Taylor & Francis
Taylor & Francis Group

# The Miocene birds of Abu Dhabi (United Arab Emirates) with a discussion of the age of modern species and genera

JOHN R. STEWART[1] & MARK BEECH[2]

[1]*Biology Department, University College London, Gower Street, London WC1E 6BT, UK, and* [2]*Abu Dhabi Islands Archaeological Survey (ADIAS), P.O. Box 45553, Abu Dhabi, United Arab Emirates*

**Abstract**
A new fossil vertebrate site dating to the late Miocene yielding bird remains was recently discovered at Ruwais in Abu Dhabi, United Arab Emirates. The fossils from the new locality come from the Baynunah Formation which is largely composed of fluvial deposits. The bird remains from Ruwais and other late Miocene localities with Baynunah Formation deposits are here described. The taxa and material represented are Struthioformidae eggshell, and *Anhinga* sp. and Ardeidae postcranial skeletal material. The presence of a modern genus in the Miocene has prompted a discussion here of the maximum age of modern genera in the fossil record, which in many cases appears to be Neogene. The latter can in turn lead to the identification of modern species because a past member of a modern genus falls within the size range of a modern species.

**Keywords:** *Late Miocene, Baynunah Formation, Struthioformidae eggshell, Anhinga,* Ardeidae

## Introduction

In April 2002 Miocene fossil vertebrates were located at Ruwais, on the site of the proposed TAKREER Ruwais BeAAT Project Facility, in Abu Dhabi, UAE. This work was undertaken by the Abu Dhabi Islands Archaeological Survey (ADIAS) led by Mark Beech, Peter Hellyer and Simon Aspinall. The location of the site and Miocene exposures in Abu Dhabi can be seen in Figure 1. The subsequent fieldwork at Ruwais has led to an important new collection of Miocene vertebrates (Beech and Hellyer 2002; Beech et al. 2003; Beech 2005; Beech and Hellyer 2005) to complement that described in Whybrow et al. (1990) and Whybrow and Hill (1999). Most finds were made during surface collecting. To date, the bird remains have not been given systematic attention. In Whybrow and Hill (1999) the birds found during the earlier collecting expeditions of the 1980s were briefly mentioned in a table summarizing the finds. Therefore, this paper represents the first systematic description of bird bone remains from Miocene localities in Abu Dhabi. Note, however, that Bibi et al. (2006)

mention that they found several osteological bird specimens in Abu Dhabi Western Region which they have tentatively referred to genera not previously described from the region, and that they plan to describe this at a later date. The present paper, because it deals with modern genera, finishes with a discussion of the likely age of modern bird species and genera.

## Regional Miocene stratigraphy of Abu Dhabi Emirates, UAE

The Miocene deposits in the Western Region of the Abu Dhabi Emirate form the most significant Pre-Quaternary rock outcrops in the region. They are composed of three formations: the Dam Formation, a marine carbonate; the Shuwaihat Formation, made up of a sequence of evaporitic sediments with aeolian sands, and the Baynunah Formation, a series of fluvial sands and gravels. The latter has yielded vertebrate fossils that were described in detail by various authors in Whybrow and Hill (1999).

Correspondence: J. R. Stewart, Biology Department, University College London, Gower Street, London WC1E 6BT, UK.
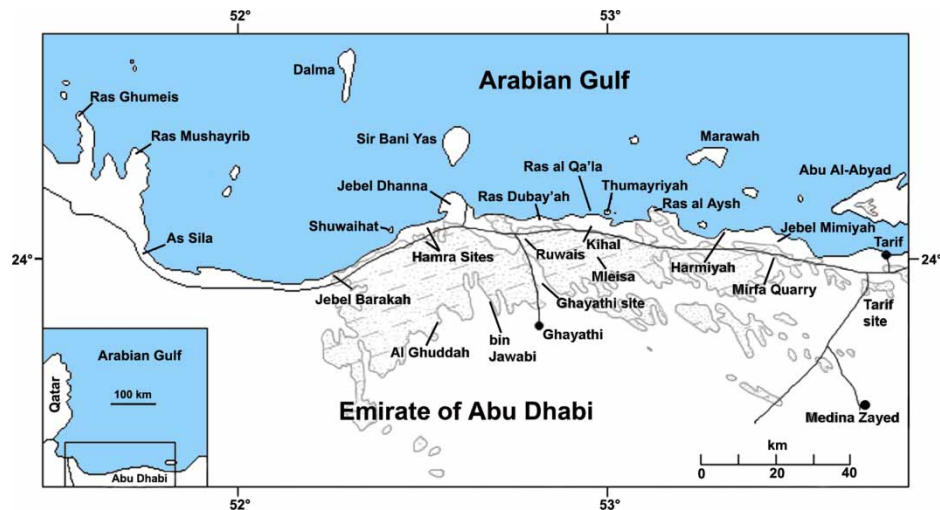E-mail: thejohnstewart@yahoo.co.uk

Figure 1.   Location of Miocene Baynunah Formation in the Western region of Abu Dhabi Emirates, United Arab Emirates (after Whybrow (1989)).

## The Dam Formation

This formation was first described first in Saudi Arabia, and is considered to be middle Miocene in age. Outcrops occur at As-Sila where the formation consists of fine grained marine dolomitic limestones with bivalves (Whybrow et al. 1999).

## The Shuwaihat Formation

This formation was first described by Whybrow et al. (1999) and Bristow (1999) and was defined as the lower-most sandstones and mudstones formerly in the Baynunah Formation. These sands are aeolian with cross-bedded units and fine sand and mud units. Sedimentary structures such as climbing ripples attest to some fluvial deposition within this formation. These deposits are separated from the overlying Baynunah Formation fluvial deposits by an unconformity which is marked by a dramatic change in the cementation of the deposits.

## The Baynunah Formation

This formation was first defined by Whybrow (1989) and Jebel Barakah is the stratotype where it sits above 7.5 m of Shuwaihat formation. All Miocene sediments to the east of Jebel Barakah and Shuwaihat are solely made of the Baynunah Formation. Sediment types include gravel, fine sands, mudstones and thin limestones. The formation is divided into a lower and an upper Baynunah Formation. The lower Baynunah Formation has fluvial gravels and fine sandstones while the upper Baynunah Formation has no gravel or mudstones and limestones are more common. This is an informal division described by Whybrow et al. (1999).

Due to the fact that the Shuwaihat Formation occurs mostly to the west end and does not extend as far east as the Baynunah Formation it is possible that they partly represent lateral facies changes and are, therefore, contemporary deposits.

However, the ages of the Baynunah and Shuwaihat Formations have been deduced from palaeomagnetic dating. This suggested ages of $15 \pm 3$ Ma for the Shuwaihat Formation (middle Miocene) and $6 \pm 3$ Ma for the Baynunah Formation (late Miocene) (Hailwood and Whybrow 1999). Unfortunately stable isotopic dating failed to provide dates for the two formations because the isotopes reflected the diagenetic (post-depositional) histories of these deposits rather than the depositional histories themselves (Peebles 1999).

## Description and interpretation of the local stratigraphy at Ruwais

Three sections at Ruwais were recorded on the basis that they were close to locations where fossils had been found (Stewart 2003) (Figure 2).

## Sections 1 and 2

Two sections (Sections 1 and 2, see Figure 2. Section 1–E 52.76594, N 24.07125; Section 2–E 52.76660, N 24.07138–co-ordinate datum: WGS84) were in a recent quarry on the site and form part of the same sequence with Section 2 located above Section 1. However, due to the stepped nature of the quarry, Section 2 was approximately 60 m from Section 1, and due to the fact that Section 1 ended above the base of Section 2, there is overlap between the two sections (Figure 2). The sequence consists of fine sands of variable colour (from red to vivid yellow through buff and brown) with variable cementation and an unsorted matrix supported gravel 40 cm thick approximately half way up the profile. The gravel has calcrete intraformational clasts and no exotic clasts were observed.
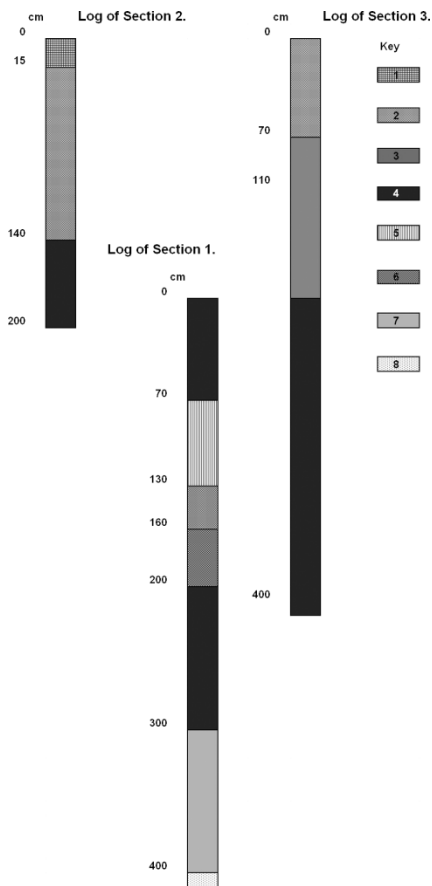
Figure 2.    Logs of three sections at Ruwais.
Key: 1 – Jointed brown sand; 2 – Pale buff, sorted, hard cemented sandstone. Unbedded / diffuse bedded; 3 – Red calcreted fine sand. Calcrete appears as white mottling of fine red sand; 4 – Pale red/brown sand. Well sorted. Bedded with darker red finer sands; 5 – Rootlet bed. Same sediment as above but many root casts of different sizes. Red sand; 6 – Unsorted gravel. Sand matrix with pale concretion-like pebbles (calcrete); 7 – Sorted yellow/green sand. No bedding structures visible. Partly cemented; 8 – Vivid yellow sand.

Little in the way of sedimentary structures are visible in the sands although, there may be some sub-horizontal bedding towards the top of the profile at the base of Section 2. At the top of the Section 1 there are rootlet casts between 0 and 130 cm in depth. These are in far greater numbers in the interval between 70 and 130 cm depth.

There are particularly well-cemented parts of the profile in Sections 1 and 2. One cemented horizon is between 130 and 160 cm in depth in Section 1 where there is a pale buff coloured sandstone and at the top between 15 and 140 cm depth of Section 2 where the sediment is clearly cemented by calcrete (pedogenetic carbonate). In the latter, freshwater bivalves were found, one of which was apparently in a vertical life position.

The very top of the profile (0–15 cm depth in Section 2) is brown in colour with jointing of the kind often associated with surface desiccation or other sub-aerial processes.

## Section 3

This section was cleaned on the side of a wadi cutting through the fossiliferous deposits and leading to the lower lying sabkah to the east of the site (E 52.77259, N 24.07401—co-ordinate datum: WGS84). This wadi was chosen for section cleaning as the promontory of ground formed by this and the next wadi was found to contain proboscidean fossils on its surface and in its uppermost horizon. The site is designated as site RW61. The fossils consist of a patch of tusk fragments, presumably indicating the presence of a degraded tusk in the ground, and two elephant molars lying parallel to each other with their occlusal surfaces facing upwards, representing the left and right molars *in situ* in the opposing maxillae or mandibulae.

Section 3 (Figure 2) has a less complex series of sediments, although it is in broad agreement with the profile represented by Sections 1 and 2. The sediments are mostly fine sands varying in colour and cementation. However, the progression in both colour and cementation is a trend towards less cementation and greater redness down the profile, characters which appear to be related. The decrease in redness upwards manifests itself as an increase in the white mottling due to greater amounts of calcrete until the sediment is completely cemented in the top 70 cm of the section. The lower part of the sequence, i.e. the fine red sand was seen to have root casts when weathered for a couple of weeks. The proboscidean fossils appeared at first to be in this calcreted fine sands and not in gravels, differing from the elephant bones described by Andrews (1999). However, while the teeth were being excavated it became apparent that this was not the case and that they were indeed in a localised gravel body.

Figure 2 shows all three sections together, approximately adjusted for by level. This has been done by assuming that the tops of Sections 1 and 3 are at approximately equal heights. There is an overlap between Sections 1 and 2 as explained above.

In order to interpret the two profiles (3 sections) it is easiest to start with the simplest which is Section 3. Here a sequence of sands, relatively uniform in grain size grades upwards in the degree of calcrete cementation. The increase in calcrete cementation upwards probably represents the zone of ground water evapo-transpiration at some point in the past. The time that this occurred was difficult to ascertain as it may have been at various times when the ground water was immediately below that of the modern surface. These periods may have been during the wetter interglacials of the last few hundred thousand years (including the climatic optimum of the Holocene) (Glennie 2001) or even during the Miocene itself. The root casts seen represent vegetation above the lower most sand layer (Figure 2).

During the excavation of the proboscidean teeth, above Section 3, it became apparent that the teeth were in a localised unconsolidated gravel unit probably

representing a small river channel. Under the gravel there was highly cemented sands like that seen at the top of Section 3. This gives us a relative age of the cementation by calcrete as it must pre-date the gravel or it too would presumably have become cemented. The cementation must, therefore, be Miocene in age.

The profile seen in Sections 1 and 2 is more variable with grain size changes, root casts and cementation differences in the sequence. The grain size variation is most easily explained as evidence of the coarser sediment bed load of a river channel interbedded with deposits representing fluvial deposition away from the channel at lower water velocities. The unsorted, matrix supported nature of the gravel, may signify that it is likely to be the result of rapid sedimentation. However, the clasts are mostly calcrete cemented sandstone indicating a probable local origin such as due to bank erosion depositing calcrete from the soil profile of the bank. This is the kind of gravel that is reported in the lower Baynunah Formation by Friend (1999). The calcrete at the top of the profile is likely to be the same as that seen in Section 3, the result of pedogenetic processes leading to the precipitation of dissolved carbonate minerals. However, the highly cemented layer in Section 1 is more difficult to explain. It may be calcrete formation and hence represents a sand deposit that underwent pedogenesis before the deposition of the rest of the profile. This seems unlikely, however, as the subsequent calcrete formation episode, forming the calcrete above it, may have remobilised the calcrete minerals lower down. The other possibility is that it represents a continuation of the gravel deposit below it and hence represents a clastic sediment rather than one that underwent pedogenesis before the deposition of the sediment above it. Therefore, this cemented layer would appear to represent a sand made up entirely of previously calcreted sand clasts that have subsequently become cemented as described by Ditchfield (1999). This would, therefore, be a fining of the clasts compared to the gravels below and hence signify a slowing of the water current at this level. The latter would seem more likely.

The root casts between 0 and 130 cm in Section 1 and below 190 cm in Section 3 clearly represent phases where surfaces had become stable enough for vegetation to become established (Friend 1999). These sediments may represent temporary stable sand bar islands or even the proximal part of the flood plain. The rootlets are more common in the lower 60 cm of the 130 cm in Section 1, as they become more sparse up the sequence. This may be due to an increase in flooding with resulting destabilisation of the vegetated surface.

The sequence represented by Sections 1 and 2 has strong evidence for being deposited by fluvial processes. The calcrete gravel fining into a cemented calcrete sand is one indication of deposition by water and the presence of freshwater mollusca at the top of the Section 1 is confirmation of that. Cross bedding was seen in a wadi south of Section 3. This would appear to be water lain and similar to that described by Friend (1999) giving additional support for a fluvial origin to these sediments.

The interpretation of the deposits at Ruwais would seem to confirm that they do indeed belong to the Baynunah Formation which is largely composed of fluvial deposits. The presence of gravels would indicate that the deposits form part of the lower Baynunah Formation according to Whybrow et al. (1999) although a facies change, as represented by a larger clast size, is of questionable use in age correlation. The other vertebrate fossils found at Ruwais are consistent with those described from the Baynunah Formation and include mammals such as *Hipparion* and *Stegotetrabelodon*, catfish and crocodile (Beech 2005; Stewart 2005). The other processes represented in the sediments of Ruwais are pedogenic and include calcrete and root cast formations. Both of these phenomena represent surface or near surface processes and indicate periods of relative stability of these horizons and that they were near corresponding contemporary ground surfaces.

The bird fossils from Ruwais, together with the other vertebrate remains, were found by surface collection and appeared to be concentrated due to deflation of the ground by the action of wind. Confirmation of this may be the facets seen on some of the Struthioniformes eggshell found. The likelihood that the bird remains as well as others emanate from the Miocene deposits upon which they were found is extremely likely which is why the description of the new site of Ruwais has been included. The geological description of the other sites can be found in Whybrow and Hill (1999).

## Systematic palaeontology of the Baynunah Formation birds

The following remains were identified by means of modern bird comparative material of the Natural History Museum at Tring in Hertfordshire, England.

The material used for comparative anatomical purposes included the following:

Ardeidae—*Tigrisoma cineatum* (1865.12.8.39); *Cochlearius cochlearius* (S/1974.13.1); *Botaurus stellaris* (1930.3.24.202); *Ixobrychus minutus* (S/1952.1.97); *Nycticorax nycticorax* (S/1988.67.1); *Nyctanassa violacea* (S/1952.3.130); *Butorides (Ardeola) striatus* (S/2001.48.43); *Ardeola ralloides* (1872.10.25.26); *Bubulcus ibis* (S/1989.15.1); *Ardea cinerea* (S/1977.25.3); *Philherodius pileatus* (1867.7.12.2); *Egretta alba* (S/1964.1.5); *Egretta garzetta* (S/1973.7.9). Anhingidae—*Anhinga melanogaster melanogaster* (1848.10.31.7); *A. melanogaster rufa* (S/1952.1.87); *A. anhinga anhinga* (S/1974.11.1); *Anhinga anhinga* (1896.2.16.17); *Anhinga* sp. (S/1952.3.159).

Anatomical description was done according to the terminology described in Baumel (1979).

Struthioniformes
Struthionidae
Genus and Species unknown

*Material*: Eggshell fragments.

*Locality*: Ruwais (TAKREER Ruwais BeAAT Project Facility) in Abu Dhabi, UAE. Collected 2002.

*Discussion*: The eggshell found at Ruwais was surface collected. The extreme thickness of the eggshell suggested that it belonged to that of a Struthiformes bird. A fragment of the eggshell was found *in situ* underneath Proboscidean teeth excavated at Ruwais confirming that at least this piece was of Miocene age. However, although it is likely that most, if not all, other eggshell is Miocene in age, the fact that an Arabian race of the Ostrich, *Struthio camelus syriacus*, is known to have existed in Abu Dhabi gave cause for concern. Therefore, a sample of the eggshell was measured in order to compare it with that of modern ostriches. Table I lists the ranges and mean thicknesses of a number of samples taken from Ruwais. Aspinall (1998) gives mean measurements for Miocene eggshell in Abu Dhabi as 3.56 mm and that from "modern ostriches" as 1.2 mm. Compared to the measurements of Aspinall (1998) those from Ruwais (Table I) are difficult to interpret as they mostly fall between them. Some of the measurements seem to be low reaching the modern ostrich eggshell mean quoted by Aspinall (1998). A histogram with all the thicknesses from Ruwais plotted together (Figure 3) shows no evidence for bimodality which seems to counter any suggestion that two species are represented among the eggshell. However, it may well be that some of the eggshell with low thicknesses belongs to recent *S. camelus syriacus* or else another Miocene member of the Struthiformes or another Ratite. Two species were found at, for instance, Lothagam in Eastern Africa (Leakey and Harris 2003). Microscopy could possibly resolve this issue (Mikhailov 1997), but this was not possible during the present study. A recent study by

Table I. Ruwais eggshell thickness measurements.

| Sample number | No. | Thickness (mm) Range | Mean |
|---|---|---|---|
| # 1191 | 26 | 2.20–3.18 | 2.74 |
| # 1385 | 29 | 1.18–3.14 | 2.46 |
| # 1395 | 46 | 1.76–3.08 | 2.58 |
| # 1396 | 53 | 1.72–3.24 | 2.68 |
| # 1416 | 10 | 2.66–3.28 | 2.99 |
| # 1418 | 8 | 2.56–3.08 | 2.73 |
| # 1504 | 5 | 2.68–2.92 | 2.79 |
| # 1544 | 28 | 1.92–3.08 | 2.77 |
| # 1701 | 4 | 2.66–2.82 | 2.75 |
| # 1762 | 9 | 1.84–3.14 | 2.67 |
| # 1771 | 9 | 2.16–2.80 | 2.48 |
| # 1834 | 11 | 1.70–2.82 | 2.56 |

Bibi et al. (2006) has identified two types of fossil ratite eggshell within the late Miocene Baynunah formation in Abu Dhabi: *Diamantornis laini* and an unknown aepyornithid-type. *D. laini* has been previously reported from the late Miocene of Namibia and Kenya. As mentioned by Bibi et al. (2006), its occurrence in Abu Dhabi strengthens this region's palaeobiogeographic affinity with Africa, specifically sub-Saharan Africa, to the exclusion of Europe and Asia.

Pelecaniformes
Anhingidae
Anhinginae
*Anhinga* sp. (Darter or Anhinga)

*Material*: Distal right humerus (ADIAS No. 1421) and distal right coracoid (no number, in the collections of the Department of Palaeontology, The Natural History Museum, London) (Figures 4–6).

*Locality*: The distal humerus (ADIAS No. 1421) is from Ruwais (TAKREER Ruwais BeAAT Project Facility), location RUW0040 (E 52.76295, N 24.07969—co-ordinate datum: WGS84), collected on the 21/11/2002 by ADIAS. The distal coracoid is from Ras Al Aysh, Site A2 (E 53.22402, N 24.07355—
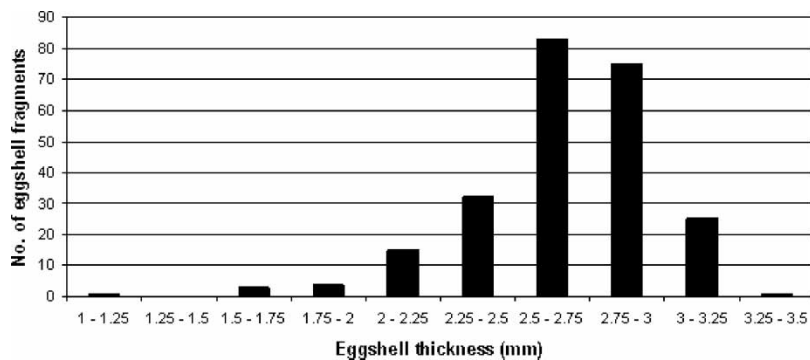


Figure 3. Histogram of all eggshell thickness from Ruwais samples (Table I) plotted together.

co-ordinate datum: WGS84), collected between 1979–1996 by Whybrow, Hill and Yasin. Both localities are in Abu Dhabi, United Arab Emirates.

*Discussion*: The distal humerus and the distal coracoid fragment conform in morphology to that of a member of the genus *Anhinga*.

The distal humerus is worn, the condylus dorsalis and the processus flexorius are damaged. The fossa musculi brachialis is filled with cemented sediment. However, there is little doubt that the specimen belongs to *Anhinga* as closely related taxa, such as *Phalacrocorax*, differ in most details, such as the relatively gracile shaft when compared to the articular dimensions. Also the greater prominence and caudally extending nature of the processus flexorious in *Anhinga* compared to *Phalacrocorax*.

The distal coracoid is consistent with that of *Anhinga* in being much more gracile than that of *Phalacrocorax* which has a much more robust shoulder extremity. In *Phalacrocorax* the sulcus musculi supracoracoidei is much more open and wide than in *Anhinga*. The cotyla scapularis is worn and there is further wear in the processus acrocoracoideus and around the facies articularis clavicularis as well as the facies articularis humeralis. The fossil specimen does appear to be very gracile compared to the modern material of the genus *Anhinga* (1981.2.16.17, S/1952.3.159, 1848.10.31.7) as confirmed by the measurements (Table II).

An examination of the skeletal material housed at the Natural History Museum, in Tring Hertfordshire yielded no useful diagnostic criteria to distinguish the coracoid or distal humerus of any of the populations of *Anhinga* living today. Table II lists the measurements of the distal humerus (ADIAS No. 1421) and appears to show that the specimen is somewhat smaller than those of modern congeners. However, the specimen's surface is worn which may make such a comparison unreliable. The distal coracoid on the other hand is less worn and, therefore, its measurement confirms the smaller size of the Miocene *Anhinga* in Abu Dhabi (Table II).
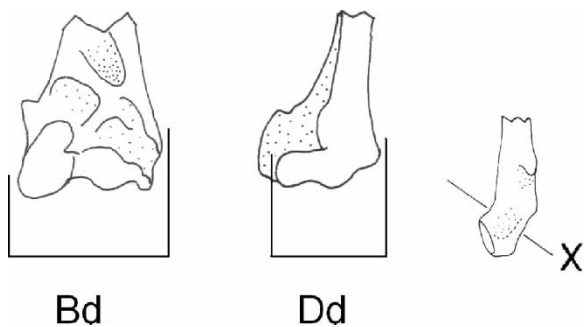


Figure 4. Measurements taken on distal humerus and coracoid of *Anhinga* spp. (The humerus measurements are: BD—measurement taken between the processus flexorius and the condylus dorsalis perpendicular to the shaft in the caudal–cranial plane; Dd—measurement taken from the condylus ventralis and the processus flexorius in the dorso–ventral plane. The coracoid measurement is: X–a measurement taken across the sulcus musculus supracoracoidei).



Figure 5. Abu Dhabi Miocene *Anhinga* sp. distal humerus in cranial (A) and caudal (B) view.

This genus has a wide ranging, circumtropical, distribution today and various taxonomic classifications have been proposed for the different local populations. There has been debate over how many species exist today with different taxonomies giving between one and four species (Johnsgard 1993). The most accepted taxonomy seems to be that which views the genus as having two modern species *A. anhinga* and *A. melanogaster* from the Americas and Afro-Asia
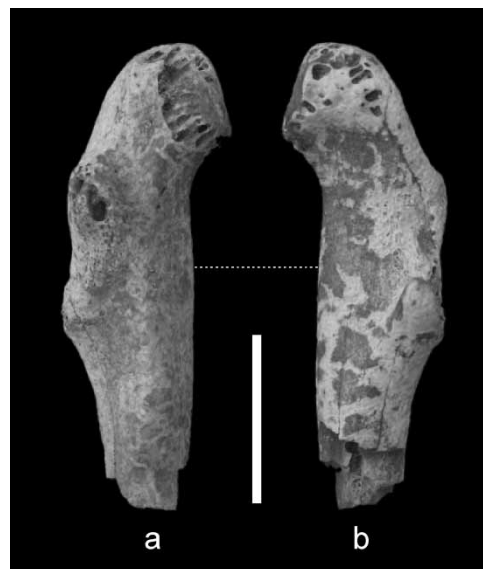


Figure 6. Abu Dhabi Miocene *Anhinga* sp. coracoid fragment in dorsal (A) and ventral (B) view.

Table II.   Measurements of the Miocene and modern *Anhinga* sp.

| | Humerus BD | Humerus DD | Coracoid measurement X |
|---|---|---|---|
| Ruwais specimen (ADIAS No. 1421) | 11.7 | 11.5 | – |
| Ras Al Aysh specimen | – | – | 6.95 |
| *Anhinga melanogaster melanogaster* (Japan) 1848.10.31.7 | 13.6 | 12.56 | 8.45 |
| *A. melanogaster rufa* (Madagascar) S/1952.1.87 | 13.20 | 12.52 | – |
| *A. anhinga anhinga* (Rio Atrato, Colombia) | | | |
| S/1974.11.1 | 13.72 | 12.64 | – |
| *Anhinga anhinga* (No history) 1896.2.16.17 | 12.46 | 11.30 | 8.25 |
| *Anhiga* sp. (No history) S/1952.3.159 | 13.30 | 12.94 | 8.3 |

respectively, with five subspecies, two in the former (*A. a. anhinga* and *A. a. leucogater*) and four in the latter (*A. m. melanogaster, A. m. rufa, A. m. vulsini* and *A. m. novaehollandiae*) (Dickson 2003).

The fossil record of *Anhinga* (Brodkorb 1963; Olson 1985; Mlíkovsky 2002) includes the upper Miocene (formerly considered lower Pliocene) *Anhinga pannonica* (Lambrecht) from Hungary. This species has tentatively been identified from the late Miocene of the Siwalik series in Pakistan (Harrison and Walker 1982) and the late Miocene of Tunisia (Rich 1972). *A. pannonica* is slightly larger than *A. anhinga* according to Harrison and Walker (1982). There is also the late Miocene *Anhinga grandis* from Nebraska (Martin and Mengel 1975), which is 25% larger than *A. anhinga* and *Anhinga hadarensis* from Ethiopia and Tanzania from the late Pliocene to early Pleistocene thought to be ancestral to *A. m. rufa* (Brodkorb and Mourer-Chauviré 1982). *A. hadarensis* appears to have been slightly smaller than *A. m. rufa* in many dimensions which may ally the taxon to the Abu Dhabi material. This is difficult to confirm without direct comparison of the coracoid remains which have been found in both regions. The fact that the coracoid from Olduvai Gorge is Plio-Pleistocene in age and that from Abu Dhabi is upper Miocene may cause one to question their being conspecific. The latter is worth bearing in mind, however, if any further Miocene *Anhinga* material turns up in Abu Dhabi. In contrast to the Olduvai material, Lothagam in Kenya produced late Miocene *Anhinga* material which was assigned to *Anhinga* cf. *A. rufa* and was said to be the same size as *A. rufa* in Africa today (Leakey and Harris 2003).

Other records include the upper Pleistocene *A. parva* (DeVis) from Queensland, Australia and the Quaternary *A. nana* (Newton and Gadow) from Mauritius and Madagascar (Brodkorb 1963). These two species have since been shown to be small living species of *Phalacrocorax*. *A. laticeps* (DeVis) from South Australia may be a valid taxon, although Brodkorb and Mourer-Chauviré (1982) considered it debatable.

Therefore, it is safest to consider the specimens here described to be an undiagnosed member of the genus *Anhinga*. However, it does appear that the material is smaller than the modern *Anhinga* species, as well as the Miocene *A. pannonica* of Hungary and that referred to it from Tunisia according to Rich (1972) and Pakistan (Harrison and Walker 1982). The Abu Dhabi material may be similar in size to *A. hadarensis* from the Plio-Pleistocene of East Africa although it remains to be seen if this is evidence that they are conspecific. It is tempting, due to the geographical context, to consider the present material as part of the Old-World Anhingas, as opposed to those from the Americas. This is not certain though due to their relative antiquity, therefore, the specimen is left at the level of genus.

Ciconiifomes
Ardeidae

*Material*: Fragmentary left scapula and distal right coracoid (No nos., formerly in the in the collections of the Department of Palaeontology, The Natural History Museum, London, now in care of ADIAS, Abu Dhabi, UAE) (Figures 7 and 8).

*Locality*: The scapula is from Shuwaihat, Site S1 (E 52.44228, N 24.11718—co-ordinate datum: WGS84), Sieve b and the coracoid is from Shuwaihat, Site S2 (E 52.43341, N 24.11308—co-ordinate datum: WGS84) Bed II. Both were collected between 1979–1996 by Whybrow, Hill and Yasin in Abu Dhabi, United Arab Emirates. The two specimens were collected from the Baynunah Formation.

*Discussion*: The scapula and the coracoid fragments conform in morphology to those of a member of the family Ardeidae but due to the incompleteness of the specimens and the overlap of morphology amongst the Ardeidae further diagnosis has not been possible. Harrison (in Whybrow and Hill (1999) had referred the coracoid to the great white egret *E. alba*. Although this is possible, after comparison with many Ardeidae taxa it was felt that it would be best not to identify the specimen further than to family level.

In the coracoid, the processus procoracoideus is damaged but appears to have been prominent in the manner of members of the Ardeidae. Damage, due to wear, also occurs to other prominent regions of the bone such as the facies articularis clavicularis, the edge of the sulcus musculi supracoracoidei just above the

Figure 7. Abu Dhabi Miocene Ardeidae coracoid fragment in dorsal (a) and ventral (b) view.

cotyla scapularis and the processus acrocoracoideus. The specimen is broken at the shaft about 16 mm from the base of the cotyla scapularis. The shaft is broken open revealing sediment infilling the shaft cavity.



Figure 8. Abu Dhabi Miocene Ardeidae scapula fragment in dorsal (a) and ventral (b) view.

A concretion of sediment adheres to the surface of the sulcus musculi supracoracoidei. The sulcus musculi supracoracoidei is broad and wide like those of members of the Ardeidae. The facies articularis humeralis and the cotyla scapularis are well developed like those in the Ardeidae. These features are more like those of the great white egret *E. alba* than those of the night heron *N. nycticorax*. However, the facies articularis clavicularis is most similar to that of a night heron. When viewed medially the base of this facies is broad, tapering away from the sternum, where as in *E. alba* it is narrow at the base widening away from the sternum and unlike that in *B. stellaris* where it is more gracile Therefore, it is not clear which to which modern genus of the Ardeidae the specimen belongs or if it indeed belongs to a modern genus.

In the scapula, the shape of the facies arcticularis humeralis in relation to the tuberculum coracoideum is like that of the Ardeidae. The tuberculum coracoideum is not prominent as it is damaged. This is seen in a reference specimen of *E. alba* where it was sheared off when it was detached from its corresponding coracoid. This may explain the damage to the fossil. The bone may have been attached to the coracoid and hence fresh when the damage was done during their disaggregation. The acromion is also missing due to damage. The specimen is broken into two fragments at the corpus scapulae about 14 mm from the edge of the facies arcticularis humeralis (although it is now fixed) and is missing its extremitas caudalis after another 18 mm of corpus scapulae.

Kellner (1986) gives characters to distinguish the coracoid and scapula of the various European Ardeidae but these do not seem to aid in conclusively identifying these specimens due to damage and the possibly intermediary state of the characters in the Miocene specimen.

## Conclusion

The Miocene bird remains from Abu Dhabi that can be identified to any significant level appear to belong to the modern, extant genus *Anhinga* or to the family Ardeidae. Their age is approximately 6 Ma (± 3 Ma), late Miocene (Hailwood and Whybrow 1999), which exceeds the generally accepted maximum age of modern species. This prompts a discussion of the maximum age of genera and the likely identity of the fossils from the Abu Dhabi Miocene.

When our modern bird species first evolved has been a subject of debate over the years. As reported by Selander (1965), Wetmore (1952) had expressed "a firm belief that our living kinds had their evolution both as genera and as species in the Miocene and Pliocene periods". Brodkorb (1960) on the other hand, believed that most species had developed during the Pleistocene and notes that "almost no avian species are known to cross epochal lines". More

recently, Olson and Rasmussen (2001) published the results of a study of Pliocene and Miocene marine birds from Lee Creek Mine in Carolina, USA. In this instance they concluded that some groups had evolved rapidly, such as the divers (Gaviidae), and were assigned to fossil species while the shearwaters and albatrosses, that are thought to have evolved more slowly, were attributed to modern species.

The subject has received renewed attention from molecular biologists (Klicka and Zink 1997; Avise and Walker 1998; Johnson and Cicero 2004; Weir and Schluter 2004; Zink et al. 2004; Lovette 2005). This debate has focused on the significance of the ice ages in the formation of our recent avian species. Klicka and Zink (1997) started the controversy by questioning the crucial role of these dramatic climatic events. This was followed by a counterclaim by Avise and Walker (1998). More recently, Stewart (2002) and Tyrberg (2002) gave two different perspectives on this issue using meta-analyses of the fossil records. Stewart (2002) concluded that circumstantial evidence indicated that species evolution must have been progressing through the Quaternary but that because of the conservative ambiguous morphological nature of species in genera this was difficult to prove. Tyrberg (2002) meanwhile concluded, using the half-life method of Kurtén (1959), that at least half of avian species in the Palaearctic evolved during the Pliocene. This he compared with the results of similar analyses of mammal longevity which he stated were an order of magnitude larger for birds. This difference may well be due to the lack of rapidly evolving teeth in birds. A recent review of the evidence for species evolution in mammals during the quaternary gave much support for the hypothesis that species had arisen during the quaternary, particularly those that are today adapted to the cold such as the polar bear *Ursus maritimus*, the arctic fox *Alopex lagopus* and lemmings *Lemmus* spp. (Lister 2004).

The subject of the age of genera has, however, had comparatively little attention. Campbell and Lack (1985), in quoting Ernst Mayr, define the genus as "a systematic category including one species or a group of species of presumably common phylogenetic origin, which is separated from other similar units by a decided gap". Brodkorb (1971) noted that of the 86 genera (10% of modern genera) reported from the Tertiary, 10% dated back to the Oligocene, with 42% dating back to the Miocene and 34% to the Pliocene. He mentioned that occasional occurrences of modern genera from the Eocene can be ignored as unreliable. Since this 1971 contribution to the topic little seems to have been mentioned.

Voous (1992) reviewed the significance of the genus to ornithology and concluded that, unlike the species, it has less reality in nature. While this may be true for neontology it is less so in palaeontology. Fossil species are hypothesized species to a far greater extent than are living species. Therefore, it is generally at a higher taxonomic level that any certainty regarding taxonomic identity exists. Stewart (2002) made the point that species within genera (sometimes in families) are often distinguished on metrical characters rather than 'discrete', 'nonmetrical' characters. Often the earliest appearance of modern genera are Neogene, which has led to claims of extant species from as far back as the Miocene. It is not suggested here that these claims are necessarily invalid, although it is not clear how such claims can be reliably tested. If a particular genus, such as the modern genus *Turdus*, were to date back to the Miocene (which it is according to Mlíkovsky (2002)) and remains were found that conformed to the size and proportions of the blackbird *T. merula*, it would be difficult to have a great degree of confidence that a particular fossil is indeed a blackbird. The latter is so because the members of the genus *Turdus* today can only be partly separated on metrical characters and even then there is much overlap between species (Stewart 1992). Therefore, it is proposed that in such instances identifications should not exceed that of the genus with perhaps a referral to a modern species by the use of cf (Stewart 1999).

It seems, therefore, that because the first occurrences of many genera are in the Miocene, and that species within genera are difficult to distinguish, this will inevitably lead to modern species being identified in the Miocene. This is particularly the case if a fossil appears to agree in size and proportions with a modern species. While this does not invalidate the possibility that modern species existed already in the Miocene this should be borne in mind when working on fossils of this age.

of the Pleistocene birds of the site of Boxgrove, Sussex (Harrison and Stewart 1999). Tabitha and Matilda are thanked for making us smile.

# References

Andrews P. 1999. Taphonomy of the Shuwaihat probiscidean, late Miocene, Emirate of Abu Dhabi, United Arab Emirates. In: Whybrow PJ, Hill A, editors. Fossil vertebrates of Arabia. New Haven: Yale University Press. p 338–353.

Aspinall S. 1998. New ostrich eggshell finds. Tribulus 8.2:28.

Avise JC, Walker D. 1998. Pleistocene phylogeographic effects on avian populations and the speciation process. Proc R Soc London B Biol Sci 265(1395): 457–463.

Baumel JJ, editor. 1979. Nomina anatomica avium. London: Academic Press.

Beech M, Hellyer P. 2002. Fossil research at Ruwais—An interim report on fieldwork. Report Presented to TAKREER. Abu Dhabi Islands Archaeological Survey.

Beech M, Higgs W, Aspinall S, Hellyer P. 2003. A newly discovered late Miocene fossil site at Ruwais—Final Report. Report presented to TAKREER. Abu Dhabi Islands Archaeological Survey.

Beech M. 2005. The late Miocene fossil site at Ruwais. In: Beech M, Hellyer P, editors. Abu Dhabi 8 million years ago: Late Miocene fossils from the western region. Abu Dhabi: Abu Dhabi Islands Archaeological Survey. p 21–33. ISBN 9948-03-188-1. 68pp.

Beech M, Hellyer P, editors. 2005. Abu Dhabi 8 million years ago—late Miocene fossils from the western region. Abu Dhabi: Abu Dhabi Islands Archaeological Survey. ISBN 9948-03-188-1. 68pp.

Bibi F, Shabel AB, Kraatz BP, Stidham TA. 2006. New fossil ratite (Aves: Palaeognathae) eggshell discoveries from the late Miocene Baynunah Formation of the United Arab Emirates, Arabian Peninsula. Palaeontol Electronic 9(1), 2A: 13p. Online (554 Kb): http://palaeo-electronica.org/paleo/2006_1/eggshell/issue1_06.

Bristow C. 1999. Aeolian and sabkha sediments in the Miocene Shuwaihat Formation, Emirate of Abu Dhabi, United Arab Emirates. In: Whybrow PJ, Hill A, editors. Fossil vertebrates of Arabia. New Haven: Yale University Press. p 50–60.

Brodkorb P. 1960. How many species of bird have existed? Bull Flo State Mus Biol Sci 5(3):41–56.

Brodkorb P. 1963. Catalogue of fossil birds. Bull Flo State Mus Biol Sci 7(4).

Brodkorb P. 1971. Origin and evolution of birds. In: Farner DS, King JR, editors. Avian Biology. Vol. 1. New York: Academic Press.

Brodkorb P, Mourer-Chauviré C. 1982. Fossil anhingas (Aves: Angidae) from early man sites of Hadar and Omo (Ethiopia) and Olduvai Gorge (Tanzania). Geobios 15(4):505–515.

Campbell B, Lack E, editors. 1985. Dictionary of birds. London: Poyser Ltd.

Dickinson EC, editor. 2003. The Howard & Moore complete checklist of birds of the world. 3rd ed. London: Christopher Helm.

Ditchfield PW. 1999. Diagenesis of the Baynunah, Shuwaihat, and Upper Dam Formation sediments exposed in the western Region, Emirate of Abu Dhabi, United Arab Emirates. In: Whybrow PJ, Hill A, editors. Fossil vertebrates of Arabia. New Haven: Yale University Press. p 61–74.

Friend PF. 1999. Rivers of the Lower Baynunah Formation, Emirate of Abu Dhabi, United Arab Emirates. In: Whybrow PJ, Hill A, editors. Fossil vertebrates of Arabia. New Haven: Yale University Press. p 39–49.

Glennie KW. 2001. Evolution of the Emirates' land surface: An introduction. In: Al Abed I, Hellyer P, editors. United Arab Emirates, a new perspective. London: Trident Press Ltd. p 9–27.

Hailwood EA, Whybrow PJ. 1999. Palaeomagnetic correlation and dating of the Baynunah and Shuwaihat Formations, Emirate of Abu Dhabi, United Arab Emirates. In: Whybrow PJ, Hill A, editors. Fossil vertebrates of Arabia. New Haven: Yale University Press. p 75–87.

Harrison CJO, Walker CA. 1982. Fossil birds from the upper Miocene of Northern Pakistan. Tert Res 4(2):53–69.

Harrison CJO, Stewart JR. 1999. The birds remains. In: Roberts MB, Parfitt SA, editors. The middle Pleistocene site at ARC Eartham Quarry, Boxgrove, West Sussex, UK. English Heritage Monograph Series 16, London. p 187–196.

Johnsgard PA. 1993. Cormorants, Daters, and Pelicans of the world. Washington and London: Smithsonian Institution Press.

Johnson NK, Cicero C. 2004. New mitochondrial DNA data affirm the importance of Pleistocene speciation in North American birds. Evolution 58(5):1122–1130.

Kellner M. 1986. Vergleichend morphologische untersuchungen an einzelknochen des Postkranialen skeletts in Europa vorkommender Ardeidae. Ludwig-Maximilians-Universität München.

Klicka J, Zink RM. 1997. The importance of recent ice ages in speciation: A failed paradigm. Science 277:1666–1669.

Kurtén B. 1959. On the longevity of mammalian species in the Tertiary. Commentationes Biologicae 21(4):1–14.

Leakey MG, Harris JM. 2003. Lothagam: The dawn of humanity in Eastern Africa. New York: Columbia University Press.

Lister AM. 2004. The impact of quaternary ice ages on mammalian evolution. In: Willis KJ, Bennett KD, Walker D, editors. The evolutionary legacy of the ice ages. *Philosophical Transactions of the Royal Society; Biological Sciences*. 359(1442). p 221–241.

Lovette IJ. 2005. Glacial cycles and the tempo of avian speciation. Trends Ecol Evol 20(2):57–59.

Martin LD, Mengel RM. 1975. A new species of anhinga (Anhingidae) from the upper Pliocene of Nebraska. Auk 92:137–140.

Mikhailov KE. 1997. Fossil and recent eggshell in amniotic vertebrates: Fine structure, comparative morphology and classification. London: The Palaeontological association.

Mlíkovsky J. 2002. Cenozoic birds of the world, part 1: Europe. Prague: Ninox Press.

Olson SL. 1985. The fossil record of birds. In: Farner DS, Parks KC, editors. Avian biology. Vol. 7. New York: Academic Press. p 79–238.

Olson SL, Rasmussen PC. 2001. Miocene and Pliocene birds from the Lee Creek Mine North Carolina. Smithsonian Contrib Palaeobiol 90:233–265.

Peebles RG. 1999. Stable isotope analysis and dating of the Miocene of the Emirate of Abu Dhabi, United Arab Emirates. In: Whybrow PJ, Hill A, editors. Fossil vertebrates of Arabia. New Haven: Yale University Press. p 88–105.

Rich PV. 1972. A fossil avifauna from the upper Miocene Beglia Formation of Tunisia. Notes Serv Geol Tunis 35:29–66.

Selander RK. 1965. Avian speciation in the quaternary. In: Wright Jr. HE, Frey D, editors. The quaternary of the United States. Princeton: Princeton University Press. p 527–542.

Stewart JR. 1992. *The Turdidae of Pin Hole Cave, Derbyshire*, Unpublished M.Sc. Dissertation, City of London, North London and Thames Polytechnics.

Stewart JR. 1999. The avifauna. In: Ashton NM, Lewis SG, Parfitt S, editors. *Excavations at the Lower Palaeolithic Site at Barnham 1989–94*. British Museum Press.

Stewart JR. 1999. The evolution of quaternary birds in the Western Palaearctic: Aspects of taxonomy and ecomorphology. University of London. Unpublished PhD Dissertation. 410 pp.

Stewart JR. 2002. The evidence for the timing of speciation of modern continental birds and the taxonomic ambiguity of the quaternary fossil record. In: Zhou Z, Zhang F, editors. Proceeding of the 5th symposium of the society of avian paleontology and evolution. Beijing: China Science Press. p 252–280.

Stewart JR, 2003. Preliminary report on the geological setting of the Miocene vertebrate fossils from Ruwais, Abu Dhabi, UAE. Unpublished report to ADIAS.

Stewart JR. 2005. Miocene geology and fossils of Abu Dhabi. In: Beech M, Hellyer P, editors. Abu Dhabi 8 Million Years Ago: Late Miocene Fossils from the Western Region. Abu Dhabi: Abu Dhabi Islands Archaeological Survey. p 14–20. ISBN 9948-03-188-1. 68 pp.

Tyrberg T. 2002. Avian species turnover and species longevity in the Pleistocene of the Palearctic. In: Zhou Z, Zhang F, editors. Proceeding of the 5th symposium of the society of avian Paleontology and evolution. Beijing: China Science Press. p 281–289.

Voous KH. 1992. Reflections on the genus in ornithology. In: Monk JF, editor. Avian systematics and taxonomy. *Bulletin of the British Ornithologists' Club.* p 261–266.

Weir JT, Schluter D. 2004. Ice sheets promote speciation in boreal birds. Proc R Soc Lond B 271:1881–1887.

Wetmore A. 1952. Recent additions to our knowledge of prehistoric birds, 1933–1949. X International Ornithological Congress Proceedings. p 51–74.

Whybrow PJ. 1989. New stratotype; the Baynunah Formation (late Miocene). United Arab Emirates: Lithology and palaeontology. Newsl Stratigr 21:1–9.

Whybrow PJ, Hill A, Yasin al-Tikriti W, Hailwood EA. 1990. Late Miocene primate fauna, flora and initial palaeomagnetic data from the Emirate of Abu Dhabi, United Arab Emirates. J Hum Evol 19:583–588.

Whybrow PJ, Friend PF, Ditchfield PW, Bristow CS. 1999. Local stratigraphy of the Neogene outcrops of the coastal area: Western Region, Emirate of Abu Dhabi, United Arab Emirate. In: Whybrow PJ, Hill A, editors. Fossil vertebrates of Arabia. New Haven: Yale University Press. p 28–38.

Whybrow PJ, Hill A, editors. 1999. Fossil vertebrates of Arabia. New Haven: Yale University Press.

Zink RM, Klicka J, Barber BR. 2004. The tempo of avian diversification during the Quaternary. In: Willis KJ, Bennett KD, Walker D, editors. The evolutionary legacy of the ice ages. *Philosophical Transactions of the Royal Society; Biological Sciences.* 359 (1442). p 215–220.