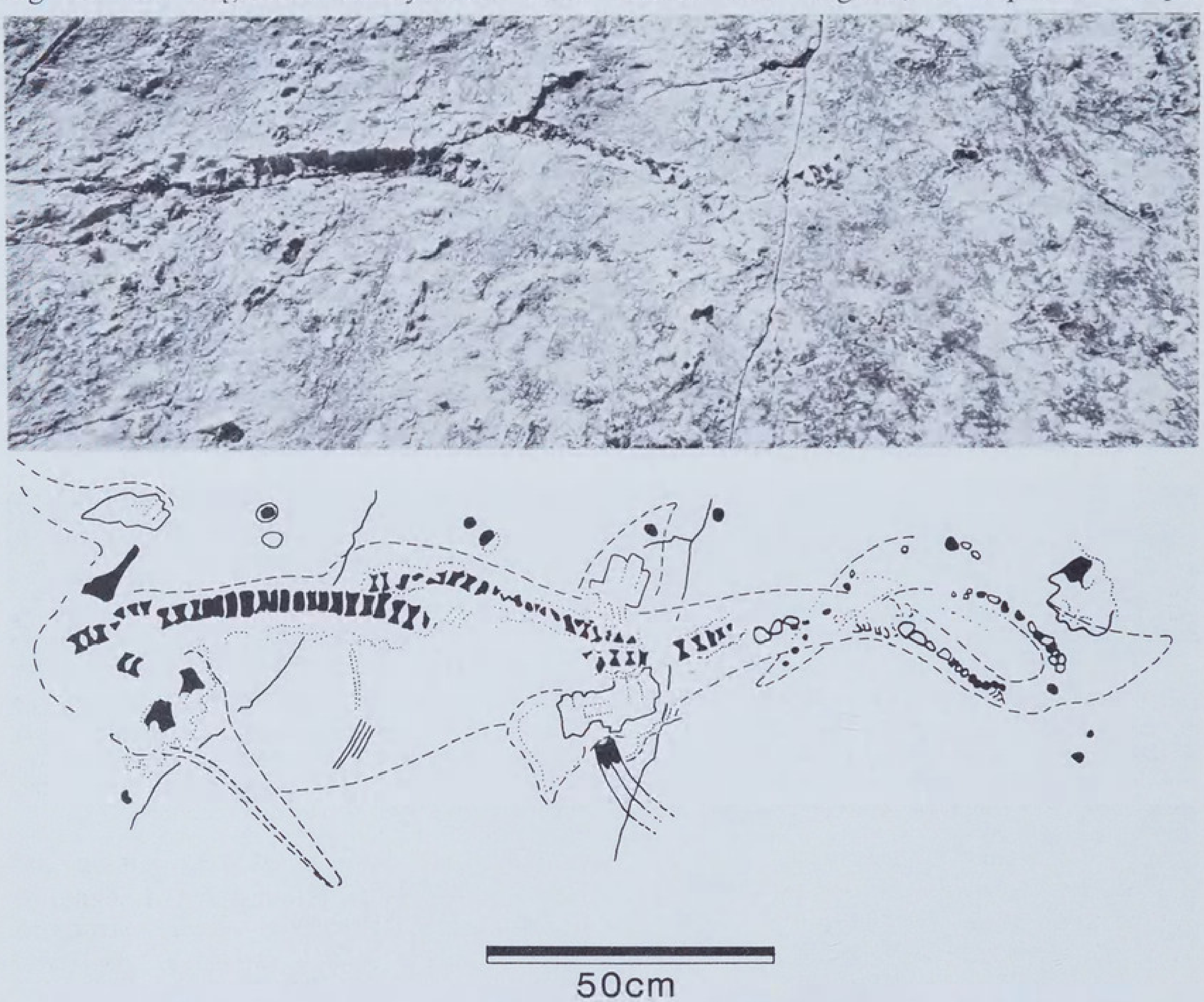

Fig. 5. Photograph and interpretive sketch of the Nightcliff ichthyosaur. Almost the entire vertebral array can be traced by careful examination of the weathered surface of the matrix. All of the mineralized bony elements are compressed to the extent that the nearly circular vertebral centra are ellipsoidal with proportions of approximately 3:5. The remains of the cranium are crushed flat and poorly preserved, its approximate position indicated by small bone fragments grading into a cast of the matrix. The majority of the dorsal vertebral centra are moulds with little bone present. Elsewhere the centra are represented by casts and moulds or combinations of the two. Low relief casts of the pelvic fins and a mould of the rostrum are clearly visible. Sedimentary structures such as old strand lines and differential erosion and deposition of fines around the skeleton can be seen near the tail vertebral series (as faint rays). The possible fin casts may have developed from partial infillings of the original bony structure obscured to some extent by dessicated soft tissue.

Over one hundred centra, from the head end to the approximate termination of the tail can be accounted for by including shallow moulds, aligned nodules and by filling gaps in the vertebral array with displaced vertebrae of the appropriate diameter. Given the small size of the caudal vertebrae, the original number must have been greater, although only about twenty of them can actually be identified (Fig. 7). A number of rib fragments are preserved, two of which appear to be near their points of articulation. Other elements are undoubtedly present, but represented by irregular infillings with partial preservation of the original bone. Positive identification of most of these structures is not possible, but the use of a reconstructed ichthyosaur as a guide suggests the probable identity of some elements in which outline shape and surface detail has been preserved. While the material is generally undiagnostic, a brief description of it may prove useful.

Cranium. A possible cranial element is represented by a strongly crested bone fragment that grades into an irregular, but symmetrical flattened mass about 12 cm across. The definable portion of the bone could be the post frontal and post orbital process that delineates the inferior orbital margin. The cranium was crushed, missing the upper jaw and acutely bent downward and backward when it was embedded in the sediments. A gently curved, elongated impression with a distinct midline, terminating with a bone fragment embedded in the matrix, may represent a fragment of the rostrum and lower jaw (Fig. 5). Near the tail segment, a flattish irregularly oval structure determined to be at least partially represented by well preserved bone, could be cranial base elements.

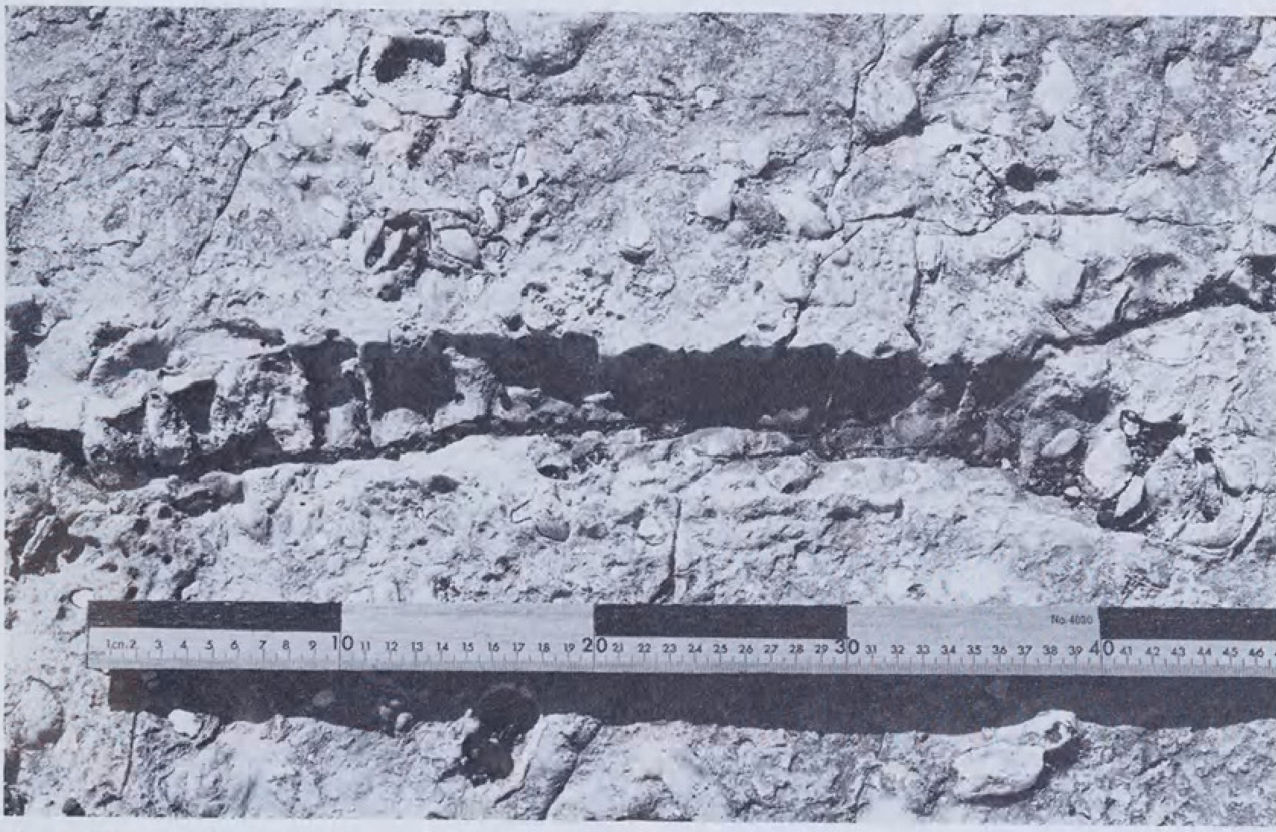

Fig. 6. Photograph of a segment of dorsal vertebrae consisting primarily of moulds; the inferior border of the moulds are delineated by a lip of matrix which shows faintly on the photograph; the anterior dorsal vertebrae in the series consist of silicified bone; an articulated rib fragment is visible extreme left centre. Another rib, mostly mould but with some preserved bone, is right centre, 5 vertebrae from the left on the dorsal side. Rib apophyses are faintly visible as deep, circular impressions obscured by shadows.

Pectoral girdle. The pectoral girdle of the right side is represented by a section of bone having a broad distal articular surface that appears to bear two facets, interpreted as the glenoid fossa and the coracoid articulation. A stout process arises from the proximal end which appears to represent the scapular blade.

The visible portion of the structure is approximately 95mm long and an estimated 50 to 65 mm across the articular end. The base of the scapular spine is about 25mm across. The bone is robust with strongly oriented, fine trabeculae and thick compactum and in outline form generally resembles the scapulae of *Ophthalmosaurus* figured by Romer (1968), as well as those of *Stenopterygius*.

Vertebral column. The vertebral elements are the typical compressed, waisted amphicoelous vertebrae characteristic of ichthyosaurs (Figs 5-9). The centra are compressed anteroposteriorly with a shallowly fluted circumference. Indentations suggestive of rib apophyses are present on some of the moulds of dorsal vertebrae and indicate that the ichthyosaur was lying on its right side (Fig. 9). Definite cervical differentiation could not be determined. The anterior 3 dorsal vertebrae are poorly preserved, friable remnants from which no reliable measurement could be obtained. Due to lateral compression, the dorsoventral diameters given are approximately 0.2 to 0.3 greater than before distortion (Fig. 9d). The anterior- most measurable mould is 44mm dorsoventrally and 21mm anteroposteriorly. A sample of 3 dorsal vertebrae from anterior to posterior measure 63mm x 24mm, 64mm x 25mm and 59mm x 23mm, respectively. Between 40 and 45 dorsal vertebrae can be accounted for. A presacral mould measures 43mm x 21mm and immediately postsacral, 32mm x 16mm. A series of three large anteriorly displaced vertebrae are probably sacral. The largest measures 52.5mm x 29mm (Fig. 7). Caudal vertebrae in the probable

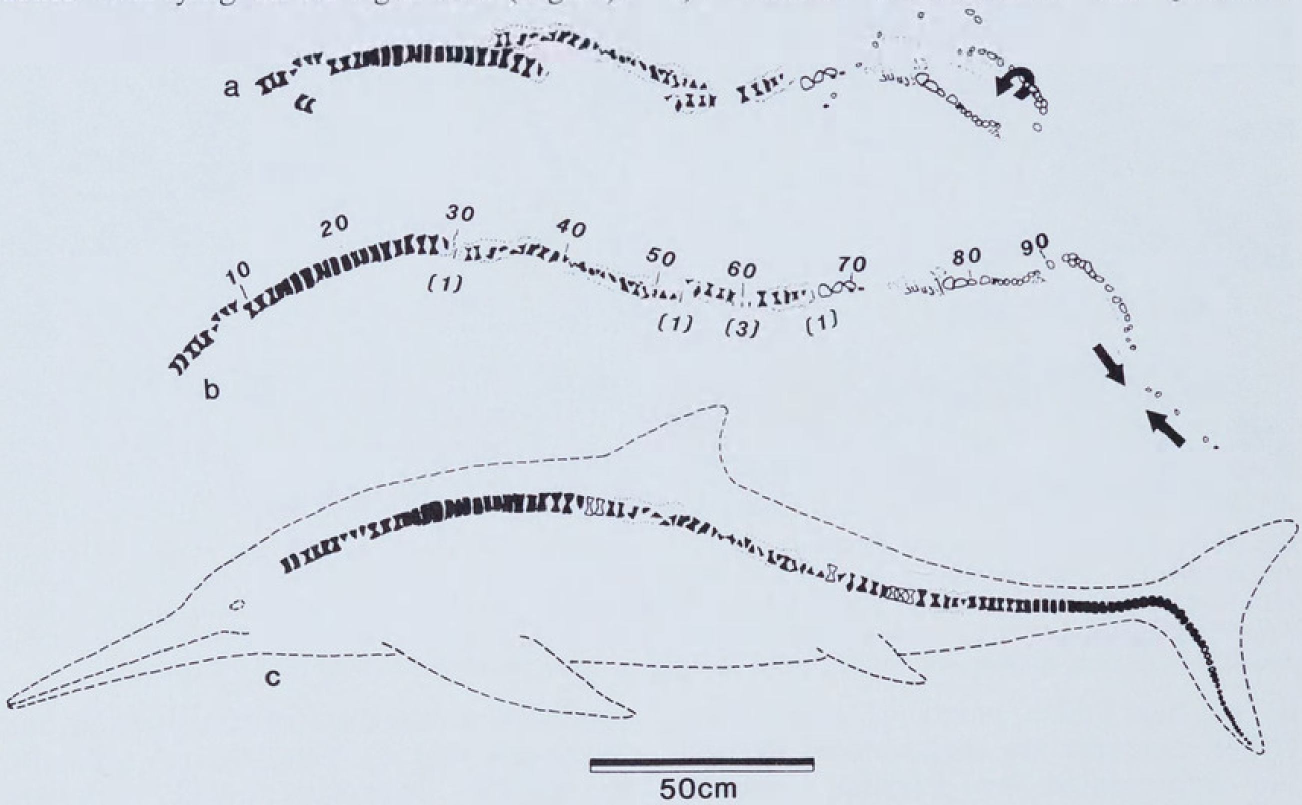

Fig. 7.a, Schematic drawing of the vertebral centra of the Nightcliff icthyosaur in which traces and aligned phosphate nodules (presumably obscuring the actual centra) have been plotted in addition to 60° well preserved vertebrae. Approximately 30 vertebrae can be accounted for by shallow, oriented traces and irregularly shaped but aligned nodules. Nearly all of the preserved bony material has been replaced or altered by phosphatic precipitate. The moderately large centra partially underlying the second segment of dorsal vertebrae are probably the sacrals, at between centra 54 and 64; **b**, Restoration of the vertebral column of the Nightcliff Ichthyosaur giving the maximum estimated number of vertebrae at intervals of 10. The approximate shape of the tail was achieved by reversing the vertebral series and aligning them resulting in a pattern suggestive of the tail deflection; **c**, Restored outline of the Nightcliff ichthyosaur, total length about 3m. The caudal fin has been restored as a low aspect ratio type based on the apparent angle of the upper part of the possible tail bend region and the angle of alignment of the distal vertebral series. Alternatively, the upper lobe may have been located further forward in association with a more acute angle of deflection resulting in a comparatively high aspect ratio tail.

area of the tail bend (determined by vertebral count) are 36mm x 18mm down to 23mm x 13mm. The caudal fin vertebrae range from 16mm to 8.5mm in diameter and are subtriangular at the proximal end, becoming oval distally.

Two isolated dorsal vertebra from much larger, presumably adult ichthyosaur(s) from the same horizon measure 85mm in width, 75mm in height (as the specimen is embedded in matrix, no anteroposterior dimension can be recorded) and estimated width 90mm; height, 79mm and minimum thickness (anteroposterior dimension), 32mm. The embedded specimen preserves the outline shape and details of the articular facet. The second specimen, a mould from which the positive was recently removed either naturally or by a collector, preserves the rib apophyses (Fig. 8). The outline form of both specimens show ventrally flattened centra with short lateral processes representing the diapophyses and parapophyses for the ribs. The neural arch processes are not visible on either specimen. Their articular facets consist of a shallow external basin bounded about 20mm wide, surrounding a deeper basin approximately 40mm in diameter and approximately 10.0mm deep.

Hind paddle trace. Technically this structure is not a trace, but rather vaguely delineated infilled mould that appears to represent a portion of the pelvic limb. There are two possible hind paddle traces preserved near the sacral region of the ichthyosaur. If the more clearly delineated structure is indeed a paddle, it represents the left hind limb near its original point of attachment. The description of its morphology is only a suggestion. The object near the top of the trace (Fig. 5) may represent the femur or poorly preserved, merged infilling of the tibia and fibula. The remaining squarish, tabular shapes are poorly defined representations of the digital rays. If this structure is the hind limb it indicates that the hind paddles of this species of ichthyosaur were comparatively long and narrow. An extrapolation of its outline form (Fig. 11) indicates a length of 20cm to 25cm, the latter being most likely, and a width of between 9cm and 10cm at the proximal end. Given that the body of an adult *Platypterygius australis* is about 7 times the length of its pectoral fin, the possible Nightcliff ichthyosaur fin is too short to represent a displaced fore paddle. The (conservative) estimated body length of the Nightcliff ichthyosaur is

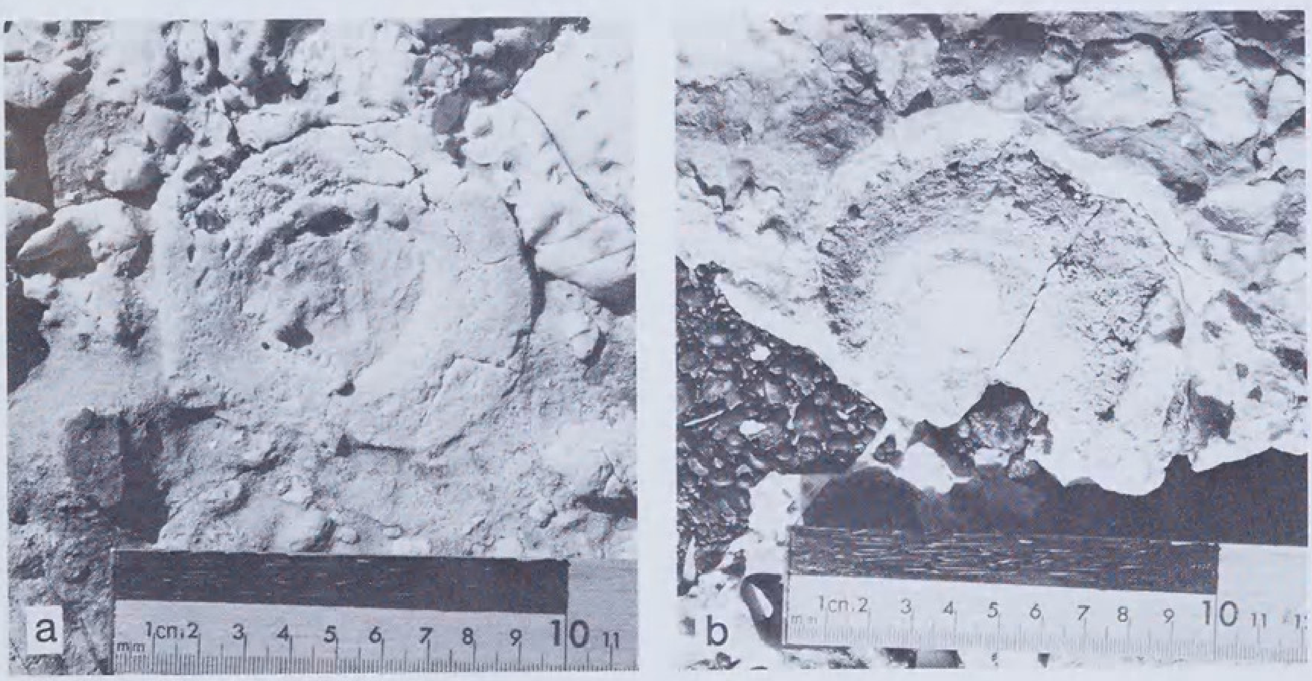

Fig. 8. Photographs of isolated adult ichthyosaur dorsal vertebral centra from Nightcliff: **a**, comparatively well preserved specimen consisting of silicified bone; **b**, a mould from which a specimen of dorsal vertebral centrum was recently removed by natural erosion or collector. The rib apophyses are well preserved.

about 10 times the length of its putative pelvic fin. The overall size and shape of the structure is therefore not outside what might be expected for a pelvic fin of *Platypterygius australis* given the extreme length of its pectoral fins documented by Wade (1984).

Other elements. Additional preparation work may clarify the identity of some of the other bony remnants that obstinately defy determination (Fig. 5). After examining over the specimen with an armatured binocular microscope, I was able to delineate a variety of bone fragments that blend imperceptibly into clayey or silty casts easily mistaken for inorganic source material such as phosphorites and phosphoritic clasts. Rib fragments are readily identified and are reasonably well preserved. A line of circular, weathered out structures, some containing remnants of bone, traverses the aligned ichthyosaur vertebral column at right angles (Fig. 5). A series of segmented and aligned infillings near the possible cranial fragment could, for example represent a sclerotic ring and a mass lying just beyond the scapula may eventually be resolved as the proximal portion of the right pectoral fin.

Overall proportions. The Nightcliff ichthyosaur is being prepared for public display, requiring for its interpretation, a restorative illustration. While I have probably over-interpreted the information available from the specimen, the rationale for it is hereby recorded.

Based on the proportions of the skull to the vertebral column of the Telemon *Platypterygius australis*, the Nightcliff specimen was between 2.5 and 3 metres long in life (no adjustment made for growth allometry). Being about 3 metres long, the specimen was about half the

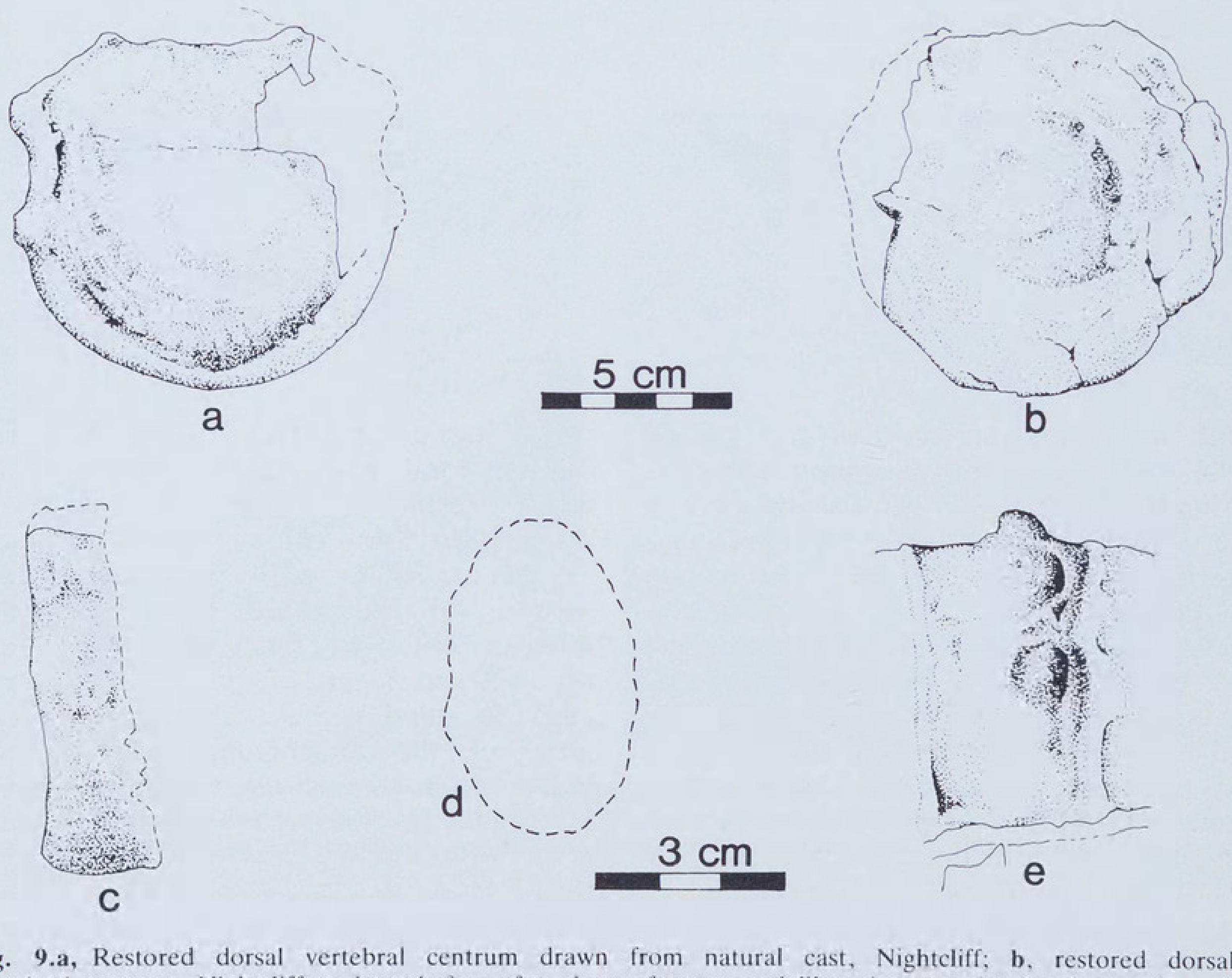

Fig. 9.a, Restored dorsal vertebral centrum drawn from natural cast, Nightcliff; **b**, restored dorsal vertebral centrum, Nightcliff; **c**, lateral view of a, drawn from a modelling clay cast showing impressions of the rib apophyses; **d**, cross-sectional outline of an anterior dorsal vertebra from the articulated Nightcliff ichthyosaur showing the extent of lateral compression of the centra; **e**, drawing of a mold of a dorsal vertebra from the articulated Nightcliff ichthyosaur to show impressions of the rib apophyses.

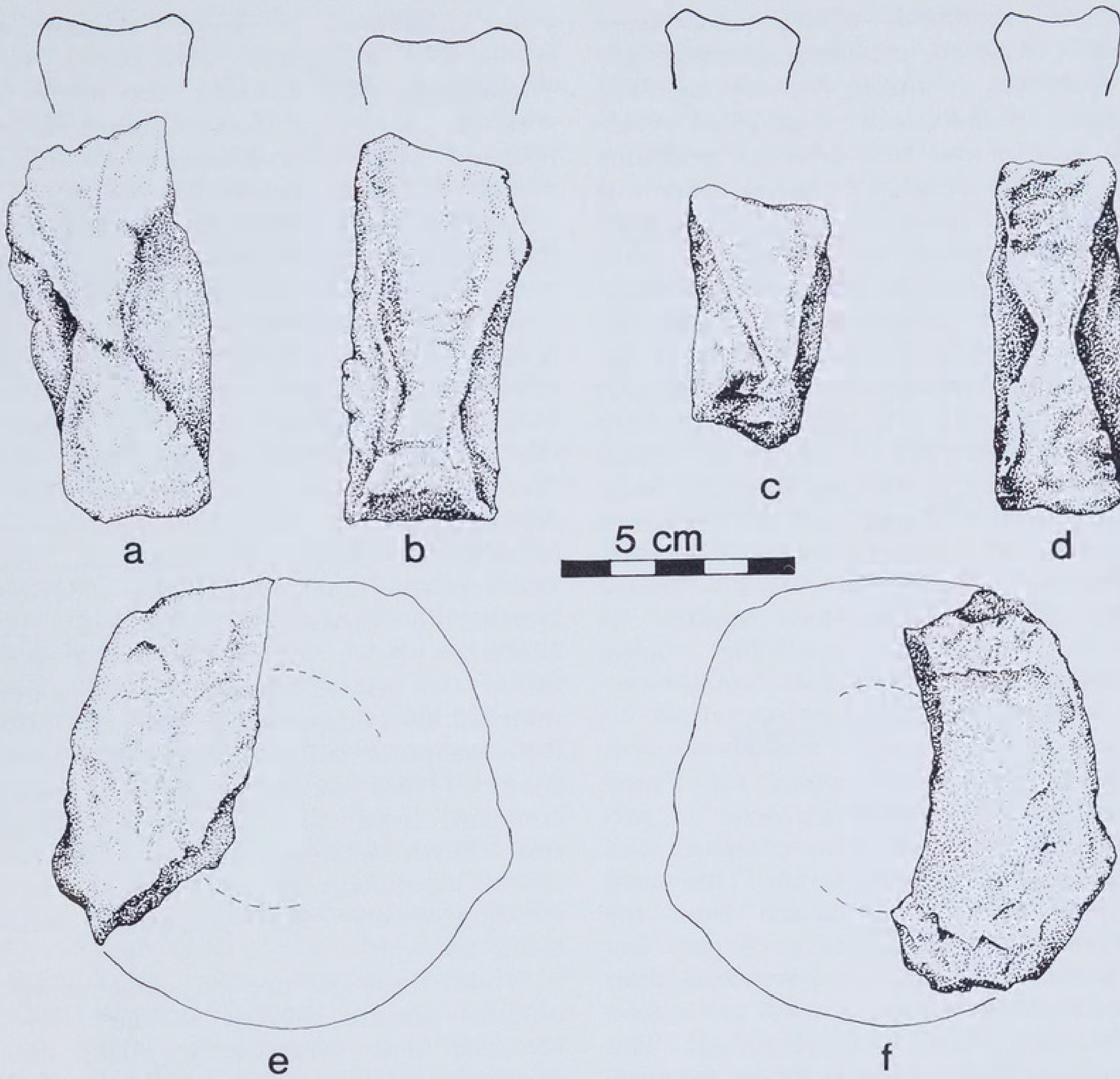

Fig. 10. Photograph and line restorations of ichthyosaur vertebral centra collected from the Casuarina Beach locality: **a-d**, lateral views of broken sections of dorsal vertebrae; **e**, restoration of section **a**; **f**, restoration of section **b**.

adult size of *Platypterygius australis* (Wade 1984). The precise length of the specimen is difficult to determine because of gaps in the vertebral array and poor preservation at both the extreme anterior and extreme posterior ends. The tail segment of specimen has been turned upwards and twisted back on itself and was restored by reversing the elements in the same relative positions, providing a suggestion of the possible region of the caudal deflection. If the small tail vertebrae are *in situ*, held together by connective tissue, a length of 40cm from the distal ventral lobe of the tail to the mid point of the deflection curvature is suggested. Given the apparent taper of the vertebrae, an approximate length of 40 to 45cm for the fin-bearing segment seems satisfactory.

The basic proportions used are as follows: total body length 2.85m; head length (estimated from *P. australis*) 65.0cm; vertebral column length (chord) 200-220cm; tail fin segment, 40-50cm; estimated tail fin chord 65cm; distance between fore and hind paddles attachments 100cm; length of fore paddle, 45cm; length of hind paddle, 25cm; linear distance of the attachment of the hind paddle from the distal ventral lobe of the caudal fin 100cm; minimum depth of body from the mid dorsal region determined from *in situ* rib fragments, 30cm (Fig. 7c).

Casuarina Beach Ichthyosaur

The fossil ichthyosaur material from Casuarina beach localities consists of casts of vertebral centra and some poorly preserved probable pectoral girdle elements (scapulae, coracoids). The condition of the fossils range from weathered discs of fine homogeneous mudstone to well-defined partial casts containing mineralized remnants of the original trabecular structure of the bone. Most of the specimens show the characteristic waisted cross section of amphicoelous ichthyosaur vertebrae (Fig. 9). All of the specimens are eroded on their periphery. The largest vertebral centra range from 92mm to 100mm dorsoventrally and 45mm to 50mm anteroposteriorly (Fig.10). None of the dozen or so specimens are preserved well enough to permit a detailed morphological comparison with known ichthyosauria. They are similar in overall dimensions to the larger specimens from Nightcliff.

Fannie Bay Ichthyosaur

Judging from photographs, the Fanny Bay ichthyosaur vertebrae may be sufficiently well preserved to compare with the Artesian Basin material. This must await its eventual extraction from the overflow store so that the roughly linear scatter of 75 centra lying with their articular facets facing out of the matrix can be closely examined (Fig. 11g). The largest vertebrae appear to be between 75mm and 90mm in maximum diameter and resemble the Nightcliff and Casuarina material in gross comparison.

SYSTEMATIC DETERMINATION

The literature on ichthyosaurs contains few specific details of Australian ichthyosaur vertebral morphology (Wade 1984; McGowan 1972) and a measured series from complete specimen giving essential morphological details might prove useful. The vertebral centra of the Darwin Ichthyosauria generally resemble those of *Platypterygius* in size and overall shape but lacking comparative material, little else can be added at this time. Many of the Darwin area centra are approximately the same size as the type *Ichthyosaurus australis* vertebra described by M'Coy (1867), but are somewhat smaller in diameter than the "Gentle Annie" and "Mangapurupuru" ichthyosaur vertebrae of Upper Albian age from the Makirikiri Formation, East Wellington, New Zealand, the largest of which is 120.0mm in diameter and 55.0mm-60.0mm long (anteroposterior dimension) (Fleming, Gregg and Welles 1971).

Lacking well preserved pectoral limb and cranial elements, none of the Darwin area ichthyosaurs can be positively assigned. Brief mention of Darwin ichthyosaurs is made by Teichert and Matheson (1944) in which they refer to the Fanny Bay material but fail to provide either a description or a reference. They state that "*Ichthyosaurus australis* (probably a *Myopterygius*) is known from a few localities in Queensland (Longman 1922) and from Fanny Bay, near Darwin, Northern Territory" (Teichert and Matheson 1944). McGowan (1972) refers all of the Albian Australian ichthyosaur material to *Platypterygius*, the only possible exception being Teichert and Matheson's (1944) indeterminate ichthyosaur centrum from the Dandaragan Chalk near Perth western Australia, believed to be Santonian in age and therefore stratigraphically the youngest ichthyosaur known.

While there is no particular morphological feature present in the Darwin Material that would differentiate them from the Albian aged Artesian Basin species, the indeterminate nature of the fossils leaves no choice but to designate them Order Ichthyosauria *gen. et sp. indet*.

TAPHONOMY

The Darwin ichthyosaur fossils occur as isolated elements scattered widely, as an articulated vertebral column and as disarticulated but associated vertebral elements. Each condition is associated with a different outcrop separated by a distance of approximately 5km.

An important consideration in taphonomy is the manner in which a carcass disintegrates after death. Because large marine reptiles are extinct, the pattern of disintegration of an ichthyosaur carcass must be inferred by analogy from recent animals of similar habits and morphology. Schafer (1972) provides detailed documentation of the rate and pattern of carcass disintegration in large marine mammals to which an ichthyosaur might be compared. The other choice perhaps, is comparison with a large fish but as there is too great a range in the structure and post-mortem deterioration pattern in fish, it is difficult to make a generalization (Schafer 1972). Moreover, it seems that the skeleton, integument and musculature of an ichthyosaur is decidedly more like that of a marine mammal than a fish.

If the carcass of an ichthyosaur disintegrates in the manner of seals and whales, then the presence of an articulated vertebral column of an ichthyosaur near the present Darwin shoreline is possibly of palaeogeographic interest. Because seals, whales and by analogy, ichthyosaurs, initially sink, then float to the surface where they may drift for weeks until their skeletal elements drop one by one from the carcass, articulated or extensive associated remains are unlikely to be embedded in sea floors. An exception to this is in poorly understood, usually benthic conditions where carcasses sink into anaerobic waters of protected ocean basins resulting in specimens like the Holzmaden ichthyosaurs from Jurassic beds near Wurttemburg, Germany. It is also true that partial ichthyosaur specimens are found in normal marine sediments from the Artesian Basin. If however, a large, articulated vertebral column is preserved in the absence of evidence of such conditions, in active waters, it is more likely to have been stranded and embedded in the shore sediments (Schafer 1972). The Nightcliff ichthyosaur skeleton therefore suggests the proximity of the upper Albian shoreline between the highest and lowest tidal ranges at the time of its deposition.

As is often the case for whale carcasses, the Nightcliff ichthyosaur was deposited on its side and when incorporated by the sediments represented a nearly complete carcass in a late stage of decay that, though separated into segments and slightly telescoped by gentle transport, was held largely intact by its leathery integument (about 30 of the larger vertebrae appear to be absent though traces and aligned phosphate nodules have replaced most of the missing elements). Intact beached carcasses usually arrive bloated by gas and stiff from dessication. If it had been drifting for several weeks, perhaps even a month or two, the skull may have become separated from the spinal column and hung limply downwards, supported by the trachea and tough connective tissues of the neck. This condition would account for the possible acutely flexed position of the skull suggested by the position of a cranial fragment (Fig. 11). The high frequency of breaks near the attachment of the rostrum to the cranium in ichthyosaurs suggests that the snout of the Nightcliff specimen may have become separated from the skull and transported to back near the hind paddle of the carcass. Both the orientation of the carcass and the position and orientation of the rostrum-jaw imprint suggest that the ichthyosaur became lodged with its head end toward the sea and the body lying at an angle of about 60° to the wave line, with both the skull and its rostral fragment lying approximately parallel to the wave line. It is inferred that the cranium, hanging loosly from some connective tissue, washed back and forth until the rostrum was dislocated. Wave action was also responsible for twisting the tail elements upwards and forward over the back at which time many small vertebrae were dispersed.

The fossil matrix is a fine siltstone containing molluscs, belemnites, wood fragments and numerous rounded or irregularly shaped phosphatic nodules suggesting a period of low deposition rate, shallowness or sea bed exposure and little current or wave action (Carter 1978a, b; Von Der Borch 1970) a sedimentary complex not dissimilar to the mud flats or shallow mud bottomed lagoons presently bordering the Darwin area estuaries. Wood fragments are impounded by the tides in the surrounding mangrove areas of the present — day estuaries of which the fossilized wood in the deposit may be an analogous expression. This does not imply however, that the Cretaceous gymnosperm flora had a mangrove like habitus, for there are conifer wood fragments found throughout the Artesian

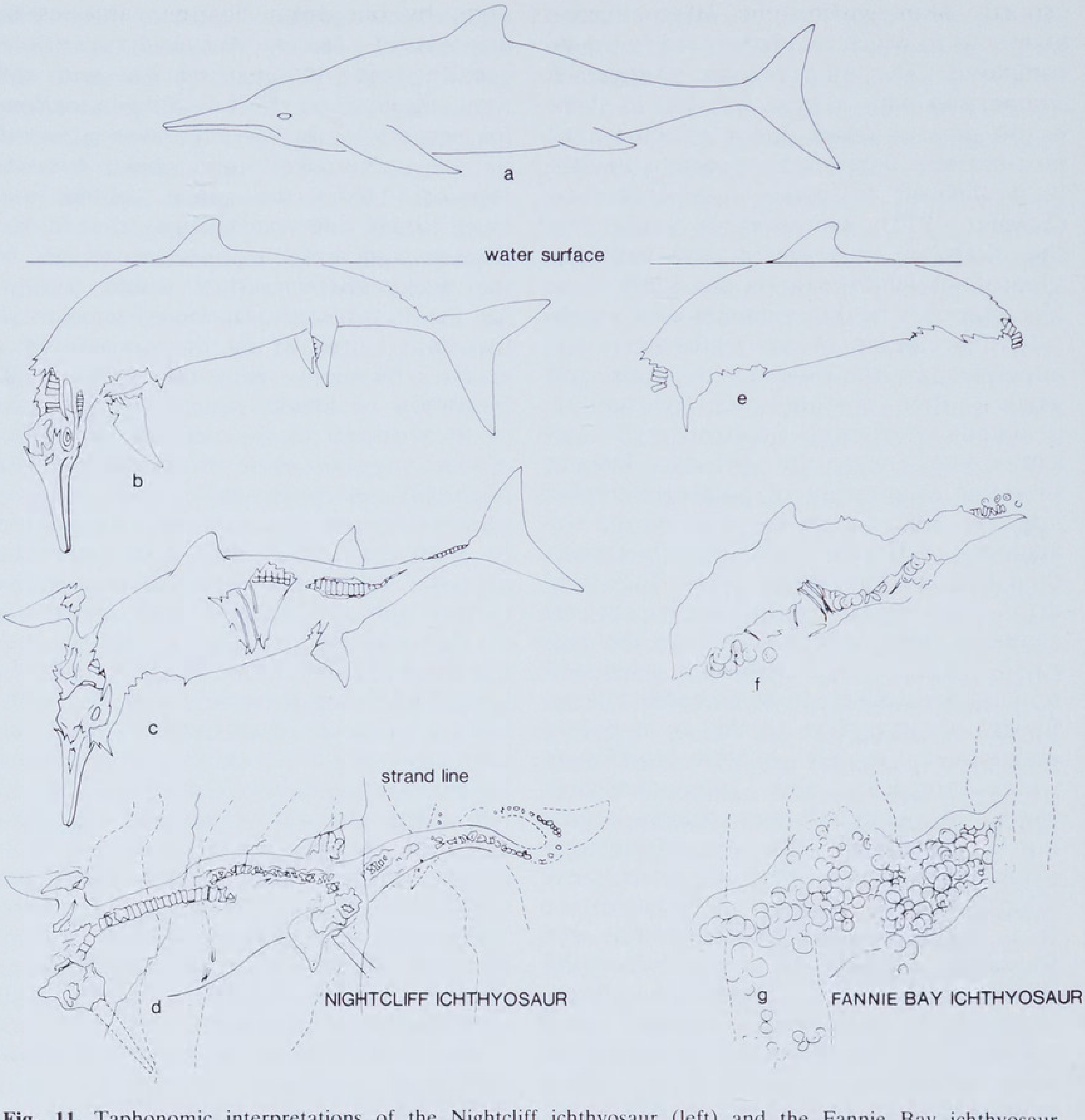

Fig. 11. Taphonomic interpretations of the Nightcliff ichthyosaur (left) and the Fannie Bay ichthyosaur fossils (right): **a**, restored ichthyosaur; **b**, bloated, floating carcass, minus its left pectoral limb; **c**, stranded carcass with cranium held only by soft tissues; **d**, cranium is rocked back and forth by wave action and loses its rostrum, the fragment stranding higher up, near the pelvic fin, and the tail segment being twisted back on itself, torn and distended; **e**, headless, limbless, bloated ichthyosaur carcass floating at sea; **f**, stranded, the carcass loses gas; **g**, skeletal elements scatter within the disintegrating integument.

Basin sedimentary record in association with both off shore and terrigenous sediments (Mary Wade, personal communication) but it does seem to indicate an area of stranded drift wood accumulation.

Summarizing the taphonomic sequence of events for the Nightcliff ichthyosaur: 1)the ichthyosaur died at sea, sank to the bottom then floated to the surface where it drifted long enough for the skull to become dislocated from the cervical vertebrae and hang freely by connective tissue, 2) at which time the carcass stranded and received subsequent gentle transport, sufficient to break the rostrum and jostle the vertebral column into 4 segments, scatter and lose some centra, twist the tail around and wash the long axis of the body at a 60° angle to the wave line, the loose skull being driven into the body parallel to the wave line and the rostral fragment carried a metre further, also coming to rest parallel to the wave line shortly after which time, 3) the carcass was incorporated into soft, muddy shallow water, perhaps shoreline, sediments.

The Fannie Bay ichthyosaur appears to have had a slightly different taphonomy although it is probably also a stranded carcass. If the sediments encasing the fossil are those represented by the main Fannie Bay outcrop, there are also some differences in its sedimentary context in that fossilized wood is absent and the bed appears to be thicker, more homogeneous and lacks the nodular pebbles that lend a conglomeritic character to the formerly described Nightcliff matrix. Schafer (1972) offers an explanation for the arrangement of the Fannie Bay ichthyosaurs vertebrae. A drifting whale or dolphin carcass remains rigid when inflated by gas. Supported by the trachea, the skull and body stay in connection for a long time. Eventually the skull drops off and undergoes its own depositional history. The bloated, headless carcass may eventually become stranded (stranding is the usual course of events in small, more or less closed ocean basins of about 400 to 800km in area) where, if it is incorporated into the sediments while still bloated, its skeleton will be preserved in an orderly manner. If however, the gas pressure inside the body is released, the body collapses in a limp mass and the vertebral elements may be deposited like a sack full of loose coins. This scenerio seems to adequately explain the associated headless disarray of vertebrae exhibited by the Fannie Bay specimen: 1) ichthyosaur carcass, still bloated with gas and without skull was stranded on a beach with moderate or slight wave action, 2) the wave action, though gentle, was sufficient to deflate the carcass and reduce it to a limp mass, 3) allowing the vertebral column to collapse into disarray while still within the integument (Fig. 11g).

At Casuarina Beach, the ichthyosaur fossils have, so far, only occurred as isolated elements. It is not possible to offer a particular taphonomic description for these occurrences because the locality is still largely unexplored. The isolated finds could be elements dropped one by one from floating carcasses into deeper water or they could represent beached ichthyosaur remains secondarily disassociated and transported by wave action.

The taphonomy of the Darwin ichthyosaurs does not exlude the possibility that they occurred in locally shallow seas and possibly in estuarine environments, but it does imply that some may have drifted a sufficiently long time to lose their cranial elements before coming ashore. For whales and dolphins this duration is not known but it may entail several weeks. For seals it takes between 14 and 15 weeks for the skull to disintegrate and fall away. Because of the unusually strong tidal flow in the Darwin area, an object, such as a tree carried down the estuary by one of its streams may float back and forth with the tides for weeks without stranding. On the other hand, flotsom from Indonesia clutters the beach front at Fannie Bay after every major storm during the wet monsoon.

One might point to the relative abundance of ichthyosaur remains occurring in a rather poor preservational environment as an indication that the ichthyosaurs were once common in local Cretaceous waters, but the condition of the fossils also supports the hypothesis that the Darwin area sediments could represent a thanatocoenosis rather remote from the source of once living populations.

DISCUSSION

The condition of the Darwin ichthyosaurs, being less than satisfactory for species determination, cheats us out of a definite extension of the range of *Platypterygius australis*. This is unfortunate because as yet the range of the species is still not clearly delineated (Wade 1984) remaining confined to the sediments of the Artesian Basin.

In spite of their commoness and completeness as fossils, ichthyosaur distribution and palaeoecology is still inadequately known. Wade's (1984) analysis of the functional morphology of *Platypterygius australis* draws the conclusion that in spite of its refined marine adaptations for high speed swimming and manoeverability, the animal may have been confined to shallow seas and inland basins.

If the Darwin ichthyosaurs eventually prove to be *Platypterygius australis* it implies at least some capability for open water dispersal for the species because the Artesian Basin and the Darwin area Mullaman Beds are independant sedimentary units (Day 1969). McGowan (1972: 6) states that "at this stage of enlightenment, the Australian and North American specimens (of *Platypterygius*) appear to be so very closely similar that they might even be referred to the same species". Wade (1984) bases the separation of *Platypterygius australis* and *Platypterygius americanus* on the presence of an ulnar facet on the humerus of *P. australis*, the absence of which in *P. americanus* indicates that the American species developed from a form in which the ulnar accessory had not contacted the humerus, while a major radial accessory facet developed in *P. americanus*. This seems to support the case for allopatric speciation of a genus apparently endowed with highly refined swimming and sensory adaptations that for all appearances might have been pelagic. If diagnostic material from the Darwin area does eventuate it may modify the known range for the species but it seems to have no special implications for a mechanism or pattern of oceanic dispersal of the genus since shelving waters would have been continuous from the mouth of the Artesian Basin around to central North Australia. However, because of the position of the continents in the lower Cretaceous and the connection of the Tethys sea with proto-Atlantic and proto-Indian Oceans, the water gaps were less formidable barriers to marine dispersal NW from Australia to N. America then than they are today. *Platypterygius*, which is not known before the Aptian, must have become cosmopolitan sometime after the opening of the Tethys Sea in the late Jurassic. The precursor of *P. australis* would have swam approximately the same distance to have reached Australia then as it would in the lower Cretaceous, as Australia's position remained little changed relative to Asia from early Jurassic to late Cretaceous times. The implications of continental drift combined with the parallel morphological features of the forelimbs of the American and Australian ichthyosaurs strongly support Wade's (1984) suggestion that the species remained almost entirely confined to shallow coastal waters and inland seas. The geological evidence for the Darwin region Albian indicates that the Darwin ichthyosaurs were similarly confined.

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