Fifty Years of Emirates Archaeology

BEFORE ARCHAEOLOGY: LIFE AND ENVIRONMENTS IN THE MIOCENE OF ABU DHABI

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"…I had the good fortune to find some very perfect bones, of what I believe is some sort of Mastodon or Elephant. There is nothing like geology; the pleasure of the first days partridge shooting or first days hunting cannot be compared to finding a fine group of fossil bones, which tell their story of former times with an almost living tongue."

– Charles Darwin, in a letter to his sister Catherine Darwin, from East Falkland Islands when on *HMS Beagle*, 6 April 1834.

INTRODUCTION

Evidence of mammals that lived in the past is, in general, very rare. Most animals, when they die, succumb to decomposition and dissolution. Although Arabia is a large place, comparable in size to the Indian subcontinent, there are very few sites of any age that document fossil mammals. Reports of ancient fossil vertebrates from Abu Dhabi were recorded as early as 1946 in oil company reports, but it was not until the 1980s when, stimulated by the finds of a 1983 archaeological survey of the Western Region (Al Gharbia), the work of Andrew Hill, Peter Whybrow, and Walid Yasin Al Tikriti began to treat the occurrences extensively and comprehensively. More recently, investigations have been renewed by Faysal Bibi, Hill, Mark Beech and Al Tikriti, working in association with the Abu Dhabi Authority for Culture and Heritage (ADACH). The finds are late Miocene in age; the animals lived sometime between 8 and 6 million years ago (Ma).

Research over the years has revealed a landscape and ecology quite different to that found in the region today. Many kinds of animals lived in the area then, including elephants, hippopotamuses, antelopes, giraffes, pigs, monkeys, rodents, small and large carnivores, ostriches, turtles, crocodiles and fish. Although there is evidence that desert conditions existed then as now, these creatures were sustained by a very large river system flowing slowly through the area, along which was flourishing vegetation, including large trees. The animals resemble those known from Africa during the same period, but there are also similarities with Asian and European species of that time. The Abu Dhabi specimens are the only vertebrate fossils known in the whole of Arabia between around 15 Ma and the Pleistocene. They are extremely important as they represent a window on terrestrial life and Arabian environments at the junction of the three major biogeographical zones of the Old World – the Ethiopian (African), the Palaearctic (Europe and north Asia), and the Oriental (south and south-east Asia) – at a time when the Old World terrestrial fauna was beginning to take on its modern character.

HISTORY OF RESEARCH

A fiftieth anniversary celebration such as this, of archaeology and the study of things dug up in the United Arab Emirates, invites a retrospective look at the history of discovery and the development of current knowledge. A couple of earlier publications have described the history of palaeontological investigations in the Western Region of Abu Dhabi, now Al Gharbia, in one way or another (Hill et al. 1999; Al Tikriti 2005). What follows is a brief recapitulation incorporating more recent work.

Fossil vertebrates were first remarked upon in the Western Region in the course of early explorations by oil company geologists (Glennie and Evamy 1968). Their largely unpublished reports (for example, that of Holme and Layne in 1949) were followed up by Peter Whybrow of the then British Museum of Natural History who worked at Jebel Barakah for a number of seasons beginning in 1979 (Madden et al. 1982; Whybrow 1984, 1989; Whybrow and Bassiouni 1986; Whybrow and McClure 1981).

In 1983 an archaeological survey involving Walid Yasin Al Tikriti, then of the Al Ain Department of Antiquities and Tourism, and a German group, headed by Burkhardt Vogt, found fossils at a number of localities further east of Barakah (Vogt et al. 1989). With the facilitation of Hans-Peter Uerpmann, the fossil material they collected was examined in Al Ain by Andrew Hill in 1984 at the invitation of the Department, at which time he and Al Tikriti also briefly visited the area and discovered other specimens and new sites (Fig. 1).

Hill, Whybrow and Al Tikriti subsequently collaborated in further research in a joint Natural History Museum – Yale University project, at first mainly funded by the Department, and after 1991, by the Abu Dhabi Company for Onshore Oil Operations (ADCO) (Fig. 2). The project came to involve a variety of other specialists, who covered different aspects of the work – fossil taxonomy, geology, geochemistry and other relevant matters – over a programme of sustained research that continued to 1995.[1]

This phase of investigations resulted in a number of publications (de Bruijn and Whybrow 1994; Gee 1989; Hill, Whybrow and Yasin Al Tikriti 1990; Whybrow et al. 1990; Whybrow, Hill and Yasin Al Tikriti 1991; Whybrow, Hill and Kingston 1999; Whybrow and Hill 2002) and culminated in the First International Conference on the Fossil Vertebrates of Arabia, held under the auspices of His Excellency Sheikh Nahyan bin Mubarak al Nahyan at Jebel Dhanna in March 1995.

Subsequently, these conference contributions appeared in the monograph *Fossil Vertebrates of Arabia* (Whybrow and Hill 1999a), forming the most detailed description of the Baynunah fauna, geology and regional context to date.

Fig. 1. Walid Yasin Al Tikriti holding a fossil elephant femur at Hamra, when on the first brief palaeontological survey with Andrew Hill (18 April 1984). Behind is a typical coastal outcrop of the Baynunah Formation (picture: Andrew Hill).

More popular accounts of the work were published in Whybrow (2003) and in Whybrow, Hill and Smith (1996, 1998, 2005). Also as part of the public outreach of this research an exhibition on the work was mounted at the Natural History Museum, London. A film was made to accompany this exhibition – *Hot Fossils from Abu Dhabi* – featuring and narrated by David Attenborough.[2] Another film – *Abu Dhabi - The Missing Link* – was made in both English and Arabic for ADCO in 1991.

Subsequently, work was conducted by Mark Beech and others with the Abu Dhabi Islands Archaeological Survey (ADIAS) directed by Peter Hellyer, and by another team working under the sponsorship of His Highness Sheikh Sultan bin Zayed Al Nahyan, Deputy Prime Minister, and led by Faysal Bibi (then of the University of California at Berkeley). These two projects found additional sites and fossils of considerable importance.

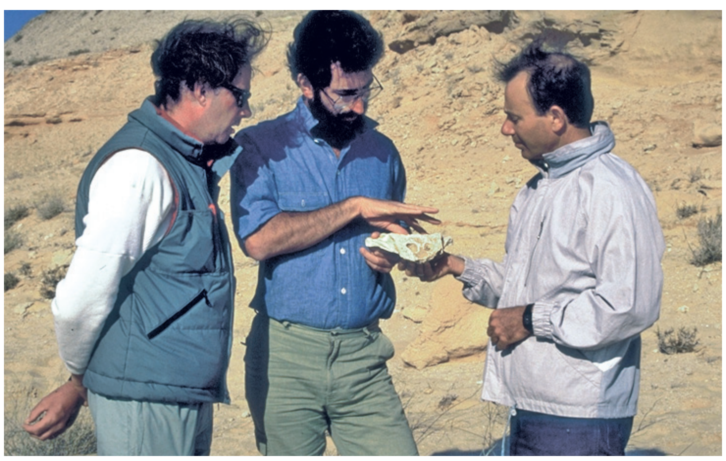

Fig. 2. Peter Whybrow, Andrew Hill and Walid Yasin Al Tikriti examining part of a fossil crocodile skull (Crocodylus, AUH 32) on Shuwaihat (9 January 1989) (picture: The Natural History Museum, London/Phil Crabb).

Among other things, the ADIAS project located new fossil occurrences, including one at Ruwais which provided additional rich evidence of proboscideans and birds (Beech, 2005a; Beech and Higgs 2005; Stewart 2005; Stewart and Beech 2006). Also the ADIAS work resulted in the identification of a number of impressive tracks made by fossil elephants and other animals (Higgs 2005; Higgs et al. 2003; Higgs et al. 2005). An exhibit on the fossils of the region was organised by Beech and Hellyer in the Environmental Research and Wildlife Development Agency – Abu Dhabi (ERWDA, now the Environment Agency – Abu Dhabi EAD) (Beech 2005b; Goodall and Larkin 2005; Hafeez et al. 2005), and a related book was published, *Abu Dhabi 8 Million Years Ago* (Beech and Hellyer 2005).

Bibi's expedition in 2003 worked principally at the coastal sites of Shuwaihat, Jebel Barakah, Kihal, Talfaha and Ras al Qal'a. Important fossils were found, such as additional elephants, much of a giraffe skeleton, and most unusually, a possibly unique synsacrum of a very large ostrich-like bird. Part of this research involved a much more detailed treatment of the Baynunah fossil ratite egg shell than had been carried out before (Bibi et al. 2006).

In 2006 the newly constituted Abu Dhabi Authority for Culture and Heritage (ADACH) kindly invited Hill and Bibi back to the Emirate once again to survey the sites and to help provide recommendations for their future investigation and conservation. This led to the current joint ADACH – Yale University expedition and since then we have conducted fieldwork annually. In addition to a planned conference and future publications, we have continued to provide reports on our work, and to advertise the importance of Abu Dhabi to the understanding of Old World palaeontology and palaeobiogeography at international scientific meetings and elsewhere (Bibi et al. 2008; Bibi et al. n.d.; Fox et al. 2008; Kraatz et al. 2009, Schuster et al., 2011).

STRATIGRAPHY

So far fossils have principally been found in rocks forming a series of *jebels* along the coast, standing above the surrounding *sabkha*, and extending from Jebel Barakah in the west of the Emirate, about 150 km east to Tarif (Hill and Whybrow 1999; Whybrow and Hill 1999a–b; Whybrow and Clements 1999) (Fig. 3), and perhaps beyond, as far as Rumaitha (Hellyer 2002). These rocks were described

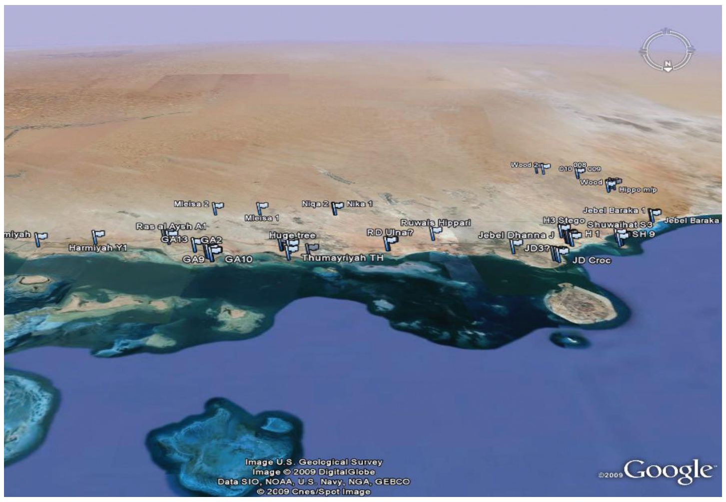

Fig. 3. A satellite view of Al Gharbia looking obliquely south from above the Arabian Gulf. It shows some of the fossil sites extending between Jebel Barakah and Tarif along the coast, and also other localities, such as Niqa and Mleisa, which are some way inland (picture: Google Earth).

by Whybrow (1989) as a geological unit he named the Baynunah Formation, with its type section at Jebel Barakah. It is likely that additional fossiliferous outcrops will be found elsewhere in the region.

Later, the lower part of the unit was removed into a separate geological formation, the Shuwaihat Formation, named after a locality where it is well represented – Jazirat Shuwaihat – and where the type section is located (Whybrow, Friend, et al. 1999; Bristow 1999). The base of this unit is not seen, and up to about 7.5 m of thickness is exposed. It is so far unfossiliferous. Whybrow and colleagues believed that it was distinct stratigraphically from the Baynunah, being separated from the overlying formation lithologically, and by an unconformity up to 6 m in relief. The Shuwaihat Formation is characterised by cross-bedded sandstones and laminar mudstones, best interpreted as aeolian sediments, possibly barchan dunes, encroaching across *sabkha* sediments (Bristow 1999; Bristow and Hill 1998). A palaeomagnetic age estimate of about 15 ± 3 Ma (Hailwood and Whybrow 1999), also gave support to the idea of the distinctiveness of the two units.

The part of the succession then remaining in the Baynunah Formation consists predominantly of riverine sediments, sandstones and mudstones, which contain the fossils (Whybrow, Friend et al. 1999; Friend 1999). More recently, fossiliferous exposures have also been discovered inland. We believe these also to belong to the Baynunah Formation, where it appears at the surface and forms the desert floor. Work on the nature of the Baynunah Formation lithology and its inferred mode of deposition is obviously important for understanding the palaeoenvironments at the time.

FOSSILS

Work in the area over the last few decades has produced an extremely rich collection of high quality fossils that give a very good indication of the animal community in the late Miocene of Abu Dhabi (Hill and Whybrow 1999; Whybrow and Hill 1999a–b). In general, fossils are well preserved, particularly those excavated from some way beneath the surface layer (e.g. Andrews 1999). Especially at the surface, however, they can be impregnated with gypsum salts, which leads to fragmentation and presents particular challenges to preservation and conservation (Larkin 2005; Fox et al. 2008).

The fossils (Table 1) provide a vivid impression of a diversity and range of large animals that today can only be witnessed – in ever-dwindling numbers – in some parts of Africa. There are also smaller creatures, some of them invertebrates, such as a terrestrial gastropod (Buliminidae) (Mordan 1999). Bivalves belonging to the families Mutelidae and Unionidae (Jeffrey 1999) are aquatic and lived in the river system which existed there at the time.

A few species of fish were identified earlier (Forey and Young 1999) and a sawfish (Pristidae) has been recovered more recently. Sawfish are ray-like creatures that are mainly marine, but can swim for considerable distances up rivers. More predominant in the collections are catfish belonging to the families Clariidae and Bagridae. In the latter a new species of the genus *Bagrus* has been described – *B. shuwaiensis*, although Gayet and Meunier (2003) have reservations about the attribution to family, and therefore to genus. Another fish in the assemblage belongs to the genus *Barbus* (Cyprinidae).

Reptiles also include aquatic forms, such as up to four species of crocodiles (Rauhe et al. 1999). There are two species which are similar to the present-day Nile crocodile *Crocodylus niloticus* (Crocodilidae), and which are adapted to eating mammals, some of which could have been quite large. Another one or two species are gavials (Gavialidae) which have quite slender and very long jaws particularly suited to devouring fish. One of these may be a new genus and species. The only living species of this group is highly endangered and confined to northern parts of the Indian sub-continent. Other reptiles include tortoises and turtles, both terrestrial and aquatic (Broin and van Dijk 1999). Among these is the very large terrestrial *Geochelone* (Testudinidae), now best known from superficially similar, though not necessarily closely related, forms from Galapagos and from some of the Indian Ocean islands. Smaller turtles from the Baynunah Formation – *Mauremys* (Testudinidae) and *Trionyx* (Trionychidae) – are aquatic. There are also

Plantae		
"Algae"		gen. et sp. indet.
Leguminosae		?*Acacia* sp.
Protista		
Foraminifera		
Mollusca		
Gastropoda		
	Buliminidae	?*Subzebrinus* or ?*Pesudonapaeus*[3]
	Thiaridae	*Melanoides* sp.[4]
Bivalvia[5]		
	Mutelidae	*Mutela* sp.
	Unionidae	*Leguminaia* sp.
Crustacea		
Ostracoda		
	Cytherideidae	*Cyprideis* sp.
Pisces [6]		
Pristiformes		
	Pristidae	
Siluriformes		
	Clariidae	*Clarias* sp.
	Bagridae[7]	*Bagrus shuwaiensis*
Cypriniformes		
	Cyprinidae	*Barbus* sp.
Reptilia		
Crocodilia[8]		
	Crocodylidae	*Crocodylus* cf. *niloticus*
		Crocodylus sp.
	Gavialidae	?*Ikanogavialis*
		Gavialidae, gen. et sp. nov.?
Testudines[9]		
	Trionychidae	*Trionyx* sp.
	Testudinidae	*Mauremys* sp.
		Geochelone (*Centrochelys*) aff. *Sulcata*
Squamata		
	cf. Colubridae	
Aves[10]		
Ratitae		
	Incertae sedis	*Diamantornis laini*
		'Aepyornithid-type' eggshell
Pelicaniformes		
	Anhingidae	*Anhinga* sp.
Ciconiiformes		
	Ardeidae	gen. et sp. indet.
Mammalia		
Proboscidea		
	Deinotheriidae	gen. et sp. indet.
	Gomphotheriidae (Amebelodontidae)[11]	cf. *Amebelodon* / ?"*Mastodon*" *grandincisivus*
	Elephantidae[12]	*Stegotetrabelodon syrticus*
Primates[13]		
	Cercopithecidae	gen. et sp. indet.
Rodentia[14]		
	Sciuridae[15]	gen. et sp. indet.
	Dipodidae	Zapodinae gen. et sp. indet.
	Muridae	*Abudhabia baynunensis*
		Myocricetodon sp. nov.?
		Parapelomys cf. *charkhensis*
		Dendromus aff. *Melanotus*
		Dendromus sp.
	Thryonomyidae	gen. et sp. nov?[16]
Soricomorpha[17]		
	Soricidae	gen. et sp. indet.
Carnivora[18]		
	Felidae	Machairodontinae gen. et sp. indet.
	Hyaenidae	gen. et sp. indet. 'very large'
		gen. et sp. indet. 'medium-sized'
	Mustelidae	*Plesiogulo praecocidens*
Perrisodactyla		
	Equidae[19]	*Hipparion abudhabiense*
		Hipparion sp.
	Rhinocerotidae	gen. et sp. indet.
Artiodactyla		
	Suidae[20]	*Nyanzachoerus syrticus*
		Propotamochoerus hysudricus
	Hippopotamidae[21]	*Archaeopotamus* aff. *Lothagamensis*
	Giraffidae[22]	*Palaeotragus* cf. *germaini*
		? *Bramatherium*
		gen. et sp. indet.
	Bovidae[23]	*Pachyportax latidens*
		Prostrepsiceros aff. *libycus*
		Prostrepsiceros aff. *vinayaki*
		Gazella aff. *lydekkeri*
		Tragoportax cyrenaicus
		cf. Neotragini

Table 1. Fossil plants and animals from the Baynunah Formation.

fossil traces of snakes, and probably at least one lizard, so far undescribed.

Birds are best known from locally abundant remains of fossil ostrich-like eggshell. These ratite remains have been principally studied by Bibi and colleagues (Bibi et al. 2006) who conclude that there are two kinds. The most common one is attributed to *Diamantornis laini*, a form that is also known from the late Miocene of Namibia and Kenya; the other is more rare and is an Aepyornithid-type shell similar to that of the extinct giant elephant-bird *Aepyornis*, of Madagascar, though it would be perhaps premature to ascribe it to that genus.

Other ratite fossils include a remarkable, complete, and large synsacrum – perhaps thirty per cent larger than the modern ostrich – possibly unique in the fossil record, and which is currently under study. Among other birds that have so far been identified are representatives of the genus *Anhinga* – the darter (Anhingidae), and of the family Ardeidae – herons and bitterns (Stewart and Beech 2006).

The most prominent mammal fossils, certainly in size and maybe in number of individuals, are those of proboscideans. The most common is an early elephant, *Stegotetrabelodon syrticus* (Elephantidae) (Tassy 1999). This is a quite large beast, differing most obviously from its modern relatives in that it has long straight tusks in the lower jaw as well as the upper. The specimens from Abu Dhabi, particularly a fairly complete skeleton from Shuwaihat (Andrews 1999), are among the best and most informative in the World, contributing significantly to our knowledge of this taxon.

Other examples of the genus *Stegotetrabelodon* are known from Miocene sites in Africa, with the same species being found in Libya. Another proboscidean is one of the first fossils found in the region. This is a tooth of a 'Mastodon', *Amebeledon* or *'Mastodon' grandincisivus* (Gomphotheriidae/Amebelodontidae), found in the very early geological explorations of Jebel Barakah, and first mentioned by Glennie and Evamy (1968; see also Madden et al. 1982; Tassy 1999). Even more inconspicuous is the fossil evidence for *Deinotherium* (Deinotheriidae), an elephant-like animal with down-curving tusks in the lower jaw, known throughout the Old World from the Miocene and later. This large animal is known in the Baynunah Formation only from a single, but distinctive, scrap of tooth enamel.

At the other end of the mammal size spectrum are monkeys and rodents. Monkeys (Cercopithecidae) are exceedingly rare. A single canine tooth of a monkey was found in 1989 (Gee, 1989; Hill and Gundling 1999), and then a cheek tooth was discovered by the current expedition twenty years later. There is no reason they could not belong to the same species, something perhaps superficially rather like the modern *Macaca*, the rhesus monkey.

A number of rodents are known, first investigated by de Bruijn (de Bruijn and Whybrow 1994; de Bruijn 1999) and on our current expedition by Kraatz (Kraatz et al. 2009) (Fig. 4). There are representatives of jerboas or jumping mice (Dipodidae), and of a range of murids (Muridae), attributed to five species. One is *Abudhabia baynunensis*, a gerbil; gerbils are generally regarded as being adapted to arid environments. There are also specimens attributable to the family Thryonomyidae, cane rats, which may be a new genus and species (Kraatz et al. 2009). And we have recently recovered the first fossil squirrel (Sciuridae) known from Abu Dhabi; the only other known in Arabia – *Atlantoxerus* – comes from the Hofuf Formation in Saudi Arabia (Sen and Thomas, 1979). Among other small mammals is a Soricomorph, a shrew (Soricidae) (de Bruijn and Whybrow 1994; de Bruijn 1999).

Fig. 4. Some of the rodent teeth discovered in 2009, displayed on a one dirham coin (picture: Brian Kraatz).

Carnivores are, of course, rare in any living community of animals and consequently as fossils, but a number are known from the Baynunah Formation (Barry 1999). There are small mustelids (Mustelidae), similar to the modern wolverine, now confined to northern latitudes. Representing large carnivores are machairodonts (Felidae), sabre-toothed cats. At present we have no sabre-tooth fossil teeth and it is difficult to identify the beast to species. There are also two species of hyaenas (Hyaenidae), one very large and another of medium size.

There are horses (Equidae) in the assemblage, probably two species, both in the genus *Hipparion*, one so far unnamed, the other a new species, *H. abudhabiense* (Eisenmann and Whybrow 1999). These are both relatively small three-toed horses.

It is interesting that some very large animals, that may have lived in herds and so would have been quite abundant at the time, are represented in the fossil assemblage by just one specimen. The elephant-like *Deinotherium* is one example; another is a rhinoceros (Rhinocerotidae) which is known in Abu Dhabi so far only by a single fragment of characteristic tooth enamel. Further exploration may reveal more about this creature.

Pigs (Suidae) are oddly uncommon in the collection, but there are some good specimens among the less than twenty that are identified so far. Two species are represented (Bishop and Hill 1999); one is *Nyanzachoerus syrticus*, a genus known from eastern Africa, and again the same species is found in Libya. The other is *Propotamochoerus hysudricus*, which shows a connection with Asia, being known from northern Indian and Pakistan Siwalik exposures dated between 10.4 and 6.8 Ma (Badgley et al. 2008).

More abundant in the Baynunah fossil record are hippopotamuses (Hippopotamidae) which are known from several mandibles, isolated teeth and post-cranial bones (Fig. 5). Originally it was described as the same genus as the extant West African hippopotamus, then known as *Hexaprotodon*; similar to a fossil species found at the site of As Sahabi in Libya, and also at the Kenyan site of Lothagam, *Hex. sahabiensis* (Gentry 1999a). Further taxonomic work has suggested that the Lothagam occurrence was sufficiently distinct to merit its own species, *Hex. lothagamensis* (Weston 2000; Weston 2003). A more recent analysis by Boisserie (2005) partitioned *Hexaprotodon* into a number of discrete genera, restoring the genus *Choeropsis* for the living species, and creating a new genus – *Archaeopotamus* – for the Lothagam and Abu Dhabi examples.

Fig. 5. Lower jaw of a hippopotamus (Archaeopotamus aff. lothagamensis, BMNH M49464) from Barakah (picture: The Natural History Museum, London/Phil Crabb).

There are two or three species of giraffes (Giraffidae). There is something like the extinct genus *Palaeotragus*, a relatively long-legged and long-necked form, and among the specimens is a remarkably complete skeleton found by Bibi's expedition, which is currently under study. Another resembles *Bramatherium*, a large- and short-limbed giraffe, fossils of which are also known from the Siwalik beds of Pakistan and India, and indicates another connection with Asia There is possibly another species less known so far.

A diverse range of bovids (Bovidae) is recognised, some with Asian affinities (Gentry 1999b). There are at least six species, most belonging to now extinct genera. They are attributable to Boselaphini, Antilopini (including *Gazella*), and there is probably a member of Neotragini, at present being investigated further. The study of these is revealing some interesting palaeogeographical implications (Bibi, 2011).

Of all these creatures, some are particularly interesting as being unique to Abu Dhabi, or were when first discovered, and this is reflected in their scientific names. There is the fish *Bagrus shuwaiensis*, for example, the gerbil *Abudhabia baynunensis*, and one of the three-toed horses, *Hipparion abudhabiense*. There is possibly a new genus and species of a thryonomyid rodent, not yet formally named. Representatives of *Abudhabia* and *H. abudhabiense* have now been discovered in other parts of the world. Various species of *Abudhabia* are now described from several other sites; for example, late Miocene localities in Afghanistan (e.g. Flynn et al. 2003), Pakistan (Flynn and Jacobs 1999), India (Patnaik 1997), probably Libya (Flynn and Jacobs 1999), and in Kenya (Winkler 2003). *H. abudhabiense* has been named as also coming from the late Miocene site of Toros Menalla in Chad (Vignaud et al. 2002; Le Fur et al. 2009).

Fig. 6. Tracks of an elephant, probably Stegotetrabelodon syrticus, at Mleisa, east of Ghayathi. A contingent of the Dubai branch of the Emirates Natural History Group is in the distance (8 December 2006) (picture: Andrew Hill).

FOOTPRINTS

Among the more extraordinary forms of evidence of the animal past preserved in Abu Dhabi are footprints of extinct creatures. Elsewhere in the world, dinosaur footprints are known (Thulborn 1990), some as close as Yemen (Schulp et al. 2008), and also those of mammals (e.g. Leakey and Hay 1979), but such occurrences are even more rare than fossil bones. The Abu Dhabi footprints are visually stunning; it is quite obvious to anyone, without any technical knowledge, that these are the footprints of large animals, and to learn that they are over 6 Ma old presents a visitor with the sensation of walking back in time, across a Miocene landscape where elephants might have strolled by just a little time before. Footprints give scientific information that skeletal fossils often do not. Bones can be transported by rivers and other agencies for considerable distances from the environment where they were once a part of a living animal, and where that animal actually lived. A footprint, however, signifies that the animal was actually there at that spot at some particular time in the past. Footprints can also provide clues to behaviour that complement different kinds of information derived from the functional anatomy of the bones.

The most prominent of the Abu Dhabi footprint occurrences, at Mleisa east of Ghayathi, were first investigated as part of the work of the Abu Dhabi Islands Archaeological Survey; they had been shown them by Mubarak bin Rashid al-Mansouri (Higgs 2005; Higgs, et al. 2003, 2005). There are a number of trackways exposed on a large calcareous exposure between sand dunes, which is believed to be a surface outcrop of Baynunah Formation sediments. The most significant track is about 170 m long, crossed by another extending about 290 m, and they obviously represent the prints of a proboscidean (Fig. 6). It is reasonable to attribute them to the most common elephant in the fossil assemblage, *Stegotetrabelodon*. Higgs and colleagues (Higgs 2005; Higgs et al. 2005) have compared the prints to those made by an Asian elephant (*Elephas maximus*) in the Blackpool Zoo, England. All measures of the fossil tracks – pace, stride and width – are greater than those made by the captive living animal. Additional relevant information, along with behavioural inferences, will appear shortly (Bibi et al., in MS).

At another nearby site are additional elephant tracks and others made by a different kind of animal, perhaps a bovid. And at Niqa there are more footprints, including some that appear to be formed by a large cat. The only large cat otherwise known in the fauna is the machairodont saber tooth, and it is reasonable provisionally to suppose that this creature might be responsible for these.

THE AGE OF THE FOSSILS

Unfortunately no rocks have been found in the Baynunah Formation that can be dated directly by radiometric techniques. This makes it difficult to obtain precise estimates of the age of the fauna. However, there are other regions of the world that are reasonably well supplied with dateable rocks and with similar fossils, principally eastern Africa, and to which comparisons can be made (Hill 1999a).

It is quite clear that some of the Baynunah fossils are similar to those found at sites in eastern Africa. The hippopotamus, for example, is the same species as, or closely related to, a species found at the locality of Lothagam in northern Kenya – *Archaeopotamus lothagamensis*. This is known from strata there dating between about 7.5–6.5 Ma (Weston 2000; Boisserie 2005). The most common elephant fossil in Abu Dhabi, *Stegotetrabelodon*, is a genus also known from sites in eastern Africa dating to around 6 and 7 Ma (Tassy 1999). And looking to Europe, de Bruijn and Whybrow (1994), who considered the rodent fossils in association with the large mammals, suggested an age correlating with the European faunal (Mammal Neogene) zone MN 13 at around 6–8 Ma. On the basis of examples such as these we can infer that the date of the Baynunah fauna is somewhere between 6 and 8 Ma, probably nearer to 6 Ma than to 8 Ma.

However, if we are to understand some aspects of palaeobiogeography, and a possible relation of faunal shifts to past climatic or geographical events, then it is desirable to achieve more precision than a two million year window. Hailwood attempted this by examining the palaeomagnetic stratigraphy and making estimates of palaeomagnetic pole positions through the formation (Whybrow et al. 1990; Hailwood and Whybrow 1999). Conclusions from this work suggested an age of 6 ± 3 Ma for the fossiliferous Baynunah levels. Unfortunately this is no more precise than the faunal correlations; in fact less so.

Techniques in palaeomagnetism have advanced since 1990 when that work was carried out, and accordingly our current expedition invited David Evans (Dept. of Geology and Geophysics, Yale University) and Daniel Peppe (Dept. of Geology, Baylor University) to re-sample the strata. They took controlled samples of rock from a number of geological sections which they are currently analysing, and we hope this may produce a better estimate.

An offshoot of work by Peebles (1999) on stable isotopes throughout the whole succession held out the hope that it might give information about the time of deposition. However, estimates proved to reflect the more recent time of diagenesis of the sediments, and therefore were not relevant to the age of the fossils.

A further and current possibility has come from a recent examination of carbonate beds just above the vertebrate fossil horizons by Stephen Lokier (Petroleum Institute, Abu Dhabi, UAE) who discovered that they contained ostracods and foraminifera. The biostratigraphy of such microfossils as these is well understood, particularly in oil-producing regions, so if they can be identified sufficiently they may also provide very helpful clues to age.

PALAEOENVIRONMENTS

Kingston and Hill (1999) summarised the then available information regarding Baynunah palaeoenvironments. It is tempting to interpret the evidence of this abundance of mammals, particularly the large ones, as an indication that during the Miocene, it was a land of profusion and plenty, with a luxuriance of vegetation and animal life – whereas nowadays the region is one of desert condition. Since then, with changing climate, aridity has supervened and the fauna has dwindled. To a certain extent some aspects of this supposition are obviously true, but not entirely. It is quite clear that there must have been enough water and vegetation to support herds of quite large mammals; bovids and giraffes, and horses, and such bulky beasts as elephants.

Water is not an issue, as we have abundant sedimentological evidence of a large river flowing through the region in Baynunah times (Friend 1999). The picture that emerges from a study of the lithology is of a large river system – possibly part of an ancestral Tigris-Euphrates – flowing predominantly towards the east-south-east. With the possible exception of the fossil sawfish (Pristidae), there is no sign of any marine influence, and indeed at the time the sea could have been a good distance away, possibly beyond the present Straits of Hormuz. The river system was composed of a substantial belt of numerous channels 2–10 m deep, separated by sand bars 2–5 m in relief. The aquatic fauna reinforces this view of the river. The crocodiles, particularly the gavials, would have required constantly flowing, large, and deep bodies of water (Rauhe et al. 1999), and although clariid catfish can withstand periods of drought, the bagrid fish are mostly bottom dwellers in slow persistently moving water (Forey and Young 1999).

There are a few fossil plants available, which are so far not thoroughly studied taxonomically. However, our recent work has discovered the trunk of a large tree at a site on Kihal. The trunk was of a good diameter, implying a considerable height in life (Fig. 7). Additional botanical information is provided by work on stable carbon isotopes from carbonate nodules in fossil soils and from herbivore tooth enamel (Kingston 1999). The ratio of carbon isotopes preserved in fossil soil nodules reflects the nature of the vegetation at the time, whether the environment is a closed, wooded habitat, or one of open grassland. The same information from herbivore tooth enamel indicates whether the animals were browsers or grazers; eating leafy vegetation or grass. This research suggests a grassy woodland near to the river channels, with more open grasslands further away from the water. The presence of grasslands is also supported by isotopic work on ostrich eggshell (Ditchfield 1999).

Fig. 7. Mark Beech and Andrew Hill discuss a large fossil tree on Kihal (31 December 2007) (picture: Faysal Bibi).

The large mammals would find a habitat of this kind quite congenial, and a plausible reconstruction based on this evidence was produced by Goodall and Larkin for the ERWDA exhibition (Goodall and Larkin 2005), and which is reproduced on the cover of the accompanying book (Beech and Hellyer 2005). A slight palaeoenvironmental complication arises from the possible lithological evidence of barchan dunes in the Baynunah succession. If this is substantiated it would suggest that a lush woodland habitat is maintained by the constantly flowing river, grading off into grassland further from its influence, with arid and fully desertic conditions taking over further still. This is a situation also envisaged for the site of Toros Menalla in Chad (Vignaud et al. 2002; Le Fur et al. 2009).

PALAEOBIOGEOGRAPHY

Arabia is pivotally situated at the junction of the three major biogeographic zones of the Old World; the Ethiopian (African), the Palaearctic (Europe and north Asia), and the Oriental (south and south-east Asia) regions. Faunas within these areas are distinctive, as a result of being separated from each other for long periods of time. However, occasionally at times in the past shifting geographic and environmental circumstances made contact between these large regions possible, and faunal interchange took place. Arabia holds the key to understanding the long history of terrestrial vertebrates in the Old World as a whole. More particularly, given its age, the Baynunah Formation documents the emergence of what is an essentially modern terrestrial vertebrate fauna, when the Old World mammal biota was beginning to take on its present character.

Arabia is a large place, comparable in size to the Indian sub-continent, but there are very few sites documenting fossil mammals. The Baynunah fossil fauna is the only example of terrestrial vertebrate animals between about 15 Ma and the Pleistocene. So these sites provide a very important glimpse into a huge gap in our knowledge of Arabian fossil faunas

Overall the Abu Dhabi fossil fauna shows strong resemblances with some of those in Africa (Hill 1999). References have already been made to the sites of As Sahabi, in Libya, for example (Boaz et al. 2008), to Lothagam in Kenya (Leakey and Harris 2003), to Toros Menalla in Chad (Vignaud et al. 2002; Le Fur et al. 2009), and to the Tugen Hills sequence in Kenya (Hill 1999a-b; 2002; Hill et al. 1985). So the Arabian fauna at this time was strongly African in general character.

However, there are differences. Some resemblance can be found to distinctly Asian faunas of this period, such as those known from the Siwalik sequences of Pakistan and India; the bovids and suids provide examples, and some genera are also found in Europe. Gentry (1999), mainly on the basis of the bovids, noted that there were very few similarities to the well-known Graeco-Iranian faunas of this time – which are well understood from occurrences at such localities and Samos and Pikermi in Greece, and Marageh in Iran. He suggested instead an east-west band of similar faunas extending just south of these sites, across North Africa and into the Indian sub-continent. Other elements of the fauna support this notion.

It will be interesting as research progresses to tease out the faunal affiliations of the Baynunah assemblage with various sites in northern and eastern Africa, and into south-west Asia, and so be able to address other questions. The Baynunah fauna largely came from Africa; as most probably did humans later in time. What environmental or other conditions allowed the African Miocene fauna to expand into Arabia? What route did the animals take to get there? The straits of Bab el Mandeb were probably not an option (Fernandes et al. 2006). Did all elements of the fauna get there at once, or were there separate migrations? What was the timing of this event or events? These are some of the biogeographical questions that the Miocene faunas of Abu Dhabi provoke, questions equally applicable to the arrival of humans and their archaeological traces in Arabia somewhat later in time.

IMPORTANCE AND CHALLENGES

The sites and fossils described here are important, and at a number of different levels. They have considerable local appeal, as is shown by the attention given to this research by people in Abu Dhabi and by the press, as they provide an uncommon window into wildlife and environments in the remote past of the Emirate, and form a significant element of the Emirate's heritage. Regionally they are significant too, as the only evidence of the past history of terrestrial life in the whole of Arabia between 15 Ma and the Pleistocene. Their great international importance stems partly from this simple rarity of sites in the region, but also because of the highly significant location of Arabia at the junction of the three classic Old World biogeographic zones. The geography and environments of Arabia through time have to a large extent controlled the nature of the current regional differentiation of animals in the Old World, and the age of these localities is additionally important in helping document the emergence of the essentially modern terrestrial vertebrate fauna. So the Baynunah fossil sites are important locally, regionally and internationally. They remain productive, and it is to be hoped that the localities and their fossils can be preserved, and that scientific work on them can be sustained.

Regarding the preservation of sites, since the Baynunah fossils were first recognised in the 1980s considerable construction has taken place in the Al Gharbia region, particularly on the coast, and much is planned for the future. There are already buildings on Hamra, Jebel Dhanna, Ras Dubay'ah, and major developments on Shuwaihat. The two most important fossil sites around Jebel Dhanna are now lost as a result of earth moving and various structures. While the desirability of the initiatives for development in Al Gharbia is of course recognised, it is also important that the more significant and productive fossil and related sites be preserved if possible from commercial, civil and military expansion. While it is reassuring to note that the protection of some key sites is proposed in the Al Gharbia 2030 Plan prepared by Abu Dhabi's Urban Planning Council, it is as yet unclear to what extent these proposals will be effectively implemented. Perhaps continued access to the internationally recognised geological type sections of the Baynunah Formation on Barakah, and of the Shuwaihat Formation on Shuwaihat could be guaranteed. Fences could be erected to protect other sites, and rangers employed to ensure their security. In this way they could be set aside as active scientific research areas, as monuments to these important aspects of local prehistory, so being protected not only for science, but as an asset to tourism and for the benefit of future generations.

A second aspect is the preservation of the fossils and the provision of facilities for their scientific study and relevant communication with the public. Once the fossils are collected, facilities are needed that:

- would bring together all Baynunah fossils under one roof in secure and accessible surroundings
- would incorporate a laboratory, along with a trained staff with expertise
- would help in preparing the fossils, so they can be studied scientifically
- would conserve them, so that they do not deteriorate, and
- would produce replicas, for display and exchange with other scientific institutions
- would house accessible comparative collections of modern animal skeletons, and replicas of significant fossils from other areas of the world
- would provide adequate space and facilities for active research and instruction.

Some of these needs are already being accommodated through ADACH initiatives, but the ideal situation would be to unite and integrate these facilities in a Centre for Palaeontology which, given the fossil and other resources of Abu Dhabi Emirate, could quickly become internationally renowned. This centre would house, prepare, and conserve the fossil material, and provide space and other services for those who study them. It would also act as the focus for publishing and disseminating the results of this research at all levels, locally and internationally. Such a centre could advantageously be part of a more public museum where the fossils could be displayed and explained in close proximity to where scientific work was being carried out. Both interests would benefit from this synergy of research and public outreach. In this way it would be similar to some of the best research museums in Europe, the USA and elsewhere.

If there were the interest and will to build on the already existing resources and opportunities of the Emirate, Abu Dhabi is poised to become the regional centre for palaeontological excellence in the Arab World.

We are most grateful to His Highness Sheikh Mansour bin Zayed Al Nahyan, Deputy Prime Minister and Minister of Presidential Affairs, United Arab Emirates, and the Ministry of Culture, Youth and Community Development, for sponsoring the conference from which this paper emerged, and to Peter Hellyer and the conference staff for organising it. Recent palaeontological work in Al Gharbia has been conducted under the auspices, and with the financial assistance, of the Abu Dhabi Authority for Culture and Heritage (ADACH), and we thank the Director General, H.E. Mohammed Khalaf Al Mazrouei, for his enthusiastic support of the project. Mohammed Al Neyadi, Head of the Historic Environment Department at ADACH, has also always been most helpful, and Zaki Nusseibah, the Vice-Chairman of ADACH, has expressed a constant and keen personal interest. His Highness Sheikh Sultan bin Zayed Al Nahyan, Deputy Prime Minister, has encouraged our work at Gerain al Aysh. Additional assistance has come from the Abu Dhabi Public Works Department, the Revealing Hominid Origins Initiative (National Science Foundation, USA, grant #0321893), the Abu Dhabi National Oil Company, the Provost's Office of Yale University, and the Yale Peabody Museum of Natural History. In Abu Dhabi we would like to thank Stephen Lokier, of the Petroleum Institute, and Drew Gardner at Zayed University. Both have kindly provided access to such laboratory facilities as microscopes, and microscopic digital photography which assisted aspects of our current research. At the Yale Peabody Museum we would like to acknowledge the support of the Director, Derek Briggs; the Head of the Division of Vertebrate Palaeontology, Jacques Gauthier; and Marilyn Fox, the Head of the Vertebrate Palaeontology Preparation Laboratory. Among other individuals to whom we are grateful are Brian Kraatz (Department of Anatomy, College of Osteopathic Medicine of the Pacific, Western University of Health Sciences, Pomona, CA, USA) and Walter Joyce (Institute for Geoscience, Eberhard Karls Universität, Tübingen, Germany). AH would also like to acknowledge with much gratitude the initial facilitation of Hans-Peter Uerpmann. It was a chance conversation with Hans-Peter at the Massachusetts Institute of Technology in 1984 that led to AH's involvement in this work and to his first research visit to Abu Dhabi.

1 In the context of the broader issues of this current volume, one of these specialists was Sally McBrearty, who described the first palaeolithic artefacts from Abu Dhabi (McBrearty 1993, 1999, and this volume).
2 Produced and directed by Dave Holmes, RKD Productions Ltd, London, 1991. Arabic version produced by Mark Beech (ADIAS), 2005.
3 Mordan, 1999.
4 Higgs et al., 2003.
5 Jeffrey, 1999.
6 Forey and Young, 1999.
7 but see Gayet and Muenier, 2003.
8 Rauhe et al., 1999.
9 Broin and van Dijk, 1999.
10 Bibi et al., 2005; Beech and Stewart, 2006.
11 Madden et al., 1982; Tassy, 1999.
12 Tassy, 1999; Andrews, 1999.
13 Hill and Gundling, 1999.
14 de Bruijn and Whybrow, 1994; de Bruijn, 1999; Kraatz et al., 2009.
15 Kraatz et al., 2009.
16 Kraatz et al., 2009.
17 de Bruijn and Whybrow, 1994; de Bruijn, 1999.
18 Barry, 1999.
19 Eisenmann and Whybrow, 1999.
20 Bishop and Hill, 1999.
21 Gentry, 1999a; Weston, 2000; Boisserie, 2005.
22 Gentry, 1999b.
23 Gentry, 1999b.

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