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GEOLOGICAL SURVEY

Mastritherium (Artiodactyla, Anthracotheriidae) from Wadi Sabya, southwestern Saudi Arabia: An earliest Miocene age for continental rift-valley volcanic deposits of the Red Sea margin

by

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MASRITHERIUM (ARTIODACTYLA, ANTHRACOTHERIIDAE) FROM WADI SABYA, SOUTHWESTERN SAUDI ARABIA: AN EARLIEST MIOCENE AGE FOR CONTINENTAL RIFT-VALLEY VOLCANIC DEPOSITS OF RED SEA MARGIN

by

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ABSTRACT

A lower jaw fragment with its last molar (M/3) from the Baid formation in Wadi Sabya, southwestern Saudi Arabia, represents the first recorded occurrence in the Arabian Peninsula of an anthracotheriid artiodactyl (hippo-like, even-toed ungulate). This fossil is identified as a primitive species of *Masritherium*, a North and East African genus restricted previously to the later early Miocene. This identification indicates that the age of the Baid formation, long problematical, is early Miocene and, moreover, shows that the age of the fossil site is earliest Miocene (from 25 to 21 Ma). The Wadi Sabya anthracothere is the first species of fossil mammal recorded from western Saudi Arabia, and more important, it indicates an early Miocene age for the volcanic deposits of a continental rift-valley that preceded the initial sea-floor spreading of the Red Sea.

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INTRODUCTION

Anthracotheres or anthracotheriids are hippopotamus-like, even-toed ungulates. These large, herbivorous mammals are now extinct; they were extant from middle Eocene to late Miocene in Europe, Asia, North America, and Africa. Anthracotheres, long thought to be ancestral to hippopotamuses (Romer, 1966), evidently appeared initially in the fossil record at Dera Bugti, Pakistan, during the the later early Miocene (Madden and Van Couvering, 1976) or Orleanian Land Mammal Age. Cheek-teeth (molars and premolars) in anthracotheriids generally are narrower, lower-crowned, and have sharper ridges and thinner enamel than the same teeth in hippopotamiids.

During the winter of 1981, Schmidt collected an anthracotheriid fossil (field specimen no. 158498C) from the Baid formation in Wadi Sabya, coastal plain of Saudi Arabia, at lat 17°13.2' N., long 42°47.1' E. (fig. 1). The Baid formation is a distinctive lake-bed facies of a volcanic sequence that was deposited in the continental rift valley prior to the opening of the Red Sea. The volcanic sequence (Jizan group) is dated 30 to 21 million years (Ma) and the sea-floor spreading of the Red Sea began about 20 Ma ago (Schmidt and others, 1992/1993). The age of the anthracothere is critical to the affirmation of the age of the volcanic deposition in the continental rift valley. Interpretations of the evolutionary history of the Red Sea previously have not recognized a continental rift-valley event, and the closely related age of the initiation of sea-floor spreading has been diversely interpreted.

The detailed comparison, description, and identification of the new Arabian anthracotheriid indicate that the Baid is of early Miocene age and further indicate that the fossil locality is of earliest Miocene age, between 25 and 21 Ma. The Sabya anthracothere is the first species of fossil mammal recorded from western Arabia and the first representative of its family (Anthracotheriidae) recorded from the Arabian Peninsula. A hippopotamus of Quaternary age appears to have been the first species of fossil mammal recorded from the Arabian Peninsula (L. S. B. Leakey, in Holm, 1960).

The following abbreviations are used in this report: USGS SAM, U.S. Geological Survey Saudi Arabian Mission, Jiddah; Ant., anthracothere; UCMP, University of California Museum of Paleontology, Berkeley; $\bar{X}$, mean of sample; $s_{\bar{X}}$, standard error of sample mean; s, standard deviation of sample mean; CV, coefficient of variation; N, number of observations in sample; OR, observed range of sample.

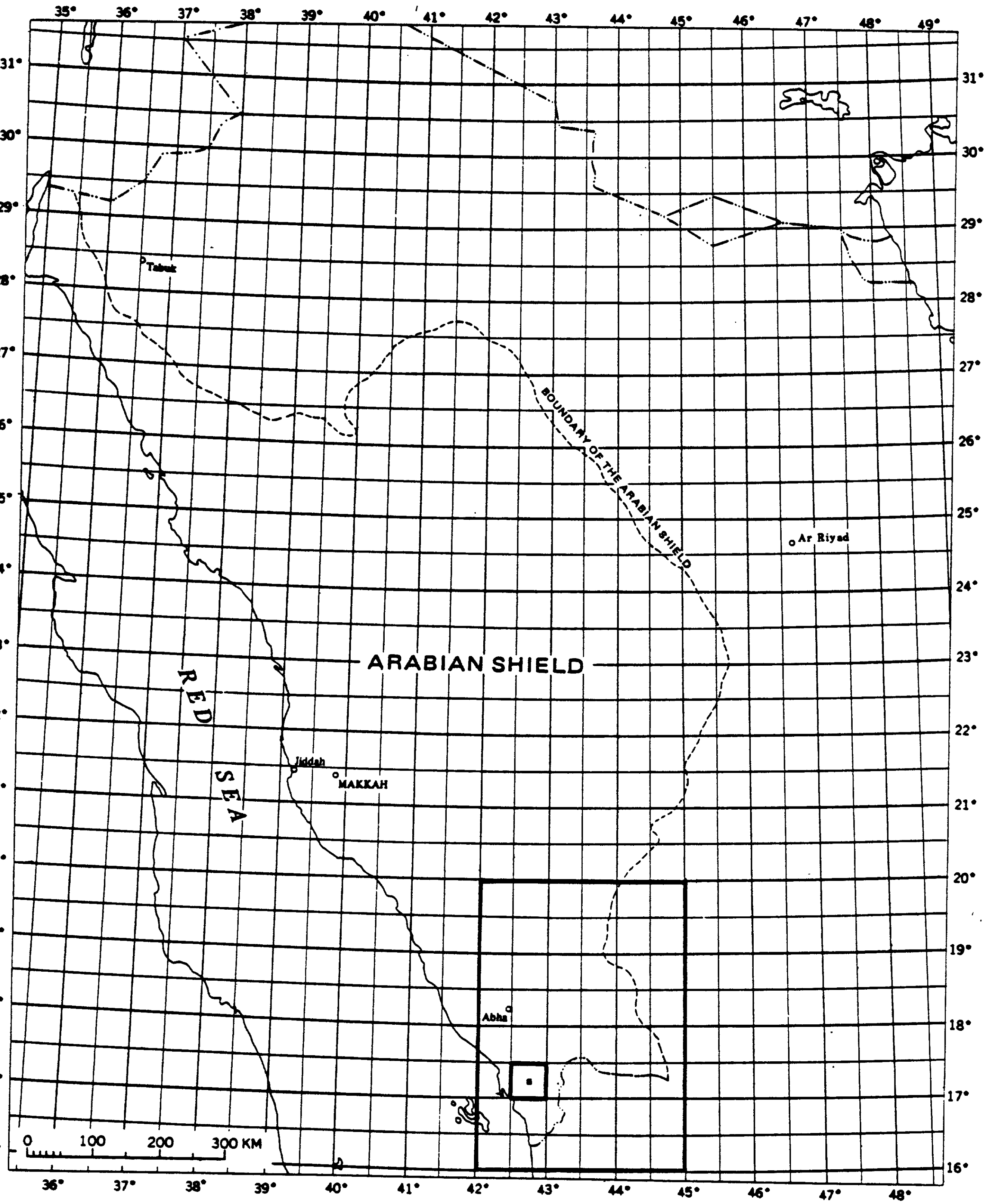

Figure 1.--Index map of western Saudi Arabia showing location of Wadi Sabya area (solid square) near the center of the Sabya quadrangle (Fairer, in press; inner square outline) within the Asir quadrangle (Brown and Jackson, 1959; outer rectangle).

Acknowledgements

This report is an outgrowth of studies conducted in accordance with a work agreement between the U.S. Geological Survey and the Ministry of Petroleum and Mineral Resources, Kingdom of Saudi Arabia. We thank the Directorate General of Mineral Resources for logistic and personnel support. We also thank C. C. Black and Peter Robinson for helpful discussions and for reading the manuscript. The specimen was prepared by Ken Carpenter, who also prepared a drawing of it (fig. 5).

STRATIGRAPHY

The Baid formation was named by Brown and Jackson (1959) for exposures in Wadi Bayd, which is 64 km northwest of Wadi Sabya where the anthracothere fossil was collected. The Baid formation was initially described as "...Gray, red, and green siliceous and tuffaceous shale; calcareous layers and lenses; and tuffaceous green sandstone.... Contains fresh-water fish fossils near Darb..." (Brown and Jackson, 1959). Fairer (in press) followed the Brown and Jackson designation of the Baid formation in his mapping of the Sabya quadrangle. In these reconnaissance studies, primary volcanic units were either included in the Baid formation or were not recognized.

During the study of the Tertiary rocks of the southern coastal plain of the Red Sea, the Baid formation was made part of the Jizan group as newly defined by Schmidt and others (1982, 1983). The Jizan group is a sequence of chiefly volcanic rocks deposited during the late Oligocene and early Miocene in a continental rift valley prior to the opening of the Red Sea. During the initial sea-floor spreading of the Red Sea, the continental margins, including the split continental rift valley and its contained rift volcanic sequence, were intruded by tholeiitic magma as extensional basalt dikes and diabase sills of the Tihamat Asir complex. This tholeiitic magma is directly related to the oceanic magma that formed the new oceanic crust of the Red Sea (Coleman and others, 1979). Both the rift-valley rocks of the Jizan group and the hypabyssal rocks of the Tihamat Asir complex are present in the Wadi Sabya area.

The local geology in Wadi Sabya is shown on figure 2 and a local, generalized stratigraphic column is shown on figure 3. The continental rift rocks of the Jizan group are provisionally assigned to the Ad Darb, Liyyah, Baid, and Damad formations on the basis of the regional study (Schmidt and others, 1982). In Wadi Sabya this partly exposed section is possibly more than 2 km thick. It is unconformably overlain by a basaltic ash sheet, 4 to 6 m thick (fig. 4), that in places in underlain and overlain by Quaternary silt, sand,

and gravel deposits. This water-worked ash is an eruptive deposit of Jabal Akwah ash Sham, a Quaternary volcano immediately northwest of the Wadi Sabya area.

The rocks of the Jizan group are partly exposed only within narrow dissection canyons, 8 to 16 m deep, of Wadi Sabya and its tributaries. Parts of the Baid and Liyyah formations are well exposed but all the formational contacts either are not exposed or are very poorly exposed. Little of the Damad formation and possibly only a few meters of the upper part of the Ad Darb formation are exposed.

The Baid formation largely consists of siliceous tuff that was derived from explosive ash and tuff deposited in thin to laminated beds in fresh-water lakes (fig. 4). The tuffaceous debris is chiefly of silt and clay size. Individual bedded units are commonly cyclic (varve-like) and graded, consisting of: a more massive, coarser grained lower part; a finer grained, thinly bedded middle part; and a finely laminated, very fine grained upper part. A few beds consist of lapilli or more rarely of breccia-size volcanic debris. The tuffs are leucocratic and weather tan, cream, or brown, and some highly siliceous rocks (beds) are a distinctive bluish gray. The silicic Baid tuffs were intially rhyolitic, but most of the original alkali feldspars have been replaced by silica in the lake environment (Schmidt and others, 1982, 1983).

Fossils are locally abundant in some of the lake beds. Sparse thin, calcareous beds, commonly highly silicified, are locally silicic coquinas containing abundant small, freshwater pelecypods and gastropods. In some tuff beds, partly articulated fish fossils are found in bedding planes, and more commonly, abundant fossil fish scales and fish bones are found widely scattered in bedding planes and within the beds. Plant debris, including short stems and woody fragments but rarely leaves, is present. The fact that coarser grained tuff and lapilli tuff beds contain sparse vertebrate bone fragments that are entirely disarticulated and isolated affirms that most of the beds were water worked. The anthracotheriid fossil was found within a 50 m section of well exposed Baid formation.

The thicknesses of the exposed rocks of these four formations were measured in the field, but the overall thicknesses given on figure 3 were scaled from an aerial photograph on the assumption that fault repetitions or deletions of section were not present and that interformational contacts were properly placed. No significant repetition of beds was seen in the measured sections, and it seems likely that the local section is not greatly affected by faults. The section, however, has been extended by the intrusion of basaltic dikes

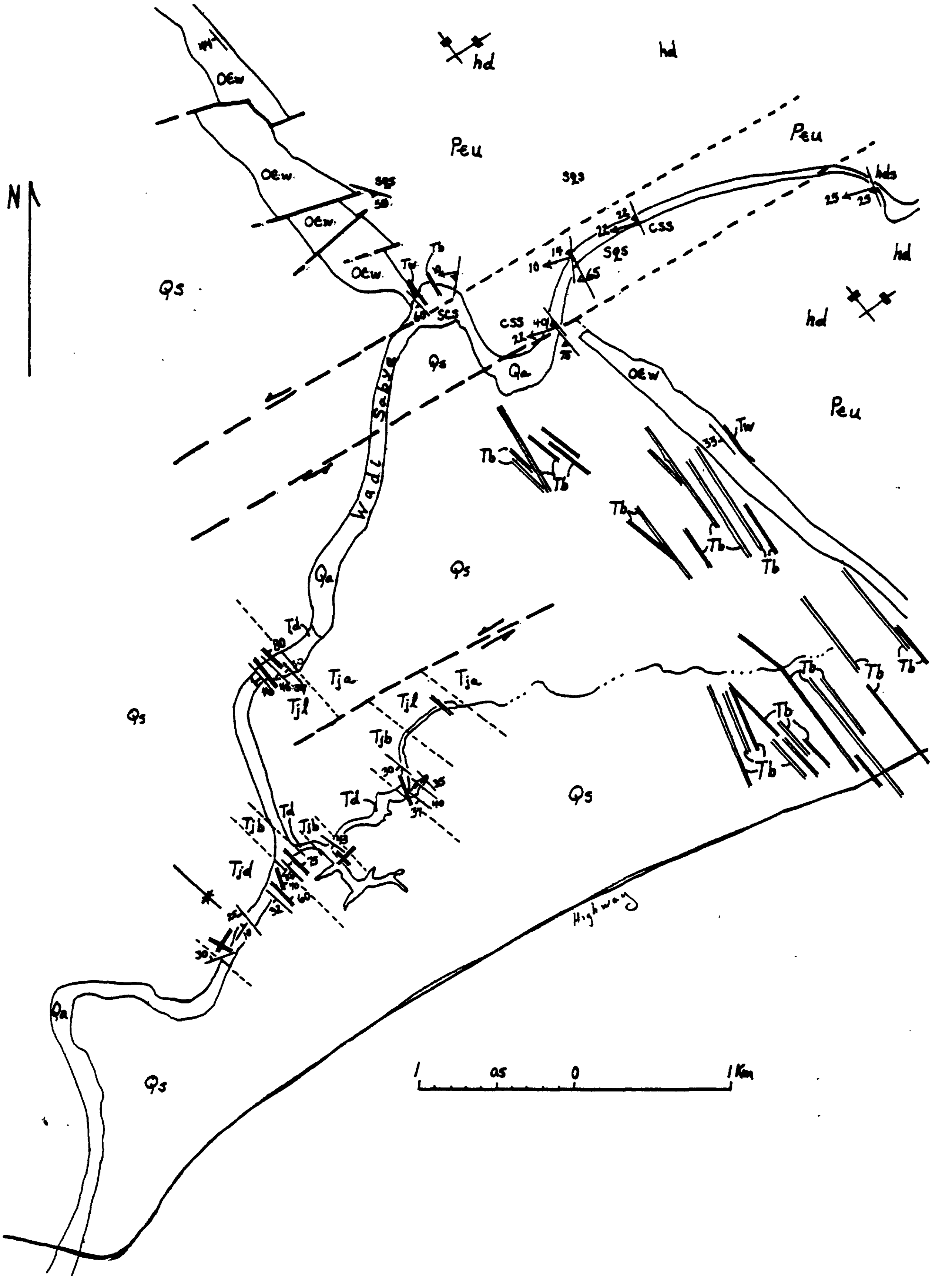

Figure 2.--Geologic map of Wadi Sabya area. Location shown by solid square on figure 1.

EXPLANATION

Qa	WADI ALLUVIUM—In Wadi Sabya canyon
Qs	SILT, SAND, GRAVEL, AND BASALTIC ASH AND CINDER BEDS
Tb, Td, Tw	TIHAMAT ASIR COMPLEX—Tb, basaltic dikes; Td, diabasic sills; Tw, leucocratic silicic dikes
Tjd	DAMAD FORMATION
Tjb	BAID FORMATION
Tjl	LIYYAH FORMATION
Tja	AD DARB FORMATION
OꞒw	WAJID SANDSTONE
PꞒu, hd, hds, sqs, css, scs	PꞒu, UNDIVIDED—Except where locally identified as: hd, hornblende diorite; hds, hornblende-diorite schist sqs, sericite-quartz schist; css, chlorite-sericite schist scs, sericite-chlorite schist
	CONTACT—Dashed where inferred
	FAULT (TRANSFORM)—Dashed were inferred; showing relative horizontal movement
	SYNCLINE—Approximately located
30	STRIKE AND DIP OF BEDDING
	STRIKE AND DIP OF FOLIATION
50	Primary
65	Secondary crenulation
14, 10	LINEATION—Showing plunge; symbol combined with foliation
	JOINT AND FRACTURE SETS—Dip approximately vertical; inferred Tertiary age; abundant in Precambrian rocks
	STREAMBED

Figure 2.—Continued.

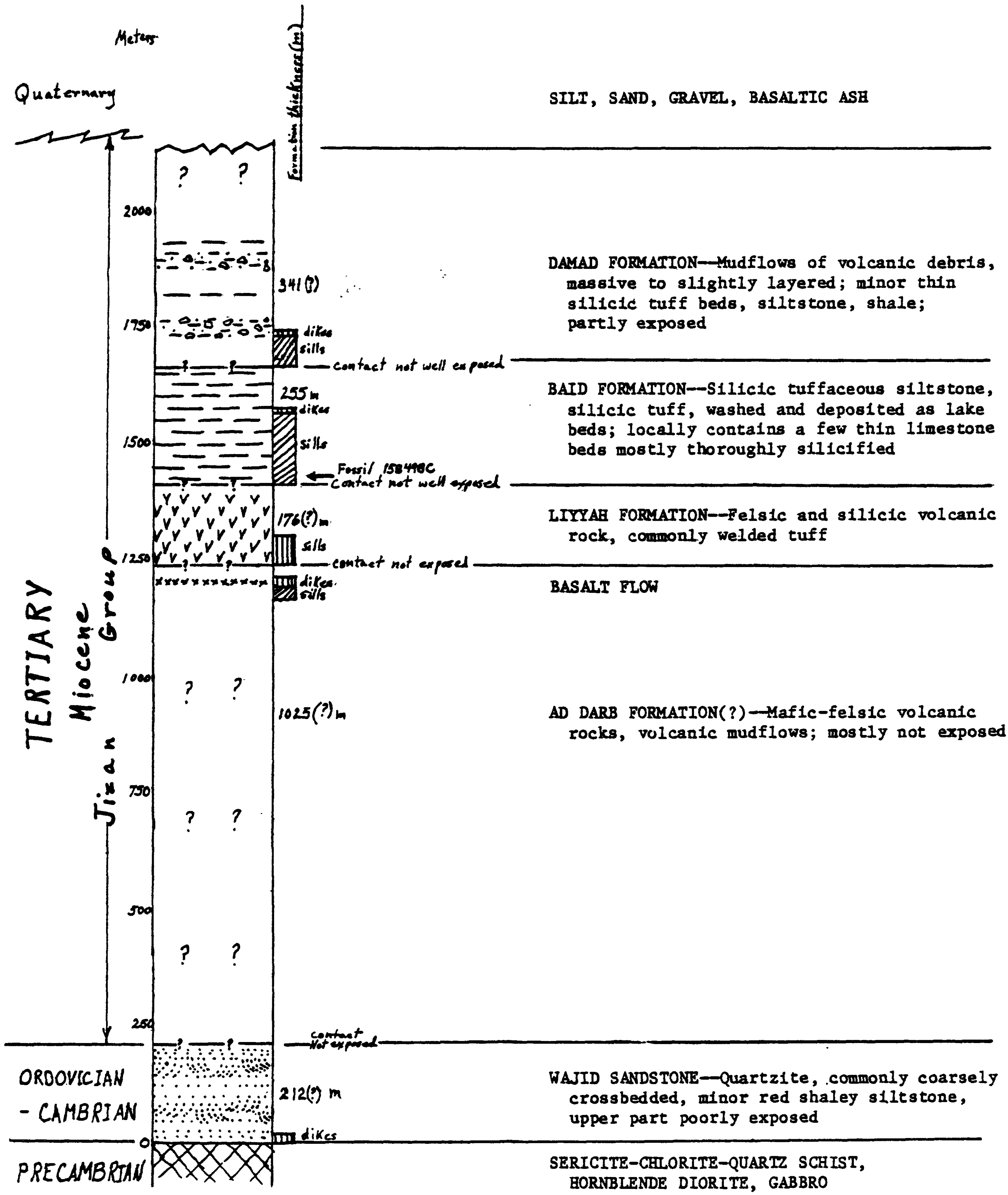

Figure 3.—Generalized stratigraphic column for Wadi Sabya area showing location of anthracothere fossil in Baid formation, Jizan group. Basaltic dikes (vertical lined pattern) and diabasic sills (diagonal lined pattern) of Tihamat Asir complex are shown on side of column; their estimated composite thicknesses within each formation are shown by the vertical height of pattern.

Figure 4.—Photograph of tilted Baid formation showing thin beds of silicified tuff of early Miocene age at Wadi Sabya. Quaternary basaltic ash and cinder beds, about 5 m thick, unconformably overlie Baid formation.

and diabase sills of the Tihamat Asir complex. The amount of expansion has been subtracted by estimating the percentage of intrusive expansion in the exposed rocks and by applying these corrections to the respective formations as a whole. The estimated formational thicknesses are necessarily approximate. During the emplacement of the mafic magma of the Tihamat Asir complex, that is, during the initiation of sea-floor spreading of the Red Sea, the rocks of the Jizan group were fractured and consistently tilted about 30° toward the newly forming Red Sea oceanic crust.

SYSTEMATIC PALEONTOLOGY

Class Mammalia Linnaeus, 1758
Order Artiodactyla Owen, 1848
Suborder Suiformes Jaekel, 1911
Superfamily Anthracotheroidea Leidy, 1869
Family Anthracotheriidae Leidy, 1869*
Genus Masritherium Fourtau, 1918

Masritherium Fourtau, 1918, p. 63, 1920, p. 63; Black, 1978, p. 427; Madden, 1980a, p. 58; 1980b, p. 242.

Brachyodus Deperet; MacInnes (in part), 1951, p. 3; Patterson (in part), in Maglio, 1969, p. 2; Madden (in part), 1972a, p. 2, 6, 9; 1972b, p. 34.

Type-species: Masritherium depereti Fourtau, 1918, p. 65, 1920, p. 65.

Contained species: The type-species; Brachyodus aequatorialis MacInnes, 1951; and Masritherium sp. (this report).

Paleozoogeographic distribution: North and East Africa (Fourtau, 1918, 1920; Black, 1978), and western Arabian Peninsula.

Temporal range: Earlier to later early Miocene.

Diagnosis: Anthracotheriids differing from North African, early Oligocene and early Miocene Bothriogenys in having relatively longer skulls and mandibles; longer diastema between premolars and canines; diastema between canines and incisors; (weakly developed or shallow) mandibular angle flange; variable absence of P/2 ("P/1"); bunoselenodont M1/1-3/3; M1/-3/ parastyles and

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* The author of this family is Leidy (1869) and not Gill (1872) as shown in Simpson (1945).

metastyles somewhat flattened to bulbous, not formed by paracone and metacone wings; relatively shorter M/1-/3 anterior protoconid and hypoconid arms; and large size (emended from Black, 1978).

Discussion: Hitherto, this genus contained two species: North African Masritherium depereti Fourtau, 1918, and East African M. aequatorialis (MacInnes, 1951; Black, 1978). The second species is more primitive and smaller than the first species. It is of later early Miocene age, being known from Rusinga Island (MacInnes, 1951), a major, general locality; Lothidok (or Losodok) locality 1 (Madden, 1972b), and Loperot, Kenya; and probably from Lake Albert locality number 445, Congo (Hooijer, 1963, 1970). The sample from Loperot, an undescribed, left maxillary fragment with occluding dP5/ (dP"4"/) and M1/ and erupting M2/ in the Kenya National Museums, Nairobi, is indistinguishable morphologically and metrically from comparable samples of M. aequatorialis. This material was identified as "...Brachyodus sp. ..." by the late Bryan Patterson (in Maglio, 1969, p. 2). The Lothidok 1 sample, UCMP 40427, an incomplete M2/, was described, figured, and identified by Madden (1972b, p. 34-36, pl. 2, fig. 3) as "...Brachyodus cf. aequatorialis MacInnes, 1951...." It also is indistinguishable morphologically and metrically from comparable samples of M. aequatorialis.

Masritherium sp.

Probably Brachyodus sp. indet. Madden, 1972b, p. 36, pl. 3, fig. 1.

Probably Masritherium sp. indet. Madden, 1980a, p. 58, 1980b, p. 242.

Samples: USGS SAM Ant. 1, left horizontal mandibular ramus fragment with M/3 and probably UCMP 41901, left horizontal mandibular ramus fragment with P/3.

Localities for samples: Wadi Sabya, Saudi Arabia, and probably Lothidok (or Losodok) locality 2, Kenya.

Paleozoogeographic distribution: Western Arabian Peninsula and probably East Africa.

Temporal range: Probably earliest Miocene, equivalent to the Agenian Land Mammal Age of Eurasia.

Description: The Wadi Sabya anthracothere fossil, USGS SAM Ant. 1, is a fragment from a lower jaw or mandible with its last or third molar, or M/3 (fig. 5). The

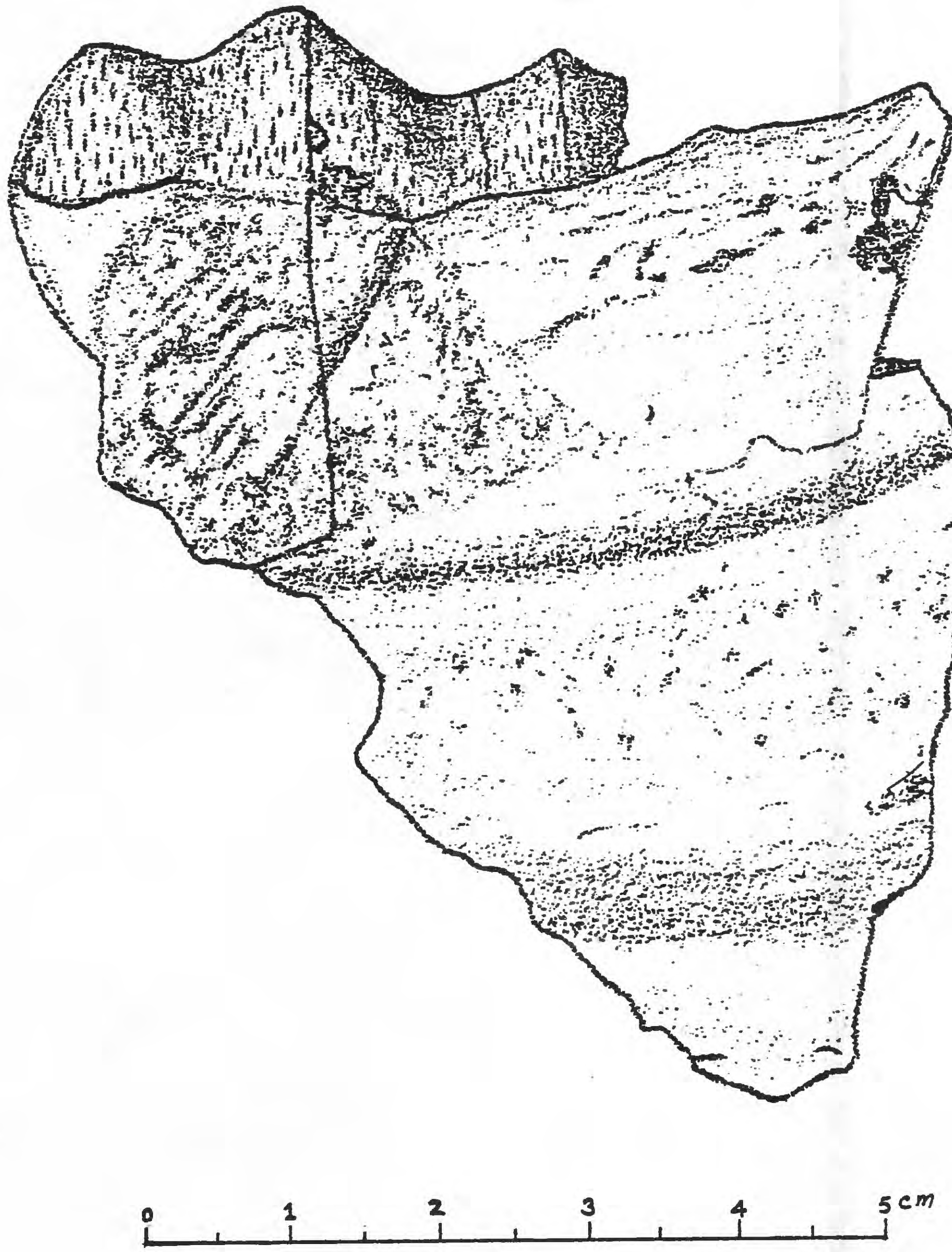

Figure 5.--Lower jaw fragment with M/3 of Masritherium Fourtau, 1918, species, of earliest Miocene age, Wadi Sabya. Depth or height of jaw fragment immediately behind M/3 (last molar) is 64 mm as preserved.

fossil is identifiable as a species of Masritherium because of its morphology and large size. The M/3 is large, like last molars in East African, later early Miocene M. aequatorialis. However, it appears to be significantly shorter than M/3 in that species. It is only 43.7 mm long as preserved, and was not significantly longer than that parameter before fossilization; third molars in the Kenyan species average 50.5 mm (table 1). The Wadi Sabya molar is also similar to those in M. aequatorialis in its height and enamel wrinkling. It is very brachyodont or low-crowned: its first cusp, or protoconid, is only 13.5 mm high, and its last cusp, or hypoconid, is only 8.3 mm high. Although described last molars of the Kenya Masritherium are well-worn and therefore not directly comparable, the Wadi Sabya molar probably was lower-crowned in that it is shorter; shorter molars in anthracotheres generally are more brachyodont than longer molars. The enamel is finely wrinkled, a characteristic MacInnes (1951) observed for molars in Masritherium ("Brachyodus") aequatorialis and Andrews (1899) and Schmidt (1913) also observed for North African, early Oligocene and early Miocene species of Bothriogenys ("Brachyodus"). A parameter for width is not observable because the M/3 is split longitudinally along its entire length. However, the width parameter may have been roughly 21.2 mm, an estimate based on the width of M/3 in M. aequatorialis.

The depth or height of USGS SAM Ant. 1, which is a fragment, is 64 mm immediately behind its M/3. The complete mandible of the Arabian Masritherium therefore was very large, as was the mandible in the African species of that genus (Fourtau, 1918, 1920; MacInnes, 1951; Black, 1972).

DISCUSSION

The anthracothere identified from the lower jaw fragment with its last molar (USGS SAM Ant. 1) from the Baid formation in Wadi Sabya is the first species of fossil mammal recorded from western Saudi Arabia. It also is the first anthracothere recorded from the Arabian Peninsula. These hippo-like, even-toed, ungulate mammals have not been recorded previously from this vast region (Leakey, in Holm, 1960; Dehm, in Glennie and Evamy, 1968, and Glennie, 1970; Tleel, 1973; Andrews and others, 1978; Hamilton and others, 1978; Thomas and others, 1978; Madden and others, 1979, and unpublished data; Sen and Thomas, 1979; Thomas and Sen, 1979; Madden, 1980c, 1983; Masry, 1980; Whybrow and McClure, 1981).

Table 1.—Length of Wadi Sabya lower third molar and sample statistics of that character for M/3 in Masritherium aequatorialis (MacInnes, 1951), M. depereti Fourtau, 1918, and Merycopotamus anisae Black, 1972

[Calculated from parameters and (or) sample statistics given by Fourtau (1918, 1920), MacInnes (1951), and Black (1972)]

	Masritherium sp.	M. aequatorialis	M. detereti	Merycopotamus anisae
$\bar{X}$	43.7	50.5	59.2	45.1
$s_{\bar{X}}$	—	—	1.46	0.47
s	—	—	3.27	2.88
CV	—	2	5.5	6.4
N	1	—	5	38
OR	—	50.0-51.0	55.0-64.0	38.9-50.5

USGS SAM Ant. 1 probably represents the same species as does a horizontal mandibular fragment with third ("second") premolar of a primitive, masrithere anthracothere initially described, figured, and identified from Lothidok (or Losodok) locality 2, Kenya, by Madden (1972b, pp. 36-37; pl. 3, fig. 1) as "...*Brachyodus* sp. indet..." and later identified by him (1980a, p. 58; 1980b, p. 242) as "...*Masritherium* sp. indet...." The third premolar in this fragment (UMCP 41901) has a morphology corresponding to what should probably be expected for that of P/3 in the Saudi Arabian anthracothere based upon the M/3 known in that species: It is very primitive and small. UCMP 41901 is very low-crowned and narrow, and it has a massive, internal cingulum, or shelf. The premolar has a height of only 12.9 mm and a width of only 11.2 mm, and probably had a length no greater than 19.0 mm (Madden, 1972b, pp. 36-37). P/3 in the primitive, Lothidok locality 2 *Masritherium* species is 19 percent narrower and 29 percent lower crowned than the same premolar in East African, later early Miocene *M. aequatorialis* (table 2).

AGE OF BAID FORMATION AND OF OPENING OF THE RED SEA

The age of the Baid formation has been problematic since 1959, when it was first described by Brown and Jackson (1959); several ages have been assigned to it (table 3). Brown and Jackson (1959) considered the Baid to be of questionable Miocene age when they originally described the formation. However, Brown (1970) later regarded the formation to be of late Oligocene or early Miocene age. Brown and Jackson's (1959) and Brown's (1970) assignments appear to have been based largely upon Dunkle's (written commun., 1953, *in* Brown, 1970) study of the fossil fish remains from Ad Darb, which he considered to be of late Oligocene or Miocene age. However, Van Couvering's studies of the Ad Darb fish samples led her to hypothesize that they were of "...Tertiary age..." (1972) and "...age unknown..." (1977). Nonetheless, Meyer (written commun., 1975) felt that fish samples collected from Ad Darb by D. L. Schmidt and D. G. Hadley in 1974 indicated an "...Oligocene or younger age...." Coleman and others (1979) regarded the age of the Baid to include potassium-argon (K-Ar) determinations between 20 and 18 Ma.

The anthracothere identified from its lower jaw fragment with its last molar (USGS SAM Ant. 1) from the Baid formation at Wadi Sabya is a species of *Masritherium* Deperet, 1918. This North and East African genus is restricted to the early Miocene (Fourtau, 1918, 1920; Black, 1978). Identification of USGS SAM Ant. 1 as representing a *Masritherium* species indicates that the age of the Baid formation is early Miocene. Moreover, the Sabya specimen represents a species of *Masritherium* that is more primitive than those known

Table 2.—Width, height, and (probable) length of UCMP 41901 and sample statistics for those characters of P/3 in *Masritherium aequatorialis* (MacInnes, 1951), *M. depereti* Fourtau, 1918, and *Merycopotamus anisae* Black, 1972

		UCMP 41901	*M. aequatorialis*	*M. depereti*[1]	*Merycopotamus anisae*[2]
Width	$\bar{X}$	11.2	13.9	19.0	15.5
	$s_{\bar{X}}$	—	0.33	—	0.5
	s	—	.58	—	1.11
	CV	—	4.2	—	7.1
	N	1	3	2	5
	OR	—	13.2–14.2	—	14.6–17.4
Height	$\bar{X}$	12.9	18.2	—	—
	$s_{\bar{X}}$	—	2.11	—	—
	s	—	3.65	—	—
	CV	—	20.1	—	—
	N	1	3	—	—
	OR	—	14.6–21.9	—	—
Length	$\bar{X}$	About 19.0	22.1	26.0	18.1
	$s_{\bar{X}}$	—	1.31	2.01	.66
	s	—	2.26	2.83	1.61
	CV	—	10.2	10.9	8.9
	N	1	3	2	6
	OR	—	20.0–24.5	24.0–28.0	16.2–21.1

1/Calculated from parameters given by Fourtau (1918, 1920).
2/Calculated from parameters given by Black (1972).

Table 3.--Previously assigned ages for Baid formation

Worker(s)	Assigned age
Dunkle (written commun., 1953, *in* Brown (1970)	late Oligocene or Miocene
Brown and Jackson (1959)	Miocene(?)
Gillmann (1968)	Middle to late Tertiary
Brown (1970)	late Oligocene or Miocene
Van Couvering (1972)	Tertiary
Meyer (written commun., 1975)	Oligocene or younger
Van Couvering (1977)	age unknown
Coleman and others (1979)	20 to 18 Ma
Schmidt and others (1982, 1983)	30 to 21 Ma

previously of that genus: North African *Masritherium depereti* and East African *M. aequatorialis*, its more primitive counterpart; however, the Arabian species has even lower and smaller last molars than the latter. Thus, if the age of USGS SAM Ant. 1 is consistent with its very primitive morphology, the Saudi Arabian *Masritherium* is probably older than *M. depereti* and *M. aequatorialis*. Those two species are of later early Miocene age, between 20 and 17 Ma (Fourtau, 1918, 1920; MacInnes, 1951; Hooijer, 1963, 1970; Patterson, *in* Maglio, 1969; Madden, 1972a, 1972b; Black, 1978). The Sabya species probably is of earlier early Miocene or earliest Miocene age, between 25 and 21 Ma. The early Miocene and more specifically earliest Miocene age determination proposed here for the age of the Baid formation should be considered tentative. This determination is based solely upon a single species, not upon a whole fauna, and that species is represented by one specimen.

Schmidt and others (1982, 1983) showed that the Baid formation was deposited in a continental rift valley in the Arabian-Nubian Shield that is the first surface expression of active mantle convection beneath an axis that was later to become the Red Sea. The continental rift-valley rocks (Jizan group) are estimated to have been deposited from about 30 to 21 Ma ago on the basis of available K-Ar dates of volcanic rocks (Schmidt and others, 1982, 1983) Sea-floor spreading of the Red Sea began about 20 Ma ago and was accompanied initially by the hypabyssal intrusion of tholeiitic magma of oceanic parentage, the Tihamat Asir complex, into the continental rift margins, that is, into the rocks of the Jizan group. The main first-stage of the Red Sea continued to spread until about 14 Ma ago.

Coleman and others (1979) consider the Baid formation to rest unconformably on the Tihamat Asir complex, and they report K-Ar dates on "basalt flows" within the Baid formation to range from 20 to 18 Ma. However, Schmidt and others (1982, 1983) show that these "basaltic flows" are actually younger than that formation; they are diabase sills and dikes, of the Tihamat Asir complex and were intruded into the Baid. The earlier early Miocene or earliest Miocene age of the Wadi Sabya anthracothere is consistent with the age of the continental rift-valley stage of evolution of the Red Sea. Study of the Baid formation requires further and intensive collection by vertebrate paleontologists competent in the Neogene mammalian faunas of Africa.

PALEOZOOGEOGRAPHY

USGS SAM Ant. 1 is identifiable as a new and primitive species of *Masritherium* Fourtau, 1918. This identification extends the paleozoogeographic distribution of *Masritherium* to Arabia. Fourtau's genus has been recorded previously from North and East Africa (Fourtau, 1918, 1920; Black, 1978). This new record of an anthracothere from Arabia is not unexpected, for Madden and Van Couvering (1976) showed that anthracotheres "...from northern Afro-Arabia...reached Eurasia during the mid-Burdigalian (now Orleanian (authors)) 'Proboscidean Datum Event'...", some 17.5 Ma ago. Anthracotheres that took part in this event were *Bothriogenys* ("*Brachyodus*") *africanus* (Andrews, 1899), *Hyoboops* Trouessart, 1904, and *Gelasmodon* Forster-Cooper, 1924 (Madden and Van Couvering, 1976; see Forster-Cooper, 1924). Evidently *Masritherium* did not take part in this event, and therefore during its early Miocene existence, this genus was restricted to Africa (then including Arabia) where it originated (Black, 1978). Incidently, Black (1978) hypothesized that *Hyoboops* originated in Asia and not in Africa; however, his hypothesis is not supported by the available evidence. Species of *Hyoboops* from Africa are morphologically more primitive and somewhat older than those from Asia (Pilgrim, 1912; Forster-Cooper, 1924; MacInnes, 1951; Madden and Van Couvering, 1976; Black, 1978). The fact that a species of *Gelasmodon* from Africa (Loperot, Kenya) also is morphologically more primitive (Bryan Patterson, oral commun., 1971) and somewhat older than those from Asia (Madden and Van Couvering, 1976) indicates that the genus also originated in Africa, like *Masritherium* and *Hyoboops*. The diversity of its known (three) species indicates that *Masritherium* originated by the earliest Miocene and probably during the latest Oligocene.

REFERENCES CITED

Andrews, C. W., 1899, Fossil mammals from Egypt: Geological Magazine, Series 4, v. 6, p. 481-484.

Andrews, Peter, Hamilton, W. R., and Whybrow, P. J., 1978, Dryopithecines from the Miocene of Saudi Arabia: Nature, v. 274, no. 5668, p. 249-251.

Black, C. C., 1972, A new species of Merycopotamus (Artiodactyla: Anthracotheriidae) from the late Miocene of Tunisia: Notes du Service Geologique Tunisie, no. 37, fasc. 2, p. 5-39.

__________ 1978, Anthracotheriidae, in Maglio, V. J., and Cooke, H. B. S. (eds.), Evolution of African mammals: Cambridge, Harvard University Press, p. 423-434.

Brown, G. F., 1970, Eastern margin of the Red Sea and the coastal structures in Saudi Arabia: Philosophical Transactions of the Royal Society of London, Series A, v. 267, p. 75-87.

Brown, G. F., and Jackson, R. O., 1959, Geologic map of the Asir quadrangle, Kingdom of Saudi Arabia: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-217 A, scale 1:500,000; reprinted, 1979, Saudi Arabian Directorate General of Mineral Resources Geologic Map GM-217 A.

Coleman, R. G., Hadley, D. G., Fleck, R. J., Hedge, C. T., and Donato, M. M., 1979, The Miocene Tihama Asir ophiolite and its bearing on the opening of the Red Sea, in Evolution and mineralization of the Arabian-Nubian Shield: King Abdulaziz University, Institute of Applied Geology Bulletin 3, v. 1: Pergamon Press, Oxford-New York, p. 173-186.

Fairer, G. M., in press, Reconnaissance geology of the Sabya quadrangle, sheet 17/42 D, Kingdom of Saudi Arabia: Saudi Arabian Deputy Ministry for Mineral Resources Geologic Map series, scale 1:100,000.

Forster-Cooper, C. C., 1924, The Anthracotheriidae of the Dera Bugti Deposits in Baluchistan: Memoirs of Geological Survey of India, v. 8, no. 2, 73 p.

Fourtau, R., 1918, Contribution a l'etude des Vertebres Miocenes de l'Egypt: Egypt, Ministry of Finance, Survey Department, 122 p.

_______________ 1920, Contribution a l'etude des Vertebres Miocenes de l'Egypt: Egypt, Ministry of Finance, Survey Department, 122 p.

Gill, Theodore, 1872, Arrangement of the families of mammals with analytical tables: Smithsonian Miscellaneous Collections, v. 11, art. 1, p. 1-98.

Gillmann, Michel, 1968, Primary results of a geological and geophysical reconnaissance of the Jizan coastal plain in Saudi Arabia: American Institute of Mining and Metallurgical Engineers, Society of Petroleum Engineers, Saudi Arabian Section, Second Regional Technical Symposium, Dhahran, Proceedings, p. 189-212.

Glennie, K. W., 1970, Desert sedimentary environments: Amsterdam, Elsevier, 222 p.

Glennie, K. W., and Evamy, B. D., 1968, Dikaka; plants and plant-root structures associated with aeolian sand: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 4, p. 77-87.

Hamilton, W. R., Whybrow, P. J., and McClure, H. A., 1978, Fauna of fossil mammals from the Miocene of Saudi Arabia: Nature, v. 274, no. 5668, p. 248-249.

Hooijer, D. A., 1963, Miocene Mammalia of Congo: Koninklijk Museum voor Midden-Afrika (Tervuren, Belgium) Annalen, Reeks in-8°, Geologische Wetenschappen, no. 46, 78 p.

_______________ 1970, Miocene Mammalia of Congo, a correction: Koninklijk Museum voor Midden-Afrika (Tervuren, Belgium) Annalen, Reeks in-8°, Geologische Wetenschappen, no. 67, p. 161-167.

Holm, D. A., 1960, Desert geomorphology in the Arabian Peninsula: Science, v. 132, no. 3437, p. 1369-1379.

Jaekel, O. M. J., 1911, Die Wirbeltiere, Eine Überzicht über die fossilen und lebenden Formen: Berline, Gebruder Borntraeger, 252 p.

Linnaeus, Carolus, 1758, Systema naturae, Editio decima, reformata: Stockholm, Laurentii Salvii, v. 1, 824 p.

Leidy, Joseph, 1869, On the extinct Mammalian fauna of Dakota and Nebraska, including an account of some allied forms from other localities, together with a synopsis of the mammalian remains of North America: Academy of Natural Sciences, Philadelphia, Journal, ser. 2, v. 7, p. 1-472.

MacInnes, D. G., 1951, Miocene Anthracotheriidae from East Africa: British Museum (Natural History), Fossil Mammals of Africa, no. 4, 24 p.

Madden, C. T., 1972a, Miocene mammals, stratigrpahy and environment of Muruarot Hill, Kenya: PaleoBios, no. 14, p. 1-12.

__________ 1972b, A Miocene Mammalian Fauna from Lothidok Hill, Kenya: M. A. Thesis, University of California, Berkeley, 45 p.

__________ 1980a, Zygolophodon from Subsaharan Africa, with observations on the systematics of palaeomastondontid proboscideans: Journal of Paleontology, v. 54, no. 1, p. 57-63.

__________ 1980b, New Proconsul (Xenopithecus) from the Miocene of Kenya: Primates, v. 21, no. 2, p. 241-252.

__________ 1980c, Systematic position of Miocene Arabian hominid: American Journal Physical Anthropology, v. 52, no. 2, p. 252.

__________ 1983, Paleocene pycnodont fishes from Jabal umm Himar, Harrat Hadan area, At Taif region, Kingdom of Saudi Arabia: Saudi Arabian Deputy Ministry for Mineral Resources Open-File Report USGS-OF-03-40, 25 p.

Madden C. T., and Van Couvering, J. A., 1976, The Proboscidean Datum Event: early Miocene migration from Africa: Geological Society of America Abstracts with Programs (Annual Meetings), v. 8, no. 6, p. 992-993.

Madden C. T., Naqvi, I. M., Whitmore, F. C., Jr., Schmidt, D. L., Langston, Wann, Jr., and Wood, R. C., 1979, Paleocene vertebrates from coastal deposits in the Harrat Hadan area, At Taif region, Kingdom of Saudi Arabia: U. S. Geological Survey Saudi Arabian Project Report 269, 29 p.; also, 1980, U.S. Geological Survey Open-File Report 80-227.

Maglio, V. J., 1969, A shovel-tusked gomphothere from the Miocene of Kenya: Museum of Comparative Zoology (Cambridge), Brevoria, no. 340, p. 1-10.

Masry, A. H., 1980, Paleontological survey of the Eastern Province: Atlal, The Journal of Saudi Arabian Archaeology (Riyadh, Department of Antiquities and Museums, Ministry of Education), v. 4, p. 120, pl. 84.

Owen, Richard, 1848, Description of teeth and portions of jaws of two extinct Anthracotherioid Quadrupeds (Hyopotamus Vectianus and Hyop Bovinus), discovered by the Marchioness of Hastings in the Eocene deposits on the N.W. coast of the Isle of Wight: with an attempt to develop Cuvier's idea of the classification of pachyderms by the number of their toes: Quarterly Journal Geological Society of London, v. 4, p. 103-141, pl. 7-8.

Pilgrim, G. E., 1912, The vertebrate fauna of the Gaj Series in the Bugti Hills and the Punjab: Palaeontologia Indica, v. 8, p. 1-65.

Romer, A. S., 1966, Vertebrate paleontology 3rd ed.: Chicago, University of Chicago Press, 468 p.

Schmidt, D. L., Hadley, D. G., and Brown G. F., 1982, Middle Tertiary continental rift and evolution of the Red Sea in southwestern Saudi Arabia: Saudi Arabian Deputy Ministry for Mineral Resources Open-File Report USGS-OF-03-6, 56 p.; also, 1983, U.S. Geological Survey Open-File Report

Schmidt, Martin, 1913, Über paarhufer der fluviomarinen schichten des Fajum, odontographisches and osteologisches material: Geologische und Palaeontologische Abhanglungen, Neue Folge, v. 11, no. 3, p. 155-263.

Sen, Sevket, and Thomas, Herbert, 1979, Decouverte de Rongeurs dans le Miocene moyen de la Formation Hofuf (Province du Hasa, Arabie saoudite): Societe geologique de France, Bulletin, v. 21, no. 1, Supplement, p. 34-37.

Simpson, G. G., 1945, The principles of classification and a classification of mammals: American Museum of Natural History (New York), Bulletin, v. 85, 350 p.

Thomas, Herbert, and Sen, Sevket, 1979, Recherches Paleomammalogiques dans le Tertiaire du Golfe Arabo-Mesopotamien (Arabie saoudite, Irak) (abs.): Reunion Annuelle des Sciences de la Terre, 7th, Lyon, 23-25 April, 1979, p. 443.

Thomas, Herbert, Taquet, Phillipe, Ligabue, Giancarlo, and Del 'Agnola, Claudio, 1978, Decouverte d'un gisement de Vertebres dans les depots continentaux aux du Miocene moyen du Hasa (Arabie saoudite): Societe geologique de France, Bulletin, v. 20, no. 2, Supplement, p. 69-72.

Tleel, J. W., 1973, Surface geology of Damman Dome, Eastern Province, Saudi Arabia: American Association of Petroleum Geologists, Bulletin, v. 57, no. 3, p. 558-576.

Trouessart, E. L., 1904, Catalogus mammalium tam viventium quam fossilium, Nova editio (prima completa): Berlin, R. Friedlander and Sohn, supplement, pts. 1-2, p. 1-546.

Van Couvering, J. A. H., 1972, Palaeontology and comparative osteology of some African cichlid fishes: Ph.D. Thesis, Cambridge University, Cambridge.

_________ 1977, Early records of freshwater fishes in Africa: Copeia, 1977, no. 1, p. 163-166.

Whybrow, P. J., and McClure, H. A., 1981, Fossil mangrove roots and palaeoenvironments of the Miocene of the eastern Arabian Peninsula: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 32, p. 213-225.