Reprinted From

SIWALIKS OF SOUTH ASIA

PROCEEDINGS OF THE THIRD GEOSAS WORKSHOP
HELD AT ISLAMABAD, PAKISTAN
MARCH 01-05, 1997

Editors

M. Ishaq Ghaznavi
S. Mahmood Raza
M. Talib Hasan

GEOLOGICAL SURVEY OF PAKISTAN, ISLAMABAD, PAKISTAN
1998

GEOLOGICAL SURVEY OF PAKISTAN

S. HASAN GAUHAR
Director General

SOUTH ASIA GEOLOGICAL CONGRESS (GEOSAS)

HILAL A. RAZA
Secretary General

Contents of papers are the sole responsibility of the authors.
The editors and reviewers have ensured uniformity and consistency of the format.

Published by:
The Director General,
Geological Survey of Pakistan,
Plot 84, Street 3, Sector H-8/1, Islamabad, Pakistan
Phone No. (051) 435146-49 Fax No. (051) 436573
E-mail: p.s@gsp.isb.erum.com.pk

First Early Eocene Land Mammals from the Upper Ghazij Formation of the Sor Range, Balochistan

Philip D. Gingerich[1], Muhammad Arif[2], Intizar Hussain[3] and S. Ghazanfar Abbas[4]

[1]*Department of Geological Sciences and Museum of Paleontology, The University of Michigan Ann Arbor, Michigan 48109-1079, USA*

[2]*Paleontology and Stratigraphy Branch, Geological Survey of Pakistan, 84, H-8/1, Islamabad, Pakistan*

[3]*Coal Resources Assessment Division, Geological Survey of Pakistan, Sariab Road, Quetta, Pakistan*

[4]*Technical Directorate, Geological Survey of Pakistan, Sariab Road, Quetta, Pakistan*

Abstract

Three new genera and species of Early Eocene land mammals are described from variegated red bed continental deposits of the lower part of the upper Ghazij Formation, Sor Range, Balochistan (Pakistan). *Sororocyon usmanii* gen. et sp. nov. and *Obashtakaia aeruginis* gen. et sp. nov. are quettacyonids (order Condylarthra) closely related to *Quettacyon parachai* described previously from a middle Ghazij coal., *Sororcyctes ghaznavii* gen. et sp. is a distinctly specialised digging mammal placed in its own family Sororyctidae nov. order indet. These mammals lived on one or more ephemeral Ghazij Islands obducted off the northwestern margin of Indo-Pakistan during closure of eastern Neo-Tethys. We cannot at present evaluate whether mammals known to date from the lower part of the upper Ghazij Formation were confined to the Ghazij Island or ranged more widely over the Indian subcontinent. Recovery of part of a molar of a tapiroid (order Perissodactyla) from the upper part of the upper Ghazij Formation suggest that the endemic *Sororocyon-Obashtakaia-Sororyctes* fauna described here was replaced by a more cosmopolitan Holarctic fauna later in the Early Eocene. This is consistent with evidence of a cosmopolitan fauna in the latest Early Eocene Kuldana Formation of Pakistan and upper Sabathu Formation of Kashmir and India.

Introduction

The Ghazij Formation of latest Paleocene and Early Eocene age is widely distributed in Pakistan. There have been occasional unsubstantiated indications of fossil bones being found in the Ghazij Formation, but the first to be reported to the Geological Survey of Pakistan (GSP) was a mammalian dentary recovered from the Tariq Habib coal mine in the Sor Range near Quetta (Figure-1). This specimen was presented by Senator Saifullah Khan Paracha of the H. M. Habibullah Coal Mines Ltd., Quetta, and described as a new genus and species *Quettacyon parachai* (Arif et al., 1997; Gingerich et al., 1997). *Quettacyon* represents an endemic South Asian family of archaic condylarthran mammals closely related to Arctocyonidae. Arctocyonids are best known from the Paleocene of Europe and North America and there is thus a suggestion of Paleocene age, but *Quettacyon* comes from the middle part of the Ghazij Formation well above the Paleocene part of the formation (see below) and arctocyonids extend into the Early Eocene: thus the new find is almost certainly Early Eocene in age. Nevertheless, it is the oldest Cenozoic land mammal known from South Asia.

We pursued discovery of *Quettacyon* by interviewing personnel at the Tariq Habib mine and other coal mines in the Sor Range in early May, 1997, to see if more fossil mammals could be recovered from middle Ghazij coals. These coals are exploited deep in underground mines where it is not feasible to search for fossil mammals, but we hope and expect that more remains will be recovered by miners in the course of their work. We concentrated subsequent efforts on investigation of the overlying upper part of the Ghazij Formation. In this report we describe new fossil mammals discovered in the course of a nine-day field investigation of the upper Ghazij Formation, placing these in tectonic and paleogeographic context (following Gingerich et al., 1997).

Ghazij Stratigraphy

The Ghazij Formation was first named as a 'group' by Oldham (1890), for " a great thickness of grey and olive-green shales, with subsidiary beds of lime and sandstone and, locally, of coal." The name Ghazij is derived from Ghazij Rud, a stream in a valley running from near Dungan Mountain to Spintangi railway station in Balochistan. This is about 45 km northeast of Sibi and 110 km southeast of Quetta. Williams (1959) and Jones et al., (1960) more or less simultaneously initiated current use of the terms Ghazij Formation and Ghazij Shale. Williams gave coordinates of the type section of the formation as 29^0 57.10' N latitude and 68 ^{0} 05.00' E longitude (topographic map 39 C/1). He repeated Oldham's description, regarded the coals as being in the upper part of the formation, and added that along the western margin of the lower Indus Basin the Ghazij

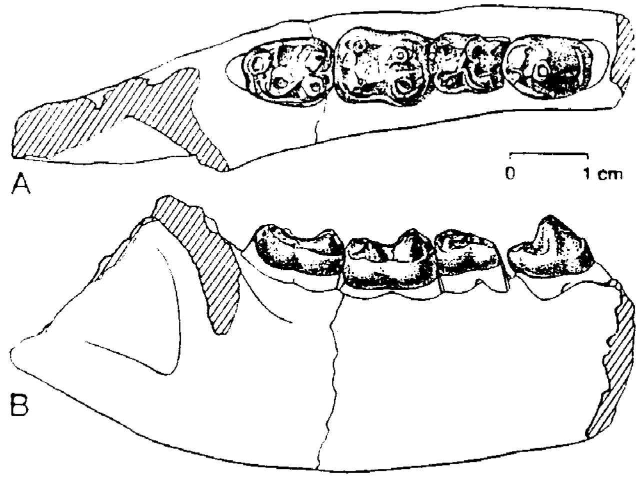

Fig. 1. Quettacyon parachai holotype (GSP-UM 4000). Right dentary with P_4-M_3 in (A) occulusal, and (B) lateral views. Note the robust dentary with deep masseteric fossa, robust but simple crown of P_4, twinned entoconid-hypoconulid and vertrolaterally-sloping posterior cingulid on talonids of M_{1-2}, absence of a paraconid, and presence of low anterior and posterior crests enclosing a distinct fovea on the trigonids of M_{2-3}. Figure is from Arif et al (1997) and Gingerich et al., (1997).

Formation includes a considerable amount of conglomerate in the upper part. Jones et al., (1960) have given the most comprehensive description of the Ghazij Formation, subdividing it first into (A) a "simple" distal facies, marine shales and limestones with subordinate sandstones bordering the Kachhi Plain north and west of Jacobabad, and (B) a 'complex' proximal facies, marine to continental shales with coal and conglomerate farther to the north and west. Here we are concerned only with the 'complex' facies.

Jones et al., (1960, p .425) subdivided the 'complex' Ghazij facies into three stratigraphic units: (1) a lower unit of gray calcareous shale weathering olive-green with subordinate calcareous sandstone in thin sparse layers; (2) a middle unit of green-gray sandstones and coal, associated with dark sulphurous shales, calcareous siltstones, and brown-weathering shelly limestones; and (3) an upper unit of predominantly reddish-weatheirng variegated claystone with a few layers of conglomerate and cross-bedded sandstones. Johnson and Khan (1994) recognised basically the same three units. Jones et al., (1960, p.124) considered the Ghazij Formation to be predominantly Ypresian (Early Eocene) in age, based on larger Foraminifera (*Assilina, Nummulites*, etc.), with the lower part of the formation being Late Paleocene in age in some places.

Jones et al., (1960, p.425) interpreted the coal of the middle Ghazij Formation as having been deposited in a Ghazij delta, formed by a southeastward-flowing Eocene river system. In the tectonic model of the time, this was interpreted as draining a former Hinterland highland formed by the central axis of an offshore geanticline bordering the Indo-Pakistan subcontinent to the north and west. This can be interpreted more plausibly in terms of modern plate tectonics (see below).

Shah (1990) raised the Ghazij Formation of most previous authors to a Ghazij Group encompassing separate Shaheed Ghat, Drug, Toi, and Baska formations (see also Kazmi, 1995). Shah's classification may have merit when the regional distribution of constituent members is better known, but we have followed Reinemund et al., (1985) in grouping all Sor Range facies in a single formation.

Mammals of the Upper Ghazij Formation

The Ghazij Formation is well exposed in the Sor Range south and east of Quetta, where we have recorded six localities yielding mammalian bones and teeth (Figure-2). The map of Reinemund et al., (1985) shows the geology in more detail. Our six localities represent three stratigraphic intervals in the middle and upper Ghazij Formation (Figure-3). Locality GH-1 is the original middle Ghazij Tariq Habib Mine locality that yielded the type specimen

Table-1. Stratigraphic interval, geographic coordinates, and faunal lists for fossil localities mentioned in the text.

Locality	Stratigraphic interval	Latitude Logitude
Locality GH-1	(Tariq Habib Mine) Upper Coal of middle Ghazij *Quettacyon parachai* dentary (GSP-UM 4000)	30^0 10.48' N 67^0 11.70' E
Locality GH-2	Upper part of upper Ghazij Midsection of intermediate metapodial (GSP-UM 4001)	30^0 11.58' N 67^0 10.16' E
Locality GH-3	Lower part of upper Ghazij Intermediate bones and mammalian tooth fragments (GSP-UM 4003)	30^0 10.46' N 67^0 11.64' E
Locality GH-4	Lower part of upper Ghazij Posterior half of tapiroid perissodactyl lower molar (GSP-UM 4004)	30^0 10.46' N 67^0 11.64' E
Locality GH-5	Lower part of upper Ghazij *Sororocyon usmanii* (GSP-UM 4007) *Obashtakaia aeruginis* (GSP-UM 4005, 4006, 4008)	30^0 09.54' N 67^0 12.39' E
Locality GH-6	Lower part of upper Ghazij *Sororyctes ghaznavii* (GSP-UM 4011) Genus and species indet. (GSP-UM 4010)	30^0 03.45' N 67^0 15.28' E

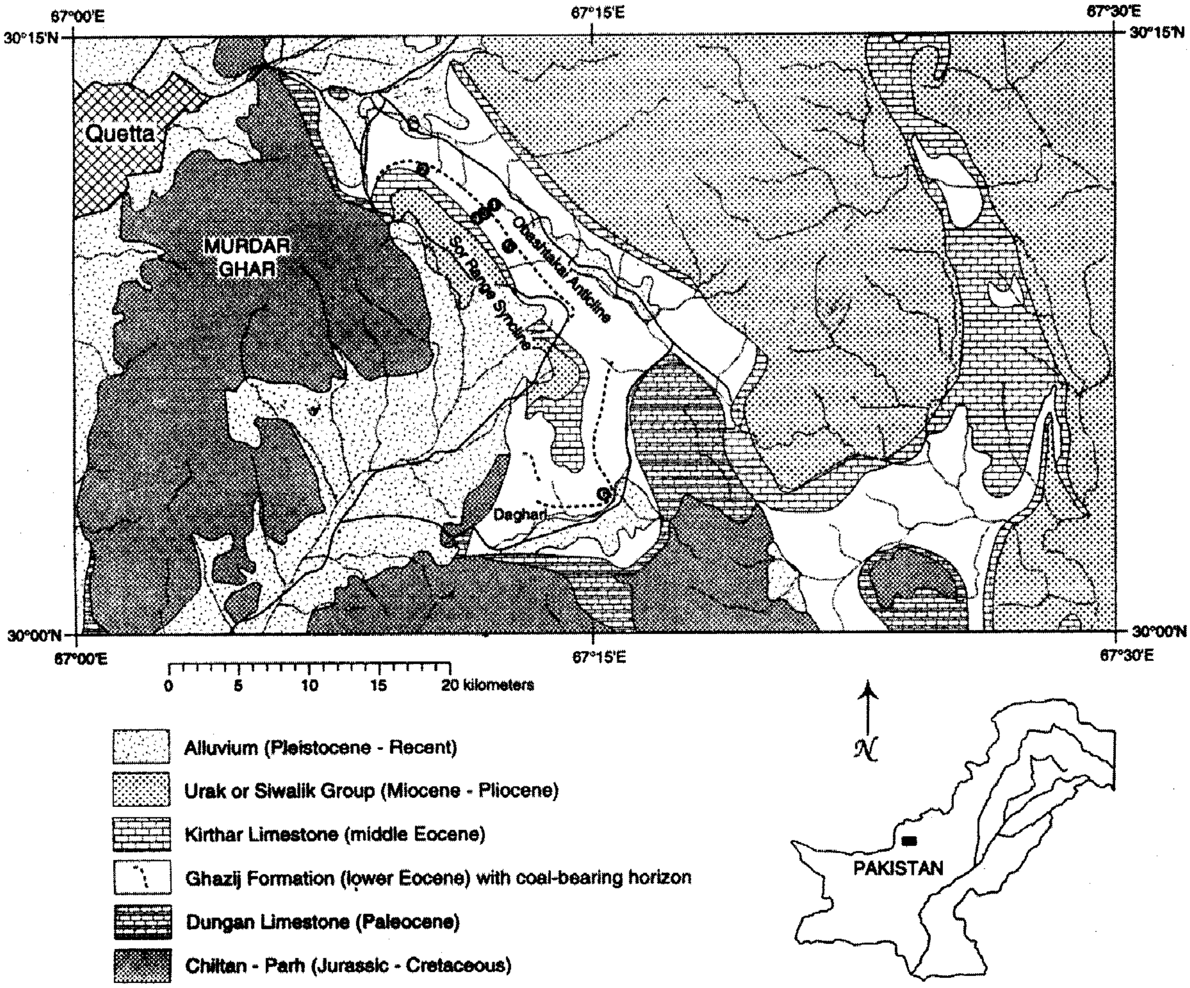

Fig. 2. Geological map of Sor Range coal field east of the city of Quetta in Balochistan. Ghazij Formation sediments (unshaded) are exposed in an anticline window through Middle Eocene Kirthar limestone and Miocene Urak or Siwalik molasse. Localities yielding fossil mammals are numbered 1(middle Ghazij) and 2-6 (upper Ghazij). Geology is from Hunting Survey (Jone et al.,,1960, map sheet 26).

of *Quettacyon parachai.* Localities GH-3 (Figure-4), GH-5 (Figure-5), and GH-6 (Figure-6) are in the lower part of the upper Ghazij Formation, just above the limestone-and-chert alluvial fanglomerate and channel sandstone at the base of the upper Ghazij. Locality GH-4 is in the upper part of the upper Ghazij Formation, just above the thick multistorey channel sandstone in the middle part of the Upper Ghazij section. Geographic coordinates and faunal lists for each locality are given in Table 1.

In addition to *Quettacyon*, three new genera and species of Ghazij Formation mammals are now known.

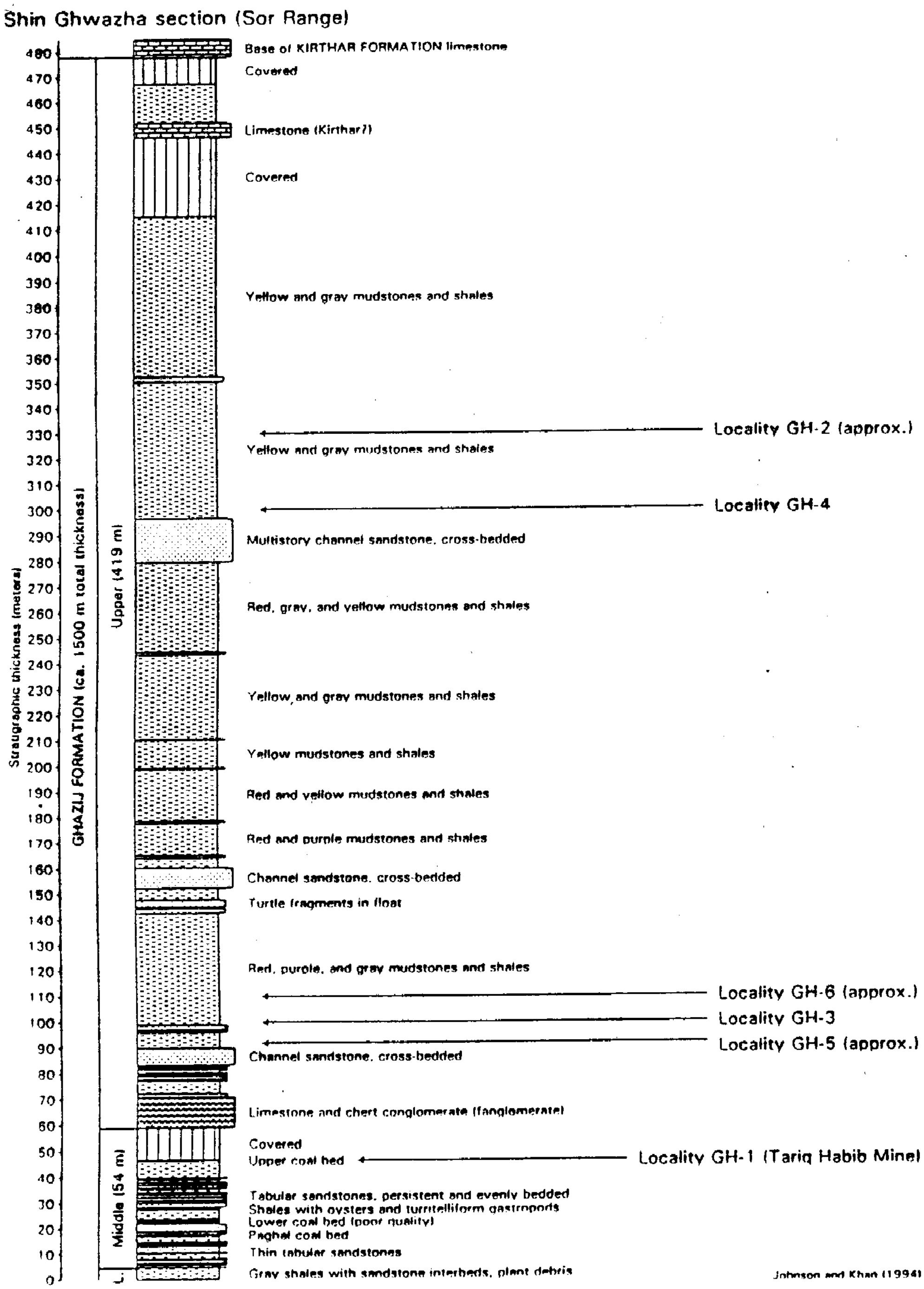

Fig. 3. Stratigraphic section of the middle and upper Ghazij Formation at Shin Ghwazha in the Sor Range. The lower Ghazij (not shown) includes approximately 1000 m of marine shales. The middle Ghazij is about 54 m thick, representing a paludal deltaic alternation of marine and continental facies. The upper Ghazij here is about 419 m thick, with well developed paleosols throughout. Fossil mammals are known from the middle Ghazij upper coal of the Tariq Habib Mine,and from upper Ghazij mudstones near the base of the upper part of the upper Ghazij Formation. Stratigraphic section is reduced from Johnson and Khan (1994). We here follow Jones et al., (1960) in placing the limestone and chert conglomerate at the base of the upper Ghazij Formation rather than at the top of the middle Ghazij. This conglomerate is interpreted as an alluvial fanglomerate reflecting tectonic uplift, and it is thus genetically part of the upper rather than middle Ghazij.

Fig. 4. Photographs of Shin Ghwazha section with lower Ghazij Formation shales at lower left *(lG)* : middle Ghazij shales, sandstones, and coals in the middle *(Mg)*; and variegated red mudstones and shales with interbedded sandstones at upper right *(uG)*. Conglomerate (c) outcrops in centre of photograph, but the overlying sandstone forms the most prominent ridge. Top of Sor Range at right is Kirthar Limestone *(K)*. Road near the base of outcrops leads to Tariq Habib coal mine (locality GH-1) around corner behind central ridge. Locality GH-3 in lower part of upper Ghazij is in right center of photograph above conglomerate and ridge-forming sandstone. Locality GH-4 in upper part of upper Ghazij is out of photograph to right. Coordinates of localities are given in Tale-1. View here is along strike to southeast. Note steep slope of weathering and dip of beds at ca.50^0 to southwest.

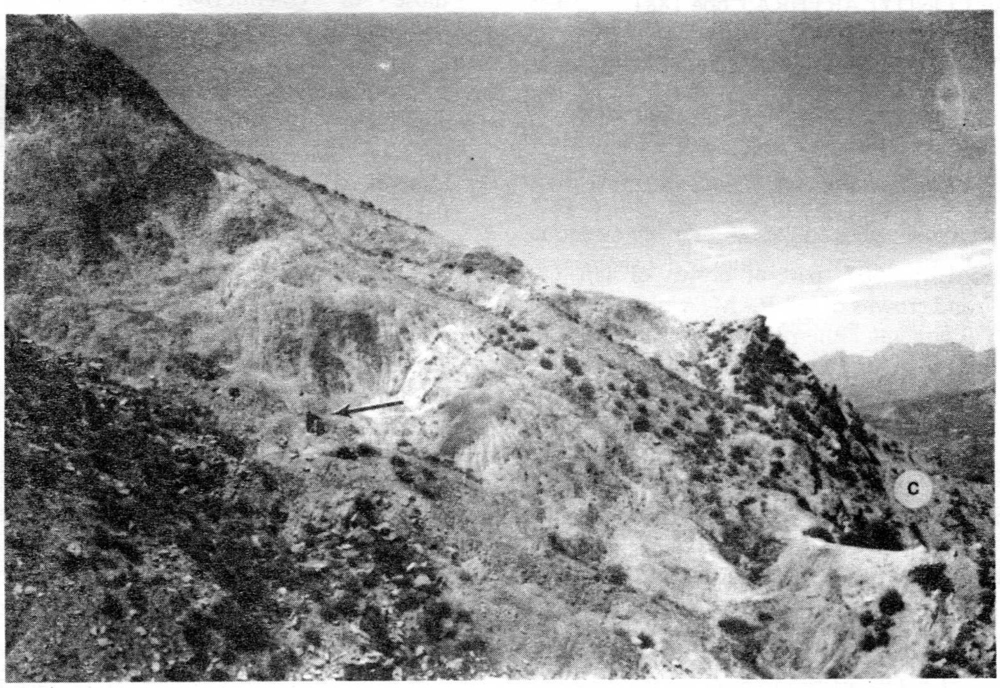

Fig. 5. Photograph of locality GH-5 above Islam Coal Company mine high above adit entrance of Pakistan Mineral Development Corporation mine. Collector (arrow) is working where GSP-UM 4005 was found. Type specimen of *Sororocyon usmanii* was found on a surface of gray mudstone in the same small valley some 6-8 meters up-slope. Conglomerate (c) and ridge forming sandstone are exposed at right of photograph, and overlying strata are variegated red and gray mudstones and thin white sandstones. Coordinates of locality are given in Table-1. View here is along strike to northwest.

Fig. 6. Photograph of locality GH-6 at the Daghari end of the Sor Range syncline. Collectors (arrow) are working in small quarry where GSP-UM 4010 and 4011, including type specimen of *Sororoyctes ghaznavii*, were found. upper Ghazij here lacks conglomerate at the base. Sequence shown is variegated red, purple, yellow, and gray mudstones with thin white sandstones. Mountain at left edge of photograph is Dungan Limestone *(D)*. Coordinates of locality are given in Table 1. View here is to the south, with strata dipping to southwest.

Order CONDYLARTHRA Cope 1881

Family QUETTACYONIDAE Gingerich et al., 1997, new rank

Sororocyon usmanii gen. et sp. nov.
Figure 7

Holotype-GSP-UM 4007, part of crown of left C^1, crown of left M^3, and crowns of left P_3- M_3, with associated bone and tooth fragments. Interproximal facets confirm articulation of left P_3 -M_3 as shown in Figure 7E, F.

Type locality-Holotype was found at locality GH-5 in the lower part of the upper Ghazij Formation (Figure 5; coordinates in Table 1). This locality is just above the Islam Coal Company mine in the Sor Range, Balochistan.

Age and distribution-Middle Ypresian (Early Eocene; see discussion of age below). *Sororocyon usmanii* is known only from the Sor Range of Balochistan (Pakistan).

Diagnosis-Quettacyonid similar in size to *Quettacyon parachai* but differs in having the crown of P_3 contacting P_4 (as evidenced by interproximal wear facets here and lack thereof in *Quettacyon*). The crown of P_4 is shorter anteroposteriorly and broader labiolingually, a ' the apical cusp is lower. Lower molar crowns are similar in length to those of *Quettacyon*, but conspicuously broader labiolingually.

Etymology-*Sor* and Greek *oros*, mountain, plus *kyon*, dog (masc.), a common root for mammalian genera; hence, literally, 'Sor Range dog. Species is named for Mr. A. H. Usmani, Director of Protocol, Geological Survey of Pakistan, whose logistical support in Quetta is much appreciated.

Description-Seven teeth are well preserved in the type specimen (Figure 7). The crown of C^1 lacks both the base and the apex (Figure $7_{A,B}$), but the middle part of the crown shows that there was a deep groove running up the anterior surface of the crown, bordered labially and lingually by distinct ridges, and there was a third ridge running up the posterior surface of the crown. The labial and lingual surfaces of the crown are inflated and convex, giving the crown a distintive cross-section. The C^1 crown, as preserved, measures about 8.7 mm in anteroposterior length and about 6.6 mm in labiolingual width.

M^3 (Figure $7_{C,D}$) is represented by a complete crown with a large protocone and large paracone, a reduced metacone, a distinct paraconule, a small metaconule, but no hypocone. The mesostyle is divided, with the anterior edge joining the postparacrista and anterior part of the buccal cingulum, while the posterior edge joins the premetacrista and posterior buccal cingulum.

The crown of P_3 (Figure $7_{E,F}$) is similar to that of P_4 in *Quettacyon* (Figure $1_{A,B}$) in having a single apical cusp, a crown that narrows anteriorly, and a talonid with one distinct cusp (hypoconid) and just a trace of a smaller more medial cusp (hypoconulid?). P_4 is similar but the apical cusp is lower and blunter, the crown does not narrow appreciably anteriorly, and the talonid has a more distinct hypoconulid cusp. Molars resemble those of *Quettacyon* in general plan, in lacking a paraconid and having a trigonid fovea surrounded by crests, and in having a twinned hypoconulid-entoconid with the hypoconulid positioned near the entoconid on the talonid. Lower molars, while similar in length, are relatively broader than their counterparts in *Quettacyon*.

Measurements of the cheek teeth of *Sororocyon usmanii* are compared to those of *Quettacyon parachai* and *Obashtakaia aeruginis* in Table 2.

Discussion- There is little doubt that *Sororocyon* is closely related to *Quettacyon*, but these genera differ in spacing and shape of premolar teeth, characteristics that commonly distinguish closely related genera. The upper canine is distinctive in cross-section, with a deep groove running up the anterior surface of the crown and a sharp ridge running up the posterior surface of the crown. This is different from the canine form characteristic of arctocyonid condylarths and, together with additional quettacyonine diversity documented here, justifies raising Quettacyoninae to the family level as Quettacyonidae.

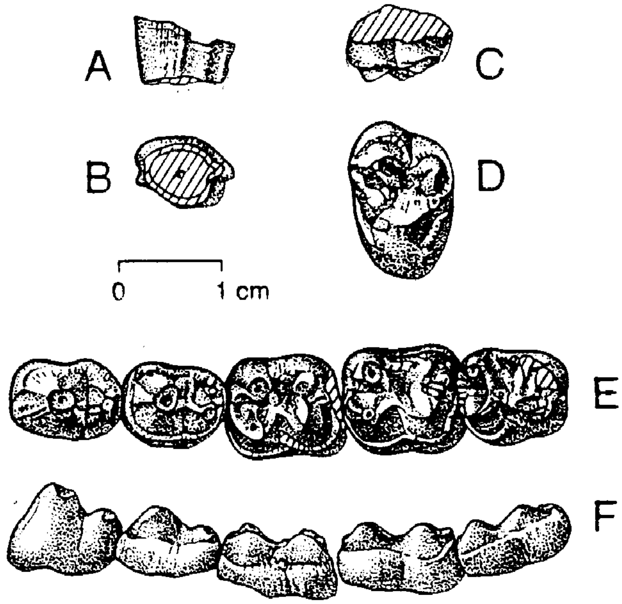

Fig. 7. *Sororocyon usmanii*, GSP-UM 4007 (holotype) from locality GH-5. A,B: part of crown of left C^1 in lateral and occlusal views. C,D: left M^3 in lateral and occlusal views. E,F: left P_3 - M_3 in occlusal and lateral views. Note divided mesostyle on M^3, contact between P_3 and P_4, and relative small and low crown of P_4, all characteristic of *Sororocyon*. Scale is in mm.

Obashtakaia aeruginis gen. et sp. nov.
Figure 8

Holotype -GSP-UM 4006, isolated right P_4

Type locality- The holotype was found at locality GH-5 in the lower part of the upper Ghazij Formation (Figure-5; coordinates in Table 1). This locality is just above the Islam Coal Company mine on a tributary of Obashtakai Nala in the Sor Range, Balochistan.

Referred specimens- Locality GH-5: GSP-UM 4005, left M^3 and right P_3 was associated tooth and bone fragments; and 4008, anterior half of left P_3 and posterior half of left P_3 and P_4.

Age and distribution-Middle Ypresian (Early Eocene; see discussion below). *Obashtakaia aeruginis* is known only from the Sor Range of Balochistan (Pakistan).

Diagnosis- *Quettacyonid* larger than *Quettacyon parachai* and *Sororocyon usmanii*. Differs from *Quettacyon* in having a substantially larger P_4 with a crown that narrows less anteriorly, contacts P_3 and has a larger hypoconulid. Differs from *Sororocyon* in having a substantially larger P_4 with a larger hypoconulid. P_3 narrows anteriorly more than does that of *Sororocyon*.

Etymology- *Obashtakaia* (fem.), named for Obashtakai Nala and for the Obashtakai anticline, where the type and other known specimens were found; *aeruginis*, Latin, copper rust, verdigris, in reference to a distinctively green copper-and-iron oxide coating teeth of one of the specimens when found.

Description- The holotype is an isolated crown of P_4. Two additional whole teeth, crowns of M^3 and P_3 are referred from the type locality.

The type (Figure $8_{A,B}$) is similar to P_4s known in *Quettacyon* and *Sororocyon* in having a large, inflated, and moderately high central cusp or protoconid. This was originally more sharply pointed, but is now blunted by occlusal wear. Enamel at the apex is perforated. There is a weak anterior clingulid on P_4 that continues around the buccal side of the tooth to the talonid, but there is no lingual cingulid. There is a very weak crest running down the back of the protoconid to join a low rounded talonid cusp or hypoconid, and there is in addition a well developed posterolingual cusp (hypoconulid?) on the talonid. There is a weak lingual cingulid enclosing a slight depression on the lingual half of the talonid, but the buccal

Table-2. Measurement of teeth in type and referred specimens of the quettacyonids *Quettacyon parachai, Sororocyon usmanii,* and *Obashtakaia aeruginis* from the Sor Range of Balochistan. Measurements are crown length (CrL), crown width (CrW), trigonid width (TriW), and talonid width (TalW). Estimates are marked with asterisks. All measurements are in mm.

Tooth position	Mea-sure-ment	*Quettacyon parachai* GSP-UM 4000	*Sororocyon usmanii* GSP-UM 4007	*Obashtakaia aeruginis* GSP-UM 4005, 4006
Upper Teeth				
M^3	CrL	-	9.3	10.3
	CrW	-	14.0	14.8
Lower Teeth				
P_3	CrL	-	10.1	10.6
	CrW	-	7.5	7.9
P_4	CrL	10.4	9.2	12.2
	CrW	8.2	7.8	9.2
M_1	CrL	9.4*	10.9	-
	TriW	8.0*	9.7	-
	TalW	8.3	9.8	-
M_2	CrL	11.1	11.0	-
	TriW	9.9	10.5	-
	TalW	9.7	10.3	-
M_3	CrL	12.0	11.1	-
	TriW	9.0	9.1	-
	TalW	7.9	8.1	-

side of the talonid slopes more and has an even weaker cingulid and less distinct depression. Unworn enamel on the crown is slightly crenulated, with crenulations running vertically. The preprotocristid is slightly raised, running down the anterior surface of the protoconid. The only conspicuous wear facet is that on the apex of the protoconid. There is a faint interproximal contact wear facet on the anterior cingulid, showing P_3 and P_4 were in contact in life.

The referred P_3 (Figure 8 $_{C,D}$) is from an individual slightly older than the type, as indicated by heavier occlusal wear. The crown resembles that of *Sororocyon* but is larger and narrower anteriorly. The protoconid and hypoconid both have enamel perforated by wear, and they are connected by a worn surface in the shape of a figure-8 that encircles both. The hypoconulid is smaller than the hypoconid; it is bulbous and closely appressed to the hypoconid. There is no anterior interproximal facet on P_3 for contact with P_2, but the posterior facet for contact with P_4 is large.

M^3 (Figure $8_{E,F}$) is a little larger than that of *Sororocyon usmanii*, which it resembles closely. It is more worn and a little less well preserved, and such differences as appear, other than size, may be attributed to wear or preservation.

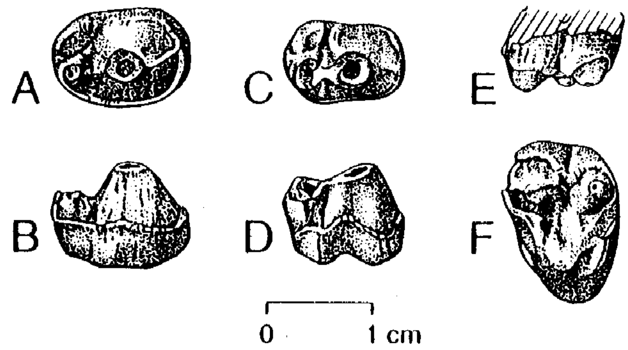

Fig. 8. *Obashtakaia aeruginis*. A,B: right P_4, GSP-UM 4006 (holotype) from locality GH-5, in occlusal and lateral views. C, D: right P_3, GSP-UM 4005 from locality GH-5, in occlusal and lateral views. E,F: left M^3, GSP-UM 4005 from locality GH-5, in lateral and occlusal views. Scale is in mm.

Measurements of the check teeth of *Obashtakaia aeruginis* are compared to those of *Quettacyon parachai* and *Sororocyon usmanii* in Table 2.

Discussion- Here again, there is little doubt that *Obashtakaia* is closely related to *Quettacyon* and *Sororocyon*, but these genera differ in the spacing and shape of premolar teeth, characteristics that commonly distinguish closely related genera. Discovery of *Obashtakaia aeruginis* and *Sororocyon usmanii* in addition to *Quettacyon parachai* indicates that there was a substantial diversification of *Quettacyon*-like condylarths during and late Ghazij time. Of these, *Obashtakaia* appears to have been the most robust with the most powerful mastication, while *Sororocyon* appears to have been the least robust with the least powerful mastication.

Order indet.

Family SORORYCTIDAE, new family

Sororyctes ghaznavii gen. et sp. nov.
Figures 9-10

Holotype-Canine or postcanine in GSP-UM 4011 interpreted as right lower (Figure 9_{F-H}), found with two additional canines or postcanine teeth interpreted as left and right uppers, and the midshaft and entepicondyle of a humerus.

Type locality- The holotype was found at locality GH-6 in the lower part of the upper Ghazij Formation (Figure 6; coordinates in Table 1). This locality is opposite the village of Jamadar Bata Khan on a tributary of Obashtakai Nala near the southeast end of the Sor Range, Pakistan.

Age and distribution- Middle Ypresian (Early Eocene; see discussion below). *Sororyctes ghaznavii* is known only from the Sor Range, Balochistan.

Diagnosis- Canines or postcanine teeth differ from those of quettacyonids in being more massive and elliptical in cross-section, with occlusal wear confined to a single curved surface. Humerus is incomplete but appears to have been short and broad, with a large deltopectoral crest, an unusually broad supinator crest, and a very large entepicondyle. These dental and humeral characteristics distinguish *Sororyctidae* from Asian Ernanodontidae (see below) and other known families.

Etymology- *Sor*, Sor Range, plus Greek *oryktes* (masc.), digger. Species is named for Dr.Muhammad Ishaq Ghaznavi of the Geological Survey of Pakistan, Islamabad, whose help and encouragement in the field yielded two of the three known teeth of this distinctive mammal.,

Description- Three canine or postcanine teeth are known; these are all relatively large teeth with massive single roots and small, simple, rounded crowns. There are two sizes of canine or postcanine teeth: the one smaller tooth is complete and measures 11.6 by 7.7 mm at the base of the crown and 35.6 mm in total crown-plus-root length (of which about 11.5 mm is crown and 24.1 mm is root); two larger teeth are broken (one in life and the other due to weathering) and measure 13.4 by 8.3 and 13.3 by 8.4 mm at the base of the crown. The first of the larger teeth is 32.1 mm long as preserved (of which about 10 mm of this is crown and 22.1 mm is root). The second of the larger teeth has a root about 22 mm long and presumably had a 10 mm crown. The two larger canines or postcanines appear to be antimeres. Striated wear is found in the same position on what is assumed to be the anterolingual surface of each larger tooth, and for this reason they are interpreted as uppers. Striated wear is found on the posterolabial surface of the smaller tooth and for this reason it is interpreted as a lower.

Both upper canines or postcanines have a long, single root that is nearly uniform in thickness with only a slight taper toward the base of the root. The crown of the more complete right tooth (Figure 9_{A-C}) is blunted by wear. No trace of enamel remains, and the pulp cavity is exposed in a small circular opening near the apex of the crown. Much of the surficial dentine on the anterior and middle parts of the labial surface of the crown must have spalled or split off in life. The apical edge of this spalled surface is smoothly rounded by subsequent wear. The middle part of the spalled surface has distinctive long and very narrow longitudinal grooves running parallel to the long axis of the tooth. These end in a sharply broken edge near the base of crown, again slightly rounded by wear, reminiscent of the transverse fractures resulting when a chisel is used to shave green wood. Steps in the spalled surface suggest that there may have been three distinct episodes of breakage. The only other detail on the labial surface worthy of note is a set of longitudinal grooves on the root, near its base, for insertion of connective tissue anchoring the tooth in its alveolus. The anterolingual surface of the right upper canine or postcanine has a narrow curved edge that is distinctly striated, with the direction of striations being approximately vertical., The surface of the crown above this is abraded, and the posterolingual surface of the tooth has a split or spalled area reminiscent of spalling on the labial surface.

The left upper canine or postcanine antimere (Figure 9_{D-E}) lacks the tip of the crown, has no enamel, and does not show the same degree of spalling. The labial surface is interesting in preserving what appears to be the trace of the dentino-enamel junction (dashed in Figures 9_{D-E}) fairly high on the root. This can be traced around the crown and falls nearly to the broken edge of the crown on the lingual surface of the tooth. The lingual surface has the same band of striated occlusal wear seen on the right upper canine or postcanine.

The right lower canine or postcanine (Figure 9_{F-H}) has a narrow root and the root is distinctly curved, with the crown curving outward relative to the base of the root. The convex lingual surface of the crown is almost entirely abraded by wear, but a small area of thin enamel remains at the posterolingual corner. The posterolabial surface of the crown has a curved and striated wear facet that matches the striated anterolingual facet of the right upper canine or postcanine exactly. There is little question that these occluded in life as shown in Figure 9_I As in the right upper canine or postcanine, there is a conspicuous area of spalled dentine on the anterolabial surface, with the same rounded distal edge, longitudinally-grooved middle surface, and gouged proximal edge. Finally, there is a circular depression at the anterior edge of the crown that suggest chemical erosion.

A humeral shaft with a separate mediodistal or epicondylar portion were found with these teeth. Combining these (Figure-10), we infer that the humerus had
an unusually large deltopectoral crest, broad supinator crest, and unusually large entepicondyle, with a large entepicondylar foramen. The humeral shaft, as preserved, is 67 mm long, and anteroposterior and mediolateral midshaft diameters are approximately 26.5 and 24.7 mm, respectively. The distal end of the humerus measures 40 mm in breadth across the supinator crest. The entepicondylar portion of the humerus was found separately from the shaft, and the two parts no longer contact. Here the entepicondyle projects some 25 mm from the ulnar flange, and the latter measures about 24.2 mm anteroposteriorly.

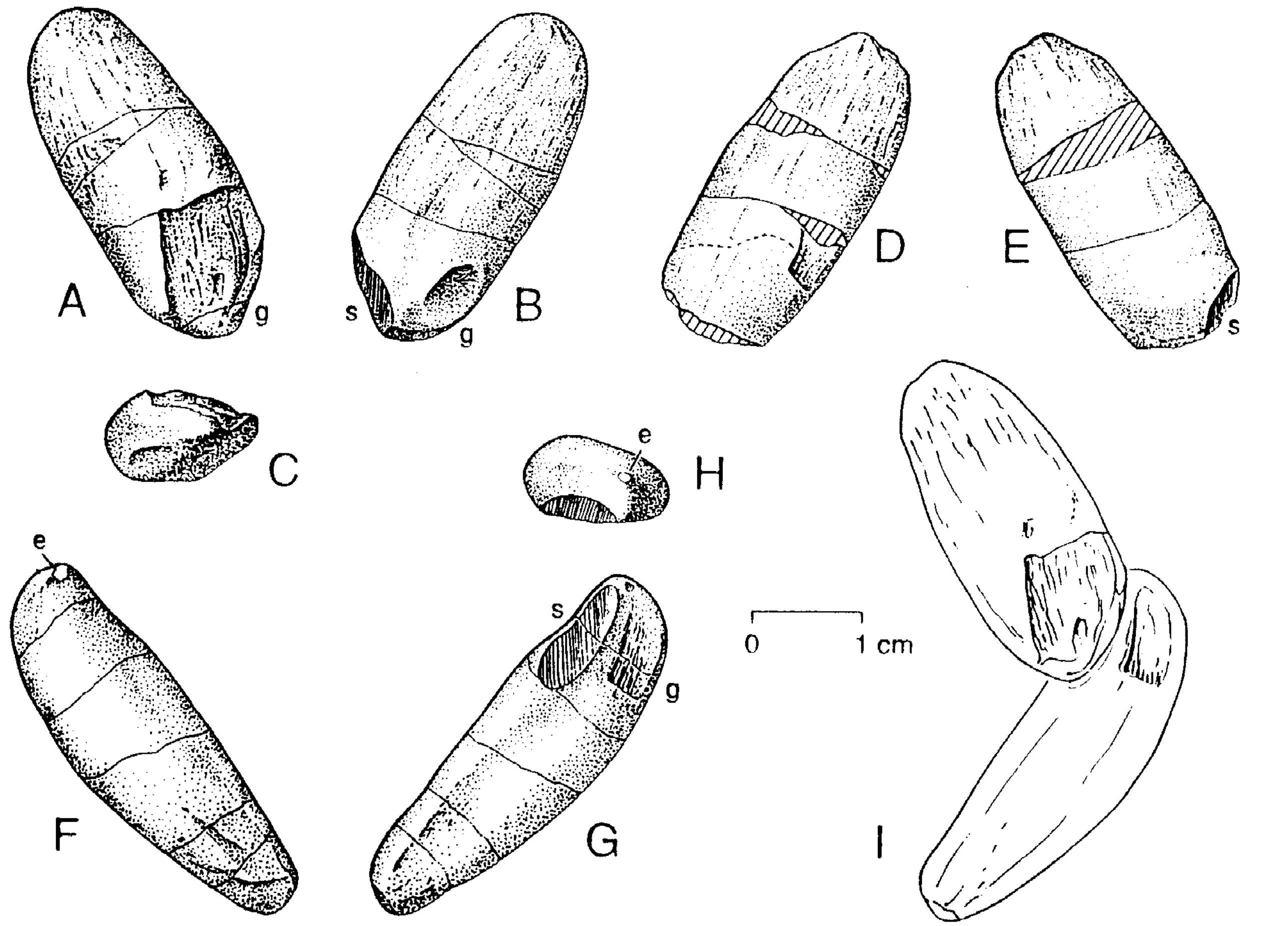

Fig. 9. *Sororoyctes ghaznavii,* GSP-UM 4011 from locality GH-6. A-C: right upper canine or postcanine in labial , lingual, and occlusal views. D-E: left upper canine or postcanine preserving what appears to be the trace of the original dentino-enamel junction (dashed), in labial and lingual views. F-H: right lower canine or postcanine (holotype) in lingual, labial and occlusal views. I: occlusion of right upper and lower canines or postcanines indicated by matching pattern of curved and striated wear facets, in labial view. Note restricted remnant of enamel on crown of lower canine or postcanine (*e*), and distinct patterns of striated occlusal wear (*s*) and grooved spalling of dentine (*g*) in addition to overall abrasion. Note too that spalling of dentine on right upper canine or postcanine continues across crown of occluding right lower canine or postcanine, with no evidence and little possibility of tooth-on-tooth occlusion. Scale is in mm.

Discussion- Specimen at the type locality were divided by size when they were collected, with similar elements grouped as GSP-UM 4010 and larger elements grouped as GSP-UM 4011. All were found together, and if there were no differences in size all would be assumed to represent *Sororyctes ghaznavii.* This could conceivably still be true, but the animal would be very unusual in having a large humerus and a seemingly impossibly small middle phalanx (see description of GSP-UM 4010 as genus and species indet. below).

The large, simple, blunt crowns of all of the known canine or postcanine teeth of *Sororyctes ghaznavii* contrast greatly with the more delicate canines of *Sororocyon* (e.g., Figure 7A-B), which are smaller and have a more complex morphology of occlusal ridges and grooves. Abrasion covers all exposed surfaces (except the striated surfaces caused by direct tooth-on-tooth conclusion), showing that the teeth were important for food acquisition, and the food ingested appears to have been covered by earth or some other abrasive. The distinctive features of the humerus, as preserved: a large deltopectoral crest, a broad supinator crest, and a very large entepicondyle, taken together, are characteristic of digging mammals. Thus we interpret *Sororcytes* a digging mammal, and abraded canine or postcanine teeth suggest that it was digging for food as well as, possibly, for shelter.

Discovery of a digging mammal in the early Eocene of South Asia invites comparison with *Ernanodon antelios*, an ernanodontid "edentate" from the late Paleocene of China (Ting, 1979). Greater size of canine or postcanine teeth and

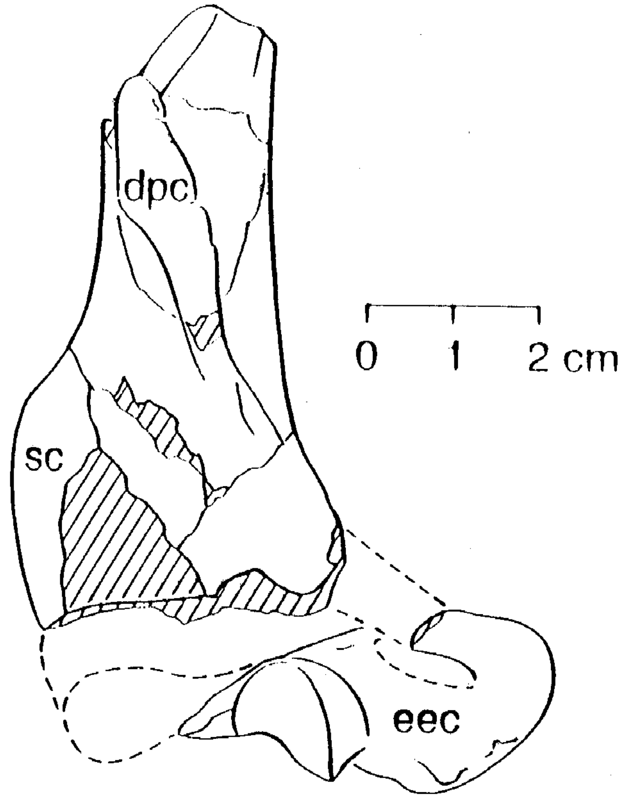

Fig. 10. Humerus referred to *Sororyctes ghaznavii*, GSP-UM 4011 from locality GH-6. Note large deltopectoral crest (*dpc*), broad supinator crest (*sc*), and very large entepicondyle (*eec*), together indicative of digging adaptation. Scale is in mm.

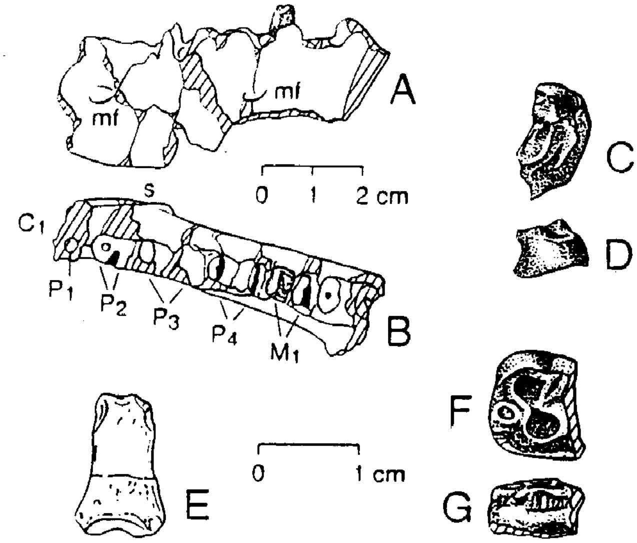

Fig. 11. Sor Range mammals known from fragmentary remains. A-E: indeterminate genus and species of an indeterminate order and family, GSP-UM 1010 from locality GH-5; including (A,B) left dentary with alveoli for C_1. P_{1-4}, and M_{1-2} in occlussal and lateral views, (C,D) talonid of left M_3 in occlusal and lateral views, and (E) middle phalanx. F-G: talonid of right M_2 (?) of tapiroid perissodactyle, GSP-UM 4004 from locality GH-4, in occlusal and lateral views. Note massive but unfused symphysis (*s*) of indeterminate genus and species in A; position of mental foramina (*mf*) in B; and simple, almost lophodont talonid on M_3 in C; and latter two characteristics indicate that this taxon is not a quettacyonid. Talonid in F-G is heavily worn but resembles closely that of tapiroid perissodactyls (e.g., North American *Homogalax)* at a similar stage of wear. Scale is in mm.

greater size of preserved parts of the humerus indicate that *Sororyctes* was a larger mammal., Radinsky and Ting (1984) interpreted *Ernanodon* as an ant-or-termite-eating mammal, and it is possible that *Sororyctes* too was myrmecophagous. It is also possible that *Sororyctes* was more tillodont-like and rhizophagous, feeding more on roots and tubers (Gingerich and Gunnell, 1979).

Family indet.

Genus and species indet.
Figure 11_{A-E}

Referred specimen- Locality GH-6: GSP-UM 4010, left dentary with part of a very worn trigonid of M_1 in place, talonid of M_3 associated; cervical, thoracic, sacral, and caudal vertebrae, additional worn teeth, and small phalanx included in GSP-UM 4010 may or may not be associated with the dentary.

Description- The dentary (Figure $11_{A,B}$) is massive like that of *Quettacyon parachai* (Figure $11_{A,B}$), but it appears to have been even deeper. The symphysis is elliptical in outline, with the lesser (more vertical) axis of the ellipse measuring about 16 mm. The greater axis cannot be measured because the anterior part of the dentary is missing. There are two mental foramina on the labial surface of the dentary, one opening below the anterior root of P_2 and other opening below the posterior root of P_4.

Alveoli in the dentary show that the canine had a root extending about 20 mm below the tops of other alveoli; P_1 was small and evidently single-rooted, with short alveoli separating it from C_1 in front and P_2 behind; and the remaining cheek teeth were all crowded together. P_3 and P_4 each had crowns about 12 mm long anteroposteriorly, while the crown of M_1 and M_2 were about 10 mm long. All preserved teeth are heavily worn. The most informative are the worn trigonid of M_1 in place is the dentary (Figure $11_{A,B}$ and the worn talonid of M_3 found separately but evidently sheared from the dentary by fracturing during small scale faulting after burial (Figure 11 $_{C,D}$). The former suggests that M_1 had a relatively narrow crown, while the latter suggests that M_3 may have been bilophodont with a small, low, anteroposteriorly-oriented crest in the position of the hypoconulid.

GSP-UM 4010 includes fragmentary cervical, thoracic, sacral, and caudal vertebrae. The best-preserved cervical vertebrae has a centrum measuring 14.5 mm in length, 14 mm in width, and 8.4 mm in height. The centrum of an anterior thoracic vertebrae measures 13.7 mm in length, 14.4 mm in width, 11.6 mm in height.

Discussion- Parts of GSP-UM 4010 (left dentary and most worn teeth, vertebral fragments, and middle phalanx) and 4011 (one large canine or postcanine tooth and midshaft of a large humerus) were found together on the surface of the outcrop within a small area not more than half a meter in diameter. Quarrying revealed one additional small tooth, two large canine or postcanine teeth, several good cervical and other vertebrae, a sacrum, and the entepicondylar process of the large humerus). These were sorted by size in the field, given two field numbers, and later separate museum numbers. It is possible that all represent one very unusual skeleton, it is more likely that large and small animals are presented, and it is of course possible that more than two animals are represented.

Order PERISSODACTYLA Owen, 1848

Superfamily TAPIROIDEA Gill, 1872

Family ? ISECTOLOPHIDAE Peterson, 1919

Gen. et sp. indet.
Figure 11$_{F,G}$

Referred specimen- Locality GH-4; GSP-UM 4004, talonid of right M_2 (?). This locality is in the upper part of the upper Ghazij in the Shin Ghwazha stratigraphic section (Figure 4; coordinates in Table 1), high above the Tariq Habib coal mine in the Sor Range, Balochistan.

Description- GSP-UM 4004 is the talonid of a right lower molar, probably M_2. It is heavily worn, but shows the essential characteristics of an early Eocene tapiroid. The hypoconid and entoconid are perforated by wear but were formerly connected to form an almost transverse hypolophid, of which confluent exposures of cupped dentine remain. The hypoconulid is low and it too is perforated by wear to expose a small isolated area of cupped dentine. The hypoconulid joins the hypoconid rather than the entoconid, from which it is separated by a faint fold in the surface enamel. Finally, there is a distinct buccal cingulid extending the length of the talonid.

The talonid of M_2 (?) measures 10.3 mm in breadth.

Discussion- This talonid from the upper part of the upper Ghazij Formation is very similar to comparably-worn molar talonids of the common North American early Eocene isectolophid *Homogalax protapirinus*. Isectolophids are common element in the still poorly known early Eocene mammalian faunas of Asia and South Asia. *Homogalax wutuensis* was described from Wutu (Shandong) by Zhou and Li (1965). *Sastrilophus dehmi* was described from Kalakot (Kashmir) by Sahni and Khare (1972). *Homogalax namadicus* was described from Tsagan-Khushu (Omono Gobi) by Dashzeveg (1979). Cf. *Homogalax* was listed from Barbora (North West Frontier) by Russell and Zhai (1987). Isectolophidae gen. et. sp. indet. was described from Chorlakki (North West Frontier) by Thewissen et al., (1987). Most recently, *Orientolophus hengdongensis* was described from Hengdong (Hunan) by Ting (1993). The Ghazij tooth resembles *Homogalax wutuensis* and *H. namadicus* in size. It is substantially larger than teeth of South Asian isectolophids known previously.

While fragmentary, making attribution to Isectolophidae uncertain, there is little doubt that GSP-UM 4004 is the talonid of a perissodactyl molar. The presence of perissodactyls in the upper part of the upper Ghazij Formation is important because it indicates faunal interchange not only with the Indian Subcontinent but also more broadly with Central Asia during the Middle to Late Early Eocene (see below).

Age of the Upper Ghazij Formation Yielding Qettacyonids

Nuttal (1925), Cox (1931), Williams (1959), and Jones et al., (1960) reported that fossils collected from the Ghazij Formation, including those from the coal-bearing middle part, are Early Eocene in age, while the lower part of the Ghazij Formation contains Paleocene fossils. This assessment was corroborated by Khan and Fritz (1966) and Fritz and Khan (1975), who made a detailed study of planktonic and benthonic foraminiferans in the Sor Range-Deghari coal fields and reported the age of the coal-bearing part of the middle Ghazij to be Early Eocene. Their conclusion was based on the presence of planktonic foraminiferans *Globorotalia formosa* var. *gracillis* Bolli, *G. quetra* Bolli, *G. rex* Martin, and *G.wilcoxensis* Cushman and Ponton in the lower Ghazij. According to Toumarkine and Luterbacher (1985) the first three of these species are now placed in *Morozovella* as *M. formosa gracillis* (Bolli, 1957), *M. quetra* (Bolli, 1957), and *M. subbotinae* (Morozova, 1929), respectively, and the fourth is now placed in *Pseudohastigerina* as *P. wilcoxensis* (Cushman and Ponton, 1932). Toumarkine and Luterbacher (1985) give biostratigraphic ranges for the four species as spanning Paleogene planktonic foraminiferal zones P6A through P7, end-P5 or P6A through P9, end-P5 or P6A through P8, and P6A through P12, respectively.

Coal-bearing horizons in the Sor Range-Deghari coal fields cannot be older than the oldest interval of overlap of these biostratigraphic ranges, that is, cannot be older than P6A. P6A is latest Thanetian (latest Paleocene) whereas P6B is Early Ypresian (earliest Eocene; Berggren and Miller, 1988). It is thus conceivable that the coal-bearing part of the Ghazij Formation in the Sor Range is latest Paleocene in age, however the Early Eocene interpretation of Khan and Fritz (1966) and Fritz and Khan (1975) is more likely when the time required for deposition of 500m of shallow marine strata separating planktonic forams (if these are P6A in age) from overlying coals, and the preponderance of overlap of the foraminiferal species ranges in P6B-P7 are considered.

The Ghazij Formation of the Sor Range is overlain conformably or paraconformably by the Early Middle Eocene Spintangi limestone of the Kirthar Formation or Group (Haque, 1960; Fritz and Khan, 1975; Johnson and Khan, 1994). If we consider the middle-and-upper parts of the Ghazij Formation to represent planktonic foraminiferal biochrons P6B or P7 through P9 and assume sediment to have accumulated at an approximately uniform rate, the presence of 500m of upper Ghazij mudstone and graywackes above the coal-bearing part of the formation indicates that the coals of the middle Ghazij were deposited in Early or Middle Ypresian time and sandstones and mudstones of the immediately overlying lower part of the upper Ghazij were probably deposited in Middle Ypresian time. This means that the fauna from the lower part of the upper Ghazij Formation described here is probably on the order of 1-3 million years older than the Kuldana-upper Subathu mammalian fauna found in the North-West Frontier and Punjab provinces of Pakistan, in Kashmir, and in India.

Paleogeographic and Tectonic Setting

The Ghazij Formation, as stated above, was named by Oldham (1890, p.95) to distinguish "a great thickness of grey and olive-green shales, with subsidiary beds of limes and sandstone and, locally, coal" in what is now Balochistan Province, Pakistan. Oldham noted many fossil shells, all of shallow-water type, associated with the coals and sandstone, which, taken together, he interpreted as indicating deposition "in the immediate proximity of land".

Jones et al., (1960) divided the Ghazij into lower, middle, and upper parts, with the middle part including the coal-bearing and conglomeratic strata of Balochistan. The lower part of the Ghazij Formation includes some 1000m of green and gray-weathering calcareous shales, while the upper part of the formation includes some 500m of red-banded calcareous clays and clay shales with lenticular sandstones (see also Johnson and Khan, 1994). Jone et al., (1960, p.45) recognized that changing depositional environments and fining grain size indicate eastward and southeastward transport of Ghazij sediments from a 'hinterland craton" source to the west and northwest. Kazmi (1962) characterised Ghazij sediments as a thick sequence of rhythmic or cyclic mudstones interbedded with graywackes, and regarded the whole as having been rapidly deposited on deltas in a slowly subsiding basin while adjacent land was subjected to continued uplift. He emphasized that rock fragments in the graywackes are largely derived from basic or ultrabasic intrusive rocks, but did not discuss their source. Kazi (1968) studied plaeocurrent indicators in the Ghazij Formation, found northwest-to-southeast flow directions, and affirmed that the principal source of sediment lay off the Indo-Pakistan subcontinent to the northwest. Kassi et al., (1987) suggested west-to-east flow, but results of Waheed and Wells (1990) support those of Kazi.

Development of a sophisticated understanding of plate tectonics in the past 25 years facilitates interpretation of paleogeography in this area, making an offshore source of Ghazij sediment more plausible than it was when first proposed. The northward movement of Indo-Pakistan relative to Africa, Europe, and Central Asia is now well documented from many independent lines of evidence. Indo-Pakistan, starting as a part of Gondwana, was long separated from Central Asia by an ancient sea called Tethys. However, Tethys is not one sea but a succession of seas with a complex history. Continental microplates have crossed it repeatedly from south to north (first separating when rifting from Gondwana and joining together again when accreting to Europe and/or Asia). In the area of interest here, the Gelmend-Argandab and Kabul microplates of Afghanistan, and the Katawaz microplate of Pakistan rifted from Indo-Pakistan with the opening of Neo-Tethys and were later rejoined by the rest of Indo-Pakistan after it rifted from Gondwana (Kazmin et al., 1986; Knipper et al., 1986). Smaller blocks were involved as well, as were island arcs and arc-trench systems (Dercourt et al., 1986). The Kohistan-Ladakh-East Nuristan island arcs, for examples, were sutured to southern Asia in the mid-Cretaceous (Treloar and Izatt, 1993).

The latest Paleocene-Early Eocene paleogeographic setting of the oceanic island chain shedding Ghazij Formation sediments, here called the Ghazij Islands, is reconstructed in Figure 12A, combining information from maps in Gaetani and Garzanti (1991), Bannert et al., (1992), and Smith et al., (1994). In a more detailed view, in Figure 12B, the Ghazij Islands 'hinterland' source is

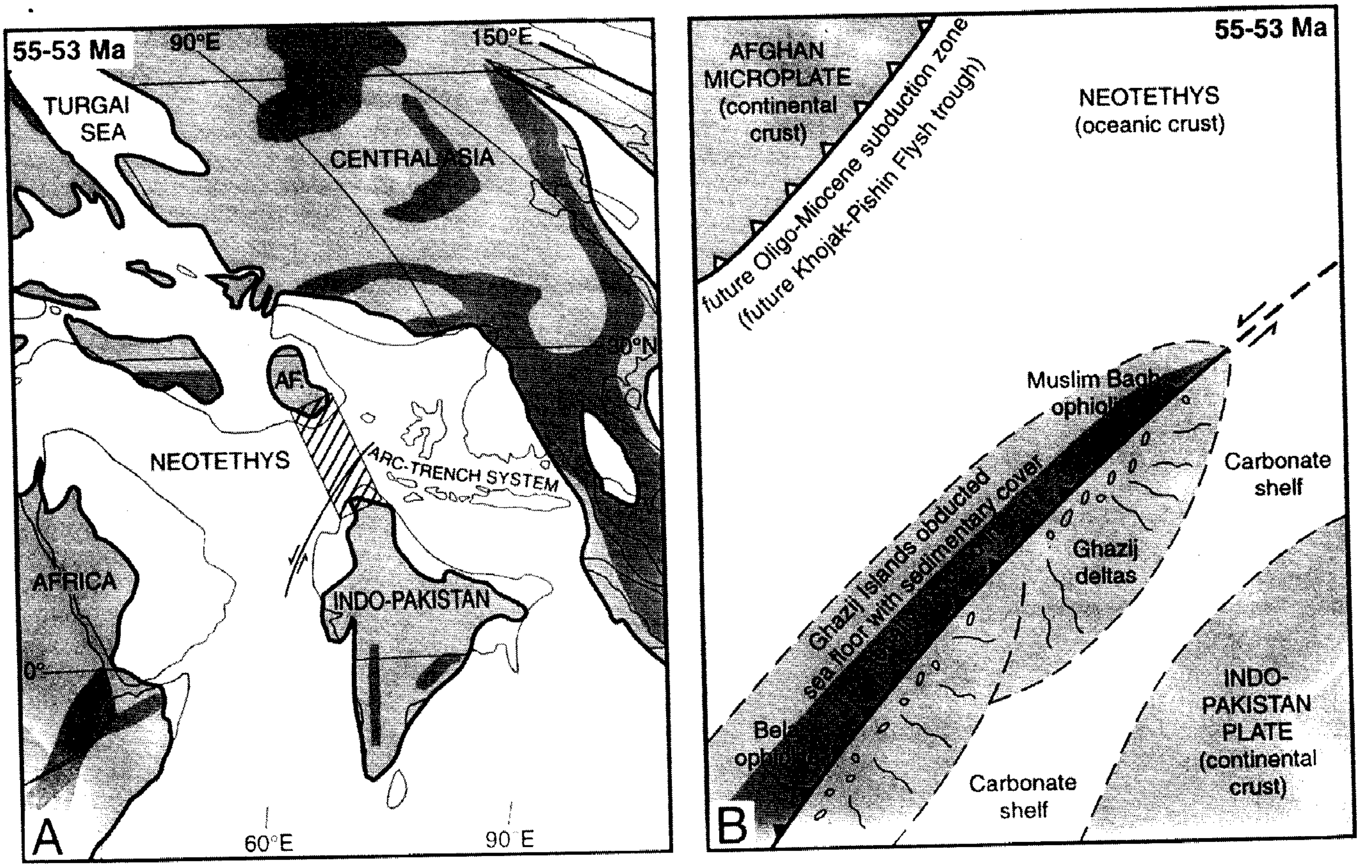

Fig. 12. Tectonic setting of Ghazij Formation deltas prograding eastward toward Indo-Pakistan from an island chain of obducted oceanic crust located offshore in Neo-Tethys. (A) Regional setting of Indo-Pakistan at the beginning of the Eocene (ca.55-53 Ma) with paleogeography reconstructed from Gaetani and Garzanti (1991), Bannert et al., (1992), and Smith et al., (1994). Obduction probably involved one side of a sea-floor side-slip fault (arrows show relative motion) overriding the other. (B) Likely conformation of the subaerially-exposed Ghazij Islands chain shedding sediment eastward into the marine foreland basin bordering Indo-Pakistan. Obduction is shown as involving predominantly side-slip motion, with the western side of the fault (serratededge) overriding the eastern side. Deltaic sediments include ophiolite-derived mafic and ultramafic graywackes and mudstones, and pre-Eocene sedimentary rocks (principally Chiltan, Parh, and Dungan formations) were eroded and redeposited as well. Note great separation of the Ghazij Islands chain from the Afghan microplate across Neo-Tehtys to the northwest (foreshortened here from inset box in A). Discovery of endemic Quettacyon, Sororocyon, Obashtakaia, and Sororyctes shows that the Ghazij Islands chain was inhabited by mammals, but it may have been isolated at times from the Indo-Pakistan subcontinent.

shown, incorporating recent observations of Johnson et al., (1993), Beck et al., (1995), Pivnik and Wells (1996), Garzanti et al., (1996), and Rowley (1996). The western edge of the Ghazij Formation with its poorly-transportable limestone and chert conglomeratic facies is distantly separated from the Afghan microplate to the northwest, which indicates both that the Afghan plate cannot have been the source of Ghazij sediment and that Neo-Tethys cannot have been closed here in the Paleocene (contradicting arguments of Beck et al., 1995; see Rowley, 1996, for discussion). We interpret the Ghazij Formation to have been shed eastward during obduction of oceanic crust overriding a major north-south-side-slip fault in Neo-Ththys. This is consistent with the mafic to ultramafic component in the sandstones documented by Kazmi (1962), which rules out both felsic or andesite-rich island arc and quartz-rich continental sources. Limestone and chert cobbles in the massive conglomerate overlying middle Ghazij coals are interpreted to have been reworked during uplift from the Jurassic Chiltan Limestone, Cretaceous Parh Limestone, and Paleocene Dungan Formation. The time of emplacement of Bela and Muslim Bagh ophiolites is well constrained as being Paleocene-to-Early Eocene (Allemann, 1979; Ahmad and Abbas, 1979) and it seems reasonable to regard Ghazij Formation deltaic sediments as a detrital record of this emplacement.

Endemism and Cosmopolitanism in Upper Ghazij Mammals

When *Quettacyon* was described from the middle Ghazij Formation we considered its possible significance of the origin of the Eocene mammalian fauna of Indo-Pakistan (Gingerich et al., 1997). Three additional genera, *Sororocyon*, *Obashtakaia*, and *Sororyctes*, are now know from the lower part of the middle Ghazij Formation, and these too represent groups not known elsewhere. This reinforces the idea that the middle and lower-upper Ghazij faunas are endemic, possibly evolving on the Ghazij Islands where they were separated from the rest of mammalian evolution. Proximity of the Ghazij Islands to Indo-Pakistan and the fact that deltas were prograding towards the subcontinent mean that the Ghazij island chain was probably connected to Indo-Pakistan from time to time during intervals of low sea stand, and the mammalian faunal endemicity documented here may have been characteristic of the entire Indian subcontinent in the early part of the Early Eocene.

Some important modern orders and families of mammals, such as Artiodactyla, hyaenodontid Creodonta, Perissodactyla, adapid and omomyid Primates, can be traced back in time to the Paleocene-Eocene boundary (Russell et al., 1982; Dashzeveg, 1988; Gingerich, 1989). However, their origin remains mysterious. Interest has centered on Africa and/or southern Asia generally (Gingerich, 1986), but Krause and Maas (1990, p.96) have focused attention on Indo-Pakistan:

> "Among early Tertiary large land-masses, the Indian subcontinent is unique in its combination of having been in the right places at the right times to provide for the development and subsequent disembarking of several new higher taxa of mammals and in having fossils that demonstrate the appropriate stages of evolution to be consistent with such a hypothesis. This hypothesis can best be tested by the discovery of Paleocene and/or more early Eocene mammals from the India subcontinent."

The Ghazij Islands chain and its mammalian fauna are in the right place and time to provoke such a test, but limited evidence available now raises doubt that modern orders like Perissodactyla evolved on the Ghazij Islands. Perissodactyls instead appear to represent a cosmopolitan immigration from elsewhere, possibly Central Asia (McKenna et al.,, 1989), arriving late in Ghazij time.

Acknowledgment

We thank Messrs. Muhammad Ali Mirza, Director General of the Geological Survey of Pakistan, A.H.Usmani, Director of Protocol and Museum, and Mirza Talib Hasan, Director of Paleontology and Stratigraphy, for encouraging and supporting this investigation. Dr. Gregg F.Gunnell and Mr. Jon Bloch read and improved the manuscript. Fossils were prepared and cast by Dr. Williams J. Sanders, and Ms Bonnie Miljour drew the illustration in Figure1-2 and 7-12. Search for Ghazij mammals was initiated with support from the office of the Vice-President for Research at the University of Michigan, and 1997 field research reported here was funded in part by National Geographic Society grant 5537-95.

References

Ahmad, Z., and Abbas, S.G., 1979. The Muslim Bagh ophiolites. *In*: Geodynamics of Pakistan, A. Farah and K.A.DeJong (eds), Geological Survey of Pakistan, Quetta: 243-249.

Allemann, F.,1979. Time of emplacement of the Zhob Valley ophiolites and Bela ophiolites, Balochistan (preliminary report). *In*: Geodynamics of Pakistan, A.Farah and K.A. DeJong (eds.), Geological Survey of Pakistan, Quetta: 215-242.

Arif, M., Abbas, S.G., and Gingerich, P.D., 1997. First Paleocene-Eocene mammal from South Asia. Geological Survey of Pakistan, Records, 109: 76-77.

Bannert, D., Cheema, A., Ahmed, A., and Schaffer, U., 1992. The structural development of the western fold belt, Pakistan. Geologisches Jahrbuch, Hannover, Reihe B, 80: 1-60(with map in three sheets).

Beck, R. A., Burbank, D. W., Sercombe, W. J., Riley, G. W., Barndt, J. K., Berry, J. R., Afzal, J., Khan, A., M., Jurgen, H., Metje, J., Cheema, A., Shafique, N. A., Lawrence, R .D., and Khan, M.A., 1995. Stratigraphic evidence for an early collision between northwest India and Asia. Nature, 373: 55-58.

Berggren, W.A., and Miller, K.G., 1988. Paleogene tropical planktonic foraminiferal biostratigraphy and magnetobiochronology. Micropaleontology, 34: 362-380.

Cox, L.R., 1931. A contribution to the mulluscan fauna of the Laki and basal Kirthar groups of the Indian Eocene. Transactions of the Royal Society of Edinburgh,57: 25-92.

Dashzeveg, D., 1979. Nakhodka *Homogalax* (Perissodactyla, Tapiroidea) v Mongolii; ego stratigraphicheskoye szacheniye [Discovery of *Homogalax* (Perissodactyla, Tapiroidea) in Mongolia and its stratigraphic significance]. Byulletin Moskovskogo Obschchestva Ispytateley Prirody, Otdel Geologicheskiy, 54: 105-111 [in Russian]

Dashzeveg, D., 1988. Holarctic correlation of non-marine Paleocene-Eocene boundary strata using mammals. Journal of the Geological Society, Lond., 145: 473-478.

Dercourt, J., Zonenshain, L.P., Ricou, L.E., Kazmin, V.G., Le . Pichon, X. ,Knipper, A.L., Grandjacquet, C., Sbortshikov, I.M., Geyssant, J., Lepvrier, C., Perchersky, D.H., Boulin, J., Biju-Duval, J., 1986. Geological evolution of the Tethys belt from the Atlantic to the Pamirs since the Lias. Tectonophysics, 123: 241-315.

Fritz, E.B., and Khan, M., 1975. Stratigraphy and paleontology of coal beds in the Ghazij Shale, Sor Range-Deghari coal field, Quetta Division, Project report PK-15. U.S. Geological Survey Open File Report 75-274: 1-16.

Gaetani, M., and Garzanti, E., 1991. Multicyclic history of the northern India continental margin (northwestern Himalaya). American Association of Petroleum Geologists Bulletin, 75: 1427-1441.

Garzanti, E., Critelli, S., and Ingersoll, R.V., 1996. Paleogeographic and paleotectonic evolution of the Himalayan Range as reflected by detrital modes of Tertiary sandstones and modern sands (Indus transect, India and Pakistan), Geological Society of America Bulletin, 108: 631-642.

Gingerich, P.D., 1986. Early Eocene *Cantius torresi* - oldest primate of modern aspect from North America. Nature, 319: 319-321.

Gingerich, P.D., 1989. New earliest Wasatchian mammalian fauna from the Eocene of northwestern Wyoming: composition and diversity in a rarely sampled high-floodplain assemblage. University of Michigan Papers on Paleontology, 28: 1-97.

Gingerich, P.D., Abbas, S.G., and Arif, M., 1997. Early Eocene *Quettacyon parachai* (Condylarthra) from the Ghazij Formation of Balochistan (Pakistan): oldest Cenozoic land-mammals from South Asia. Journal of Vertebrate Paleontology, in press.

Gingerich, P.D., and Gunnell, G.F., 1979. Systematics and evolution of the *genus Esthonyx* (Mammalia, Tillodontia) in the early Eocene of North America. Contribution from the Museum of Paleontology, University of Michigan, 25: 125-153.

Haque, A.F.M., 1960. Some middle to late Eocene smaller Foraminifera from the Sor Range, Quetta district, West Pakistan. Memoirs of the Geological Survey of Pakistan, Paleontologia Pakistanica, 2(2): 1-79.

Johnson, E.A., and Khan, I.H., 1994. Principal reference section for part of the Eocene Ghazij Formation, Shin Ghwazha Mine area, Sor Range coal field, Balochistan, Pakistan. U.S. Geological Survey Miscellaneous Field Studies, Map MF-2263-B: 1 sheet.

Johnson, E.A., Warwick, P.D., Roberts, S.B., and Khan, I.H., 1993. Limestone-pebble conglomerate facies of the Eocene Ghazij Formation, Balochistan, Pakistan: evidence for collision-related tectonism on the northwestern margin of the Indian plate. American Association of Petroleum Geologists Annual Meeting Abstracts, 1993: 124-125.

Jones, A.G., Manistre, B.E., Oliver, R.L., Willson, G.S., and Scott, H.S., 1960. Reconnaissance Geology of Part of West Pakistan (Colombo Plan co-operative project conducted and compiled by Hunting Survey Corporation). Government of Canada, Toronto, 550p.

Kassi, A.M., Qureshi, A.R., and Kakar, D.M., 1987. Sedimentology of the Ghazij Formation, Kach area, Balochistan. Geological Bulletin of the University of Peshawar, 20: 53-62.

Kazi, A., 1968. Sedimentology of the Ghazij Formation, Harnai, Balochistan. Geological Magazine, 105: 35-45.

Kazmi, A.H., 1962. Stratigraphy of the Ghazij shales. The Geologist, Geological Society, University of Karachi, 1: 27-32, 38-40.

Kazmi, A.H., 1995, Sedimentary sequence. *In*: Geology of Pakistan, F.K. Bender and H.A. Raza (eds.), Gebruder Borntraeger, Berlin: 63-124.

Kazmin, V., Ricou, L.-E., and Sbortshikov, I. M., 1986. Structure and evolution of the passive margin of the eastern Tethys. Tectonophysics, 123: 153-179.

Khan, M.U., and Fritz, E.B., 1966. Stratigraphy and paleontology of coal beds in the Ghazij Shale, Sor Range, Geological Survey of Pakistan PK Series Reports, 15: 1-16.

Knipper, A., Ricou, L.-E., and Dercourt, J., 1986. Ophiolites as indicators of the geodynamic evolution of the Tethyan ocean. Tectonophysics, 123: 213-240.

Krause, D. W., and Maas, M.C., 1990. The biostratigraphic origins of late Paleocene-early Eocene mammalian immigrants to the western interior of North America. Geological Society of America, Special Paper, 243: 71-105.

McKenna, M.C., 1989. *Radinskya yupingae*, a perissodactyl-like mammal from the late Paleocene of China. *In:* The evolution of Perissodactyls, D.R. Prothero and R.M. Schoch (eds.) Oxford University Press, New York: 24-36.

Nuttall, W.L.F., 1925. The stratigraphy of the Laki Series. Quaterly Journal of the Geological Society, London, 81: 417-453.

Oldham, R.D., 1890. Report on the geology and economic resources of the country adjoining the Sind-Pishin railway between Sharigh and Spintangi and the country between it and Khattan. Geological Survey of India, Record, 23: 93-110.

Pivnik, D.A., and Wells, N.A., 1996. The transition from Tethys to the Himalaya as recorded in northwest Pakistan. Geological Society of Americ Bulletin, 108: 1295-1313.

Radinsky, L.B., and Ting, S., 1984. The skull of *Ernanodon*, an unusual fossil mammal., Journal of Mammalogy: 155-158.

Reinemund, J.A., Khan, M.Y., Hussain, F., and Usmani, A.H., 1995. Geological map of Sor Range-Deghari, Geological Survey of Pakistan, Geologic Map Series, 97(1:31,680): 1 sheet.

Rowley, D.B., 1996. Age of initiation of collision between India and Asia: a review of stratigraphic data. Earth and Planetary Science Letters, 145: 1-13.

Russell, D.E., Hartenberger, J.L., Pomerol, C., Sen, S., Schmidt-Kittler, N., and Vianey-Liaud, M., 1982., Mammals and stratigraphy: the Paleogene of Europe. Palaeovertebrate, Montpellier, Memoire Extraordinaire, 1-77.

Russell, D.E., and Zhai, R., 1987. The Paleogene of Asia: mammals and stratigraphy. Memoires du Museum National d'Histoire Naturelle, Sciences de la Terre, 52: 1-488.

Shah, S.M.I., 1990. Coal Resources of Balochistan, Pakistan. *In:* Significance of the Coal Resources of Pakistan, A.H.Kazmi and R.A.Siddiqi (eds.), Geological Survey of Pakistan, Quetta, 63-92.

Smith, A.G., Smith, D.G., and Funnell, B.M., 1994. Atlas of Mesozoic and Cenozoic Coastlines. Cambridge University Press, Cambridge, 99 pp.

Thewissen, J.G.M., Gingerich, P.D., and Russell, D.E., 1987. Artiodactyla and Perissodactyla (Mammalia) from the early-middle Eocene Kuldana Formation of Kohat (Pakistan). Contributions from the Museum of Paleontology, University of Michigan, 27: 247-274.

Ting, S., 1979. A new edentate from the Paleocene of Guangdong. Vertebrata PalAsiatic, 17: 57-64.

Ting, S., 1993. A preliminary report on an early Eocene mammalian fauna from Hengdong, Hunan Province, China. Kaupia, Darm stadter Beit rage zur Naturgeschichte, Darmstadt, 3: 201-207.

Tourmarkine, M., and Luterbacher, H., 1985. Paleocene and Eocene planktic foraminifera. *In*: Plankton Stratigraphy, H. M. Bolli, J.B. Saunders, and K. Perch-Nielsen (eds.), Cambridge University Press, Cambridge: 87-154.

Treloar, P.J., and Izatt, C.N., 1993. Tectonics of the Himalayan collision between the Indian plate and the Afghan block: a synthesis. Geological Society of London, Special Publication, P. J. Treloar and M. P. Searle (eds.), Himalayan Tectonics, 74: 69-87.

Waheed, A. and Wells, N.A., 1990. Changes in paleocurrents during the development of an obliquely convergent plate boundary (Sulaiman fold-belt, southwestern Himalayas, west-central Pakistan). Sedimentary Geology, 67: 237-261.

Williams, M.D., 1959. Stratigraphy of the lower Indus Basin, West Pakistan. Proceedings of the Fifth World Petroleum Congress, New York, Section 1, Paper 19: 377-390.

Zhou, M., and Li, C., 1965. *Homogalax* and *Heptodon* of Shantung. Vertebrata PalAsiatica, 9: 15-21.