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Geology and planktonic foraminiferal biostratigraphy of the Paleocene-Eocene succession of the Zinda Pir section, Sulaiman Range, Southern Indus Basin, Pakistan

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Abstract: Exposed section along the Sori Nadi, a river which runs across the Zinda Pir area, eastern part of the Sulaiman Range, Southern Indus Basin, Pakistan, is a relatively continuous Middle Paleocene to Late Eocene shallow to deep marine sedimentary sequence. The sequence consists of three formations: Dunghan, Ghazij, and Kirthar Formations in ascending order. Detailed geological mapping of the western limb of the Zinda Pir Anticline along the Sori Nadi was carried out. The section was also measured to know the lithlogical variations and the thickness of the individual formations. Moreover, a total of seventy samples were systematically collected in the field for the purpose of establishing the planktonic foraminiferal biostratigraphy.

Abundant and well preserved planktonic foraminifers were recovered from the Dunghan Formation, the lowermost part of the Ghazij Formation, and the upper part of the Kirthar Formation. The upper part of the Ghazij Formation and the lower part of Kirthar Formation, however, contain little and poorly preserved planktonic foraminifera. A total of seventy-seven species and subspecies belonging to fourteen genera were identified. Subsequently, nine biostratigraphic zones were established based on occurrence of representative species: *Morozovella angulata* Interval Zone, *Planorotalites pseudomenardii* Partial-Range Zone, *Morozovella velascoensis* Interval Zone, *Morozovella subbotinae* Interval Zone, *Morozovella formosa formosa* Interval Zone, *Morozovella aragonensis* Interval Zone, *Morozovella spinulosa / Truncoroloides topilensis* Total-Range Zone, *Catapsydrax howei* Interval Zone and *Globigerina officinalis* Interval Zone in ascending order.

Based on the established planktonic foraminiferal zones, the Dunghan Formation is assigned to Middle Paleocene through Early Eocene age while the lower part of the Ghazij Formation is assigned to the Early Eocene. The Pir Koh Ls & Marl Member of the Kirhtar Formation is assigned to the Middle Eocene whereas the Drazinda Member is assigned to a late Middle Eocene through early Late Eocene age.

1. Introduction

The Zinda Pir Section, along which a dominantly marine Paleocene-Eocene sequence is exposed, is in the eastern part of Sulaiman Range, Southern Indus Basin. Sori Nadi, a small river in the Sulaiman Range which cuts across the Zinda Pir anticlinal structure at approximately right angles, provides an excellent exposure of the sedimentary sequence.

The study area is situated in the Dera Ghazi Khan, a district of the Punjab Province. It lies between 30° 24′ and 30° 25′N latitude and 70° 25′ and 70° 30′E longitude (Fig. 1) and is covered by the 39 J / 7 and 39 J / 11 (1 : 50,000 scale) topographic sheets of the Survey of Pakistan. The exact location of the section is shown in Figures 2 and 3. The approach to the area is very difficult, so much so that it has been neglected despite the excellent surface exposures.

The main objectives of the present study are; 1) to describe the geology of the section; 2) to document the planktonic foraminiferal fauna from the Zinda Pir section; 3) to establish the planktonic foraminiferal biostratigraphic zonation of the section; and 4) to make correlation of the study area with other areas of

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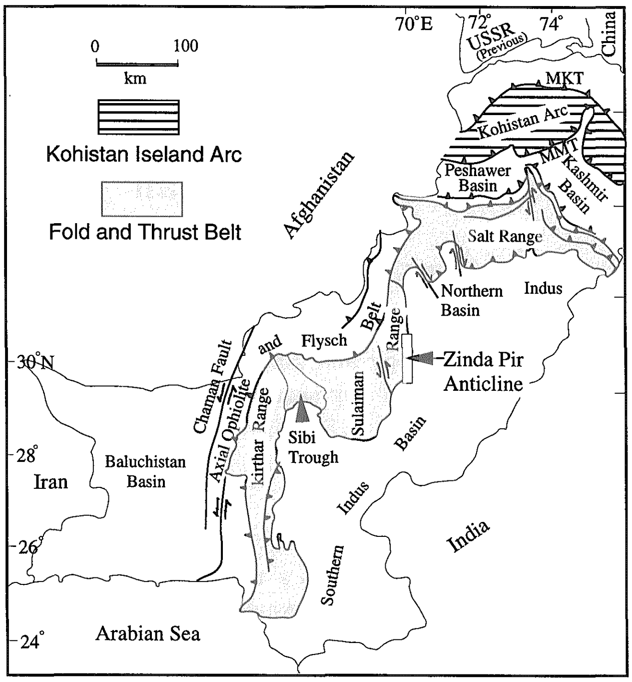

Fig. 1 Generalized tectonic map of Pakistan showing major faults and basinal divisions. Modified from Davies *et al.* (1994).

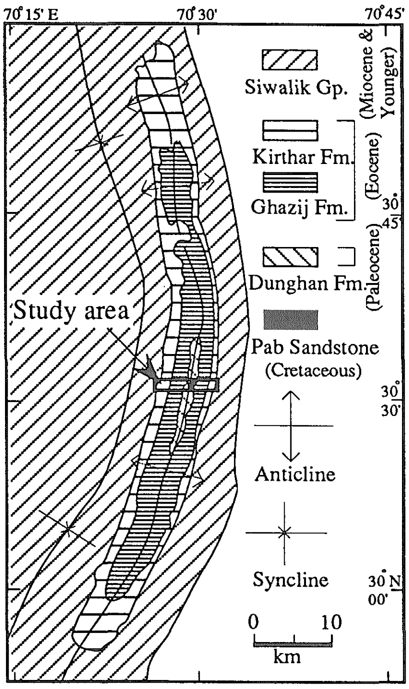

Fig. 2 Geological map showing the structure of the Zinda Pir anticline. The rectangular area corresponds to the study area. Modified after Humayon *et al.* (1991).

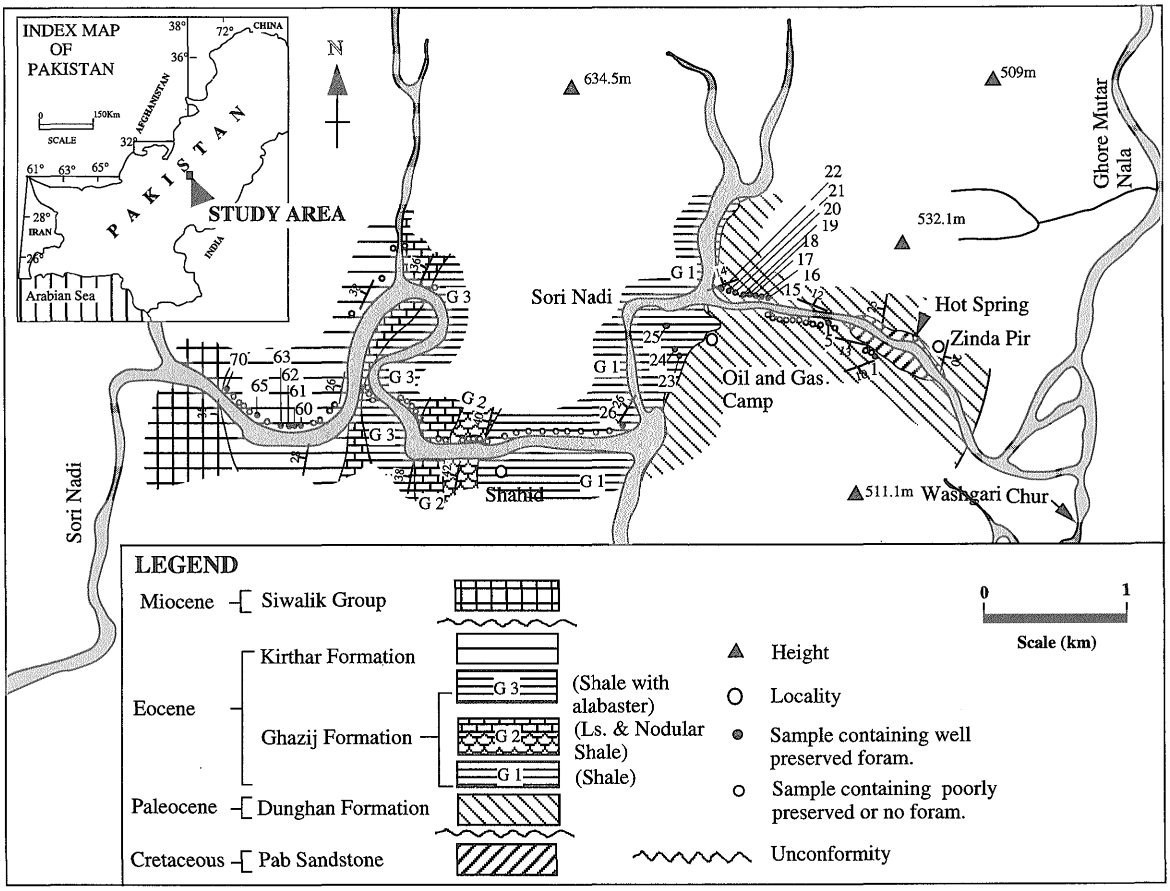

Fig. 3 A geological map along the Sori Nadi in the Zinda Pir section, Sulaiman Range, Southern Indus Basin, Pakistan.

the region.

2. Previous works

Most of the published reports on the biostratigraphy of Pakistan are based on larger foraminifera (Eames, 1952b ; Nagapa, 1959 ; Butt, 1991). Although deep to open marine sequences ranging from the Early Cretaceous to the Late Eocene are widely exposed in the Kirthar and Sulaiman Ranges in Indus Basin, little work has been done on planktonic foraminifera. Pioneering work on smaller foraminifera was done by Haque (1956), documenting the smaller foraminifera from the "Nammal George". This paper was followed by two other contributions : Smaller foraminifera of Meting Limestone (Haque, 1959a) and Eocene foraminifera of "Sore Range" (Haque, 1959b). Latif (1961) and Samanta (1973), both have attempted to provide a systematic account of the Paleocene -Eocene planktonic foraminifera of the Rakhi Nala section. Paleocene-Eocene planktonic foraminifera has also been described from the Gaj River section of the Kithar Range (Dorreen, 1974).

A deep marine sequence of the Paleocene-Eocene age is excellently exposed along the Sori Nadi in Zinda Pir area, eastern Sulaiman Range. Because of the difficult approach and inaccesibility of the area, no micropaleontologic work has so far been published. We are sure that the present work on the planktonic foraminiferal biostratigraphy of the area provides regional correlation, with the Paleocene-Eocene successions in the Indus Basin.

3. Regional geological settings

The Indian subcontinent is interpreted as having separated from Australia and Antarctica about 130 Ma and migrated northward resulting to the closure of the Tethys Sea. After the consumption of the Tethyan oceanic crust along a north dipping subduction zone, continental crust of the Indian plate collided with Asia about 50 Ma (Powell, 1979). As a result of this collision, Kohistan island arc was formed which is separated from Asian plate by Main Karakoram Thrust (MKT) in the north and from Indian plate by Main Mantle Thrust (MMT) in the south (Fig. 1). The Himalayan belts are the largest continental convergent zone which are presently active. Several fold and thrust belts have been formed as a result of the underthrusting of the Indian craton under its own sedimentary cover (Humayon *et al.*, 1991).

In Pakistan, the northern boundary of the Indian plate remain convergent whereas an oblique collision with the Afghan block formed the Sulaiman and Kirthar Ranges in a transpressional zone (Fig. 1) on the northwest and west respectively (Yeats and Lawrence, 1984).

The lobate Sulaiman Range is the broadest (more than 300 km) foreland fold and thrust belt of the Himalayan mountain system. The Sulaiman Range is borderded by ophiolite and flysch belt in the western side whereas it forms the continuation of the Kirthar Range around the tight arc of the Sibi Trough. The eastern side of the Sulaiman Range is marked by a broad fold abutting alluvial deposits of the Indus river system.

Zinda Pir is a long and narrow anticlinal structure which runs approximately north-south and is separated from a very complex folded belt of the Sulaiman Range by a narrow syncline in the west (Fig. 2). The eastern limb is relatively steep and burried under the alluvial deposits of the Indus river system. The crestal area is broad and gentle and is dislocated by very small oblique faults

4. Stratigraphy of the Zinda Pir section

Detailed geological map which covers Paleocene -Eocene sequence exposed along the western limb of the Zinda Pir Anticline was prepared (Fig. 3). The section was also surveyed in order to know the lithological succession and to measure the thickness of the individual formations. The results of the section measurements along with sample locations are plotted in Figure 4.

The Paleocene-Eocene succession of the Zinda Pir area is unconformably underlain by the Cretaceous Pab Sandstone and overlain by the Miocene Siwalik Group, respectively. This marine succession consists of three formations, namely Dunghan Formation, Ghazij Formation and Kirthar Formation. A correlation showing horizontal and vertical distribution of the Paleogene lithostratigraphic units recognized in the Southern Indus Basin are shown in Table 1. The stratigraphic subdivisions and nomenclature of Shah (1977) is adopted in this study.

4.1 Dunghan Formation

General : The name "Dunghan Limestone" was introduced by Oldham (1890) to replace the "Alveolina Limestone" of Greisbach (1881) which is a thick limestone sequence between Parh Limestone and Ghazij Formation. Williams (1959) redefined the term as "Dunghan Formation" while excluding the basal beds (his Fort Munro Limestone Member) which were found to have unconformable relationship with the rest of the unit. Shah (1977) redefined Dunghan Formation of Williams (1959) and included "Lower Rakhi Gaj Shales", "Zinda Pir Shales", and "Zinda Pir Limestone" of Eames (1952a) excluding Moro Formation, "Dab Formation" and "Karkh Group" of Hunting Survey Corporation (1961). Williams (1959) described Mirhab Tangi George, 8 km northeast of Harnai (lat. 30_08′ 38″ N ; long. 67_59′ 33″ E), Loralai District as

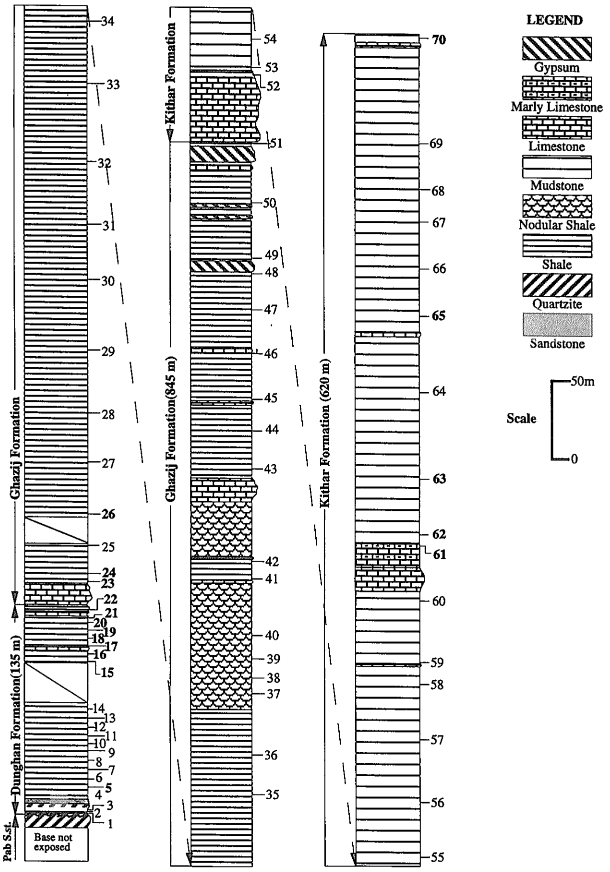

Fig. 4 Columnar section measured along the western limb of the Zinda Pir anticline exposed in the Sori Nadi, Sulaiman Range, Southern Indus Basin, Pakistan. Numbers represent sample locations and bold ones indicate samples containing foraminifers.

type section.

The Dunghan Formation mainly consists of nodular to massive limestone with subordinate shale, marl, sandstone and limestone conglomerate. The limestone is dark gray to brown and creamy white whereas on weathering, it shows brown, gray and buff yellow colors. The dark blue grey, brown and olive shale which weathers green becomes dominant in the southern Sulaiman Range. The Dunghan Formation is widely distributed in the Sulaiman Range. It is reported to be 365m thick. The lower contact of the Dunghan Formation is unconformable and marks one of the major unconformity of the basin. The upper contact with Ghazij Formation is conformable. A rich fossil assemblage including foraminifers, gastropods, bivalves and algae are recorded by several workers.

Zinda Pir Section:

At Zinda Pir, the Dunghan Formation shows typical lithology, however, shale is the dominant unit. The shale is dark black colored and sandy near the base. Some hard cream white to beige colored beds of quartzite and greenish grey glauconitic sandstone beds are also found intercalated with shales in the lower part. The shale exhibits spheroidal style of weathering (Fig. 5-A). A few thin bedded beige colored, hard limestone beds flooded with larger foraminifera are present in the upper part. Some trace fossils of about 50cm length and 2cm in diameter (Fig. 5-B) were found near the top. The formation exhibit white weathering and highly calcareous shales near the top.

The formation is unconformably underlain by the Pab Sandstone exhibiting a well defined contact (Fig.

Table 1 Paleogene comparative stratigraphic schemes of the Southern Indus Basin, as proposed by previous authors and various oil companies.

AGE			STANDARED VACUUM OIL CO.	PAKISTAN PETROLEUM LTD	PAKISTAN SHELL OIL CO.	BLANFORD GSI 1876	VREDENBURG GSI 1906	PINFOLD GSI 1939	S.M.I. SHAH GSP 1977	THIS STUDY (ZINDA PIR)
TERTIARY	PLIOCENE	Middle	SIWALIK GROUP	SIWALIK	SIWALIK	MANCHHAR	SIWALIK	SIWALIK	SIWALIK GR.: SOAN FM. ?	SIWALIK GR. (Not investigated)
		Lower							DHOK PATHAN FM.	
	MIOCENE	Upper	GAJ FM.			GAJ GR.			NAGRI FM.	
		Middle		GAJ FM.					? CHINGI FM. GAJ FM.	
		Lower								
	OLIGOCENE	Upper	NARI FM.			NARI GR. UPPER			MOMANI GR.: NARI FM.	
		Middle		NARI FM.	NARI FM.		NARI FM.	NARI FM.		
		Lower				NARI GR. LOWER				
	EOCENE	Upper Priabonian	KIRTHAR FM.	KIRTHAR FM.	KIRTHAR FM.	KIRTHAR GR.	KIRTHAR SERIES UPPER / LOWER	KIRTHAR Middle / Lower	KIRTHAR FM.: Darazinda Member; Pir Koh ls & Marl Member.; Sirki Member	Darazinda Memb.; Pir Koh ls & Marl Memb.; Sirki Memb.
		Middle Lutetian		LAKI FM.	GHAZIJ FM.				Habibrahi Ls. Member	Habibrahi Ls. Memb.
		Lower Ypresian	GHAZIJ FM.		DUNGHAN FM. LS. mb. / SH. mb.		LAKI SERIES	LAKI, GHAZIJ	GHAZIJ FM.: Bska Sh. & Alabaster Mb.; GHAZIJ FM.	GHAZIJ FM. Upper / Middle / Lower
	PALEOCENE	Landenian	DUNGHAN FM.					DUNGHAN LS.	DUNGHAN FM.	DUNGHAN FM.
		Montian	RANIKOT FM.	RANIKOT FM.	QUARTZOSE SS. FM.	RANIKOT GR.		RANIKOT FM.		
		Danian	KHADRO FM.	CARDITA BEAUMONTI	NISHPA FM.	CARDITA BEAUMONTI BEDS	CARDITA BEAUMONTI BEDS	PAB SANDSTONE	KHADRO FM.	PAB SANDSTONE.
CRETACEOUS			PAB SANDSTONE	PAB FM.		CRET. SAND STONE	PAB FM.		MORO FM.	

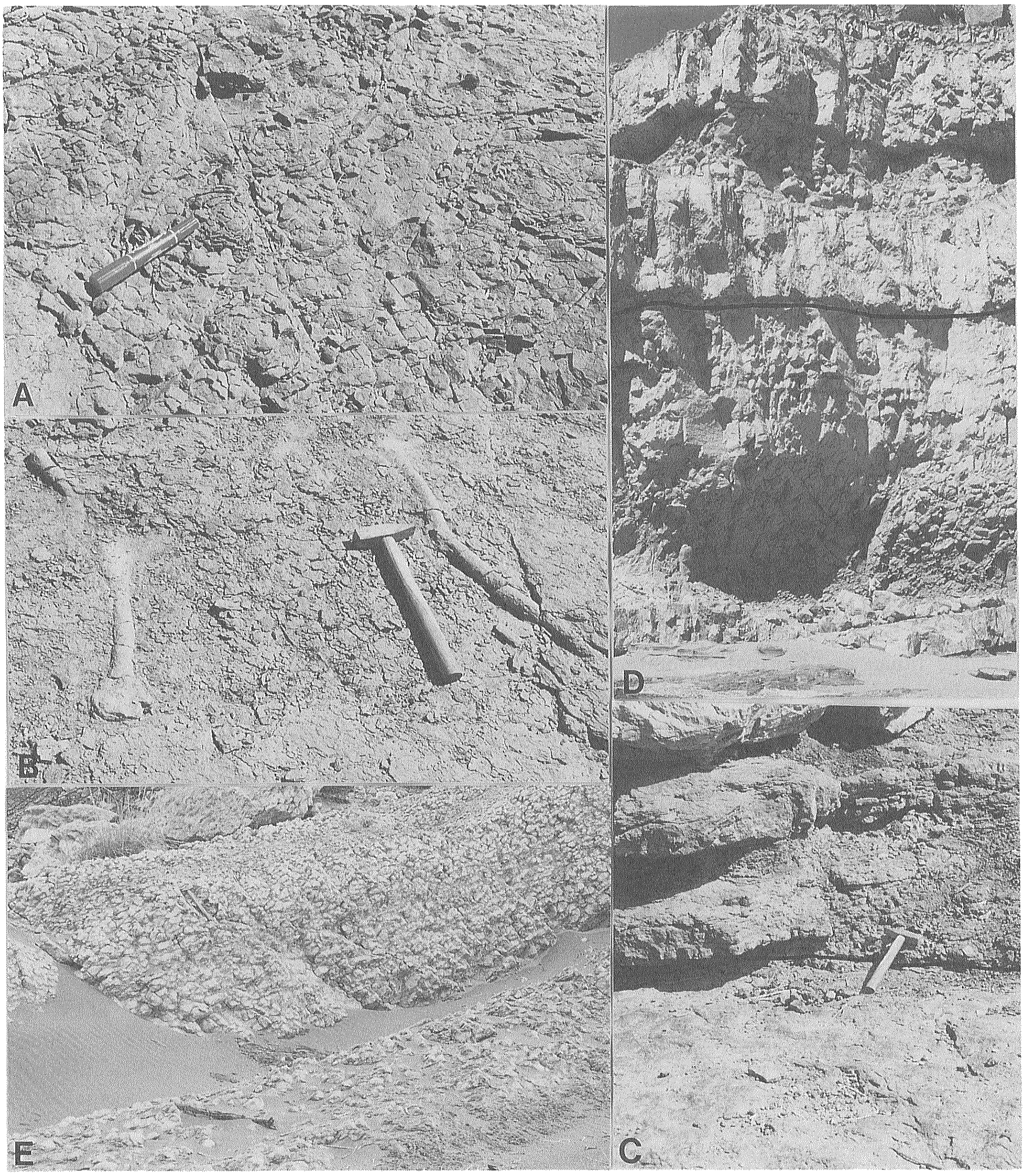

Fig. 5 Grey colored shales of the Dunghan Formation exhibit spheroidal style of weathering in the middle part of the formation (A), well preserved trace fossils found in the middle part of the Dunghan Formation (B), unconformable contact between the Pab Sandstone and overlying Dunghan Formation (C), thick bedded hard and massive limestone found at the base of the Ghazij Formation showing a well defined contact with underlying Dunghan Formation (D), marly nodular shales which become dominant lithology near the middle of the Ghazij Formation (E).

5-C) whereas the upper contact with Ghazij Formation is conformable. Dunghan Formation is measured 135m thick (Fig. 4) in the Zinda Pir section.

4.2 Ghazij Formation

General: The "Ghazij Group" of Oldhalm (1890) was redefined as "Ghazij Formation" by Williams (1959). Ghazij Formation was also adopted by Shah (1977) who also included "Shales with Alabaster, Rubbly Limestone, Green and Nodular Shales, Upper Rakhi Gaj Shales and Zinda Pir Limestone (upper part)" of Eames (1952a) described from Rakhi Nala and Zinda Pir, the "Chat beds" of Nagappa (1959) and the "Ghazij Shales", "Tiyon Formation" and upper part of the "Gidar Dhor Group" of the Hunting Survey Corporation (1961).

Shah (1977) introduced two members in the upper part of the formation. In eastern and southeastern parts of the Sulaiman Range, Baska shale and Alabaster Member was introduced which covered "Shales with Alabaster" of Eames (1952a) and "Baska shale" of Hemphill and Kidwai (1973). He introduced Marap Conglomerate Member for conglomerate which is present in subordinate amount in the western Sulaiman Range after the "Marap Formation" of the Hunting Survey Corporation (1961).

Williams (1959) has described the section at Spintangi (lat. 29°57′ N ; long. 68°05′ E) as type section for the formation. Shah (1977) described a section exposed at about 2km east- northeast of Baska village (lat. 31°29′ N ; long. 70°08′ E) as type section for Baska shale and Alabaster Member having 190m thickness and northwest edge of the Marap valley as type locality for his Marap Conglomerate Member where it is 910m thick.

The formation consists dominantly of shale with subordinate claystone, limestone, conglomerate, alabaster and coal that becomes locally abundant. The Ghazij Formation conformably overlies the Dunghan Formation and is overlain by the Kirthar Formation throughout the Sulaiman and Kirthar provinces (Southern Indus Basin). It is 590m thick at its type section.

Based on the fauna and flora (foraminifera, gastropods, bivalves, echinoides, and algae) recovered from this formation (Eames, 1952b ; Hunting Survey Corporation, 1961 ; Latif, 1961), an Early Eocene age has been assigned to the Ghazij Formation.

Zinda Pir Section :

In the Zinda Pir area, the Ghazij Formation dominantly consistsls of green colored soft shales intercalated with some thin bedded limestone (Fig. 3). A three fold division can be made within the Gazij Formation ; Lower, Middle and Upper. During geological survey, three different lithofacies exhibiting different depositional environments were distinguished and mapped. These three Lower, Middle and Upper parts of the Ghazij Formation are shown with symbols G1, G2 and G3 respectively (Fig. 3).

Lower part) Thick pile of greenish grey to dark grey colored, relatively soft shales in the loweremost part with a 12m thick, hard and massive, grey colored limestone (Fig. 5-D) which caps the Paleocene Dunghan Formation. This is taken as the base of the Ghazij Formation as Shah (1977) has included this limestone in the Ghazij Formation which was previously defined as "Zinda Pir Limestone (upper part)" by Eames (1952a). This limestone is flooded with foraminifera and is quite persistent and look like a wall against the overlying shales. This lithofacies unit is shown in the map (Fig. 3) with symbol 'G1'.

Middle part) The succeding unit consists of green colored nodular marly shales (Fig. 5-E) containing a lot of mollusca and foraminifera fossils. The nodular shales gradually change into thin bedded limestone intercalated with dark grey shales (Fig. 6-A) which becomes dominant lithology in the upper part of the unit. The limestone contain abundant larger foraminifera. This unit is shown with symbol 'G 2' in the map (Fig. 3). Moreover this unit is equivalent to, "Green and Nodular Shales" and "Rubbly Limestone" of Eames (1952a).

Upper part) In the upper part of the formation, green and greenish grey shales with beds, nodules and veins of alabaster are present which is equivalent to the Baska Shale and Alabaster Member of Shah (1977). These shales are also soft with green, dark grey and choculate colors intercalated with limestone beds flooded with fossils of mollusca and larger foraminifera. This unit is shown by symbol 'G 3' in the map (Fig. 3). There are five alabaster beds of various thickness near the top of the formation. The alabaster is grey brown to black brown (Fig. 6-B) in color and occurs within green grey shales intercalated with platy limestone flooded with mullusca. The upper most bed of alabaster is 10m in thickness overlain by 5m green colored shale showing sulfur rusting on its surface, marks the boundary with overlying Kirthar Formation through a conformable sharp contact. The measured thickness of the Ghazij Formation incuding all three parts in the Zinda Pir section is about 845m (Fig. 4).

4.3 Kirthar Formation

General : Blandford (1876) used the term " Kirthar" derived from Kirthar Range to describe the Eocene strata between his "Ranikot Group" and the "Nari" in western Sind. Later Noetling (1903) separated the lower part as "Laki Series" and retained the name "Kirthar" for upper unit only. Shah (1977) raised the "Kirthar" of Noetling (1903) to Kirthar Formation and included the "Spintangi Limestone" of Oldhalm (1890), "Brahui Limestone" and "Spintangi Limestone" of Hunting Survey Corporation (1961). Moreover, Shah (1977) has divided the Kirthar Formation into four easily recognizeable units in parts of eastern Sulaiman Province. The lowermost member is named as Habib Rahi Limestone Member after Habib Rahi Limetone of Tainsh *et al.* (1959). The Habib Rahi Limestone Member is overlain by the "Sirki Shales" and "Lower Chocolate Clays" of Eames (1952a) described in Kohat area and Zinda Pir and Rakhi Nala sections respectively by him. The two units of Eames (1952a) which exhibit similar lithology are named as Sirki Member, after Sirki Paila of Kohat. The Sirki Member is overlain by "white marl band" of Eames (1952a) which is designated as Pir Koh Limestone Member after Pir Koh (northwest of Dera Bugti). The Pir Koh Limestone Member is overlain by Drazinda Shale of Hemphill and Kidwai (1973) which represents the "passage beds", "Upper Chocolate Clays" and "Pellatispira Beds" of Eames (1952a) and is named as Drazinda Member.

The Gaj River Section (lat. 26_56′ 10″ N ; long. 67

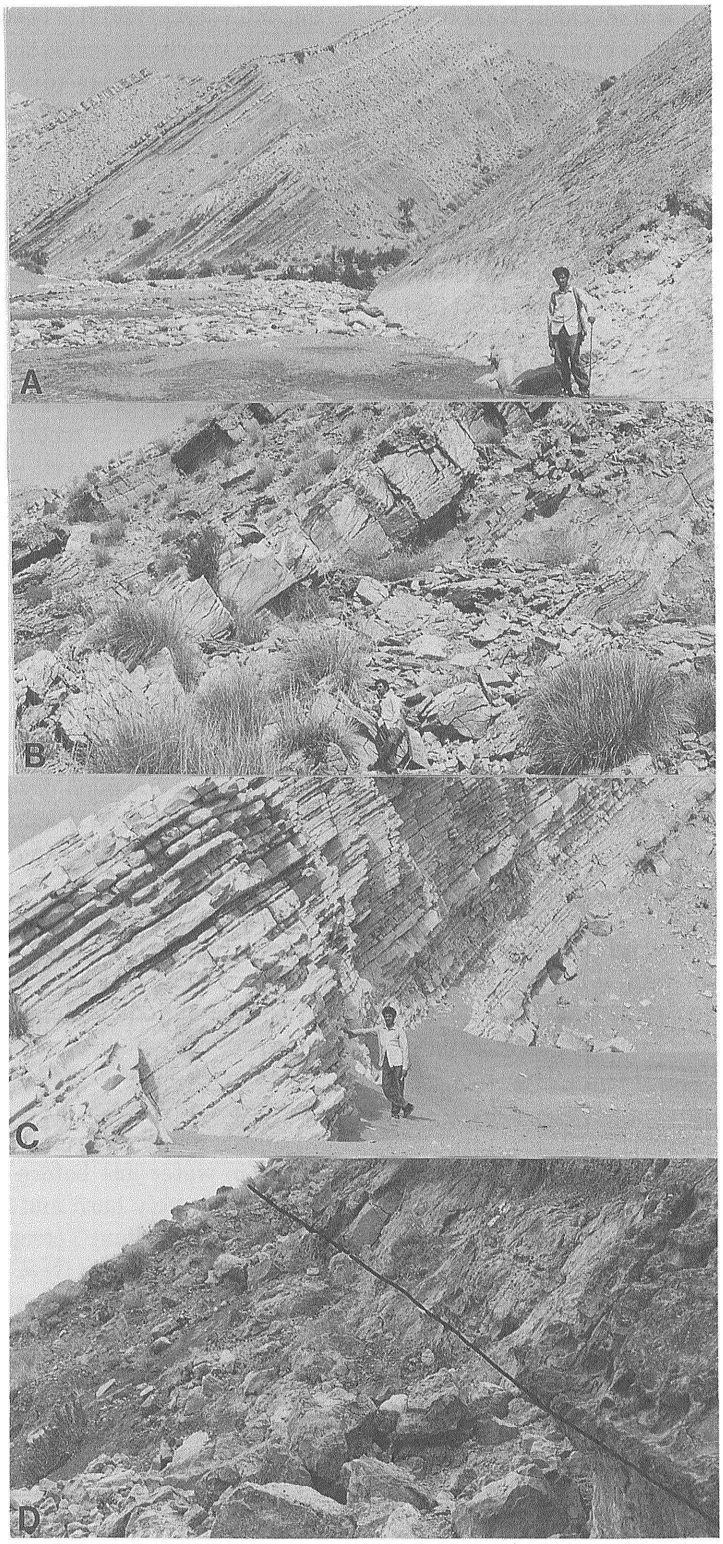

Fig. 6 Thin bedded limestone intercalated with green grey shales which becomes abundant in the upper part of the Ghazij Formation (A), Gypsum bed (four to five) found in the uppermost part of the Ghazij Formation (B), Thin bedded platy limestone having thin laminae of the black chert in the lower part of the Habib Rahi L.S Member of the Kirthar Formation (C), Dark black to rusty brown colored hematitic bed which marks the unconformity between the underlying Drazinda Member of Kirthar Formation and overlying sandstones of the Siwalik Group (D).

09′ 06″ E) in the Kirthar Range has been designated as type section. The Spintangi George in western Sulaiman Range and Zinda Pir and Rakhi Nala areas are proposed as principle reference sections.

The formation consists of interbedded series of limestone and shale with minor marl. The limestone is thick to massive bedded with light grey to cream colors weathering grey, brown or cream. The shale is calcareous, olive, orange yellow, grey, soft and earthy. The formation is widely distributed in the southern Indus Basin. At type locality in Gai River Section, it is 1270m thick. In most of the areas, the formation transitionally overlies the Ghazij Formation or Nari Formation. The upper contact of the formation is mostly unconformable with overlying Nari Formation, Rawalpindi Group or Siwalik Group in different areas.

The formation is richly fossiliferous and represent different ages in different areas ranging from the Early Eocene to Early Oligocene. In Zinda Pir and Rakhi Nala sections it is reported to range from the Middle to Late Eocene.

Zinda Pir Section

The Kirthar Formation is excellently exposed with all of its four members of Shah (1977) in the Zinda Pir area as discussed below.

a) Habib Rahi Limestone Member

This member is pale grey to buff colored, platty to thin bedded limestone which weathers whitish yellow. It contains some thin partings of the black chert (Fig. 6-C) and marly material. The limestone gives fetid smell on freshly broken surfaces. The basal marly beds which conformably overly the Ghazij Formation produce abundant larger foraminifers like *Assilina etc*. The measured thickness of the member is 50m (Fig. 4).

b) Sirki Member

This member consists of chocolate to reddish, yellow to greenish brown claystones which are more silty at certain horizons. A few thin beds of limestone having shell debries were also found. The basal part contain some stringes of gypsum. The measured thikness of the member is 220m (Fig. 4).

c) Pir Koh Limestone and Marl Member

This member consists of grey, chalky white to brown colored limestone interbedded with marl. The limestone contains some thin partings of the black chert and is succeeded by 15m green brown shales. It looks like a cliff, wedging out prominently among the low lying shales and clays of the member. The measured thickness of this member is only 30m (Fig. 4).

d) Drazinda Member

This member consists of brown, grey, green, chocolate claystones and silty shales containing gastropods. A few limestone beds flooded with foraminifera were found. Its measured thickness is 325m.

The upper contact of the Kirthar Formation is unconformable and lies between its Drazinda Member and the overlying sandstone sequences of the Siwalik Group which belongs to Miocene age. A thin, dark brown to black colored (Fig. 6-D), hematitic bed with pebbles, occurs at the boundary between the Drazinda Member of the Kirthar Formation and the overlying sandstones of the Siwalik Group.

5. Methods and material for foraminiferal analysis

In the field, approximately 500 gm samples (sample code : ZPW) consisting mostly of shale and mudstone were collected at 5 meter intervals where lithology permitted. This proved suitable for the Paleocene section where shales and mudstone predominates and planktonic foraminifers recovery was sufficient. A very thick Eocene sequence was encountered in the field but very few horizons yielded planktonic foraminifers and a sampling interval of 15 meter was adopted. All sample locations are plotted in Figures 3 and 4.

In the laboratory, hard shale samples were first broken into nut-sized particles and placed in stainless steel beakers for oven drying 60°C for 48 hours. One hundred gm of oven dried samples were then soaked in a boiled water saturated with sodium sulfate (Na_2SO_4). After allowing for about 30 minutes to insure complete penetration of solution into the samples, excess solution was drained off. Samples were then refrigerated for at least a week. Recrystallization and expansion of Sodium Sulfate (Na_2SO_4) within the pore spaces of the samples result into the disintegration of the samples. Disintegrated samples were then boiled in water and washed in a 200 mesh sieve. For soft sediment samples, oven dried samples were simply boiled in water just before washing.

For extremely hard and indurated samples, a solution of 0.2 N Sodium Tetraphenylborate (NaTPB) and 1 N Sodium Chloride (NaCl) (6.8 gm NaTPB and 5.8 gm NaCl dissolved in 100 ml of water) was used. The weight of the solution was taken twice the weight of the sample. As before, samples were first oven dried (60°C) for 48 hours and only 100 gm of the oven dried samples were soaked in the solution. The samples soaked in the solution were then placed in a vacuumed oven at room temperature for one week to ensure complete penetration of solution within the cracks and cavities of the samples. Treated samples were then washed using a 200 mesh sieve. When necessary, a 15% solution of hydrogen peroxide (H_2O_2) was used to get rid of excess residue.

Planktonic foraminifers were observed and identified under the binocular microscope (Table 2 and 3). Biostratigraphically important species were

Table 2 Occurrence of the planktonic and benthic foraminfers in the Zinda Pir section, Sulaiman Range, Southern Indus Basin, Pakistan.

Age		Formation	Member	Samples	Plank. foram	Benth. foram.	Preservation	Abundance	Others remarks
Eocene	Late	Kirthar Fm.	Drazinda Member	ZPW-70	787474	304457	well	abundant	reworked foram. were also present
Eocene	Late	Kirthar Fm.	Drazinda Member	ZPW-69	NF	NF			
Eocene	Late	Kirthar Fm.	Drazinda Member	ZPW-68	NF	NF			
Eocene	Late	Kirthar Fm.	Drazinda Member	ZPW-67	NF	NF			
Eocene	Late	Kirthar Fm.	Drazinda Member	ZPW-66	x	x	bad	rare	unidenfiable foram.
Eocene	Middle	Kirthar Fm.	Drazinda Member	ZPW-65	8160	12000	good	common	
Eocene	Middle	Kirthar Fm.	Drazinda Member	ZPW-64	x	x	bad	rare	unidenfiable foram.
Eocene	Middle	Kirthar Fm.	Drazinda Member	ZPW-63	33664	76800	well	common	
Eocene	Middle	Kirthar Fm.	Drazinda Member	ZPW-62	151808	324352	well	abundant	
Eocene	Middle	Kirthar Fm.	Pir Koh Ls & Marl Memb.	ZPW-61	94144	53120	well	abundant	
Eocene	Middle	Kirthar Fm.	Pir Koh Ls & Marl Memb.	ZPW-60	NF	NF			
Eocene	Middle	Kirthar Fm.	Sirki Member	ZPW-59	NF	NF			
Eocene	Middle	Kirthar Fm.	Sirki Member	ZPW-58	NF	NF			
Eocene	Middle	Kirthar Fm.	Sirki Member	ZPW-57	x	x		rare	unidenfiable foram.
Eocene	Middle	Kirthar Fm.	Sirki Member	ZPW-56	NF	NF			
Eocene	Middle	Kirthar Fm.	Sirki Member	ZPW-55	NF	NF			
Eocene	Middle	Kirthar Fm.	Sirki Member	ZPW-54	NF	NF			
Eocene	Middle	Kirthar Fm.	Sirki Member	ZPW-53	NF	NF			
Eocene	Middle	Kirthar Fm.	Habib Rahi Ls. Memb.	ZPW-52	x	x			unidenfiable foram.
Eocene	Middle	Kirthar Fm.	Habib Rahi Ls. Memb.	ZPW-51	NF	NF		common	
Eocene	Middle	Ghazij Fm.		ZPW-50	x	x			unidenfiable foram.
Eocene	Middle	Ghazij Fm.		ZPW-49	NF	NF		rare	unidenfiable foram.
Eocene	Middle	Ghazij Fm.		ZPW-48	NF	NF			
Eocene	Middle	Ghazij Fm.		ZPW-47	x	x	bad	rare	unidenfiable foram.
Eocene	Middle	Ghazij Fm.		ZPW-46	x	x	bad	rare	unidenfiable foram.
Eocene	Middle	Ghazij Fm.		ZPW-45	NF	NF			
Eocene	Middle	Ghazij Fm.		ZPW-44	NF	NF			
Eocene	Middle	Ghazij Fm.		ZPW-43	NF	NF			
Eocene	Middle	Ghazij Fm.		ZPW-42	NF	NF			
Eocene	Early	Ghazij Fm.		ZPW-41	NF	NF			
Eocene	Early	Ghazij Fm.		ZPW-40	NF	NF			nummulites
Eocene	Early	Ghazij Fm.		ZPW-39	x	x	bad	rare	unidenfiable foram.
Eocene	Early	Ghazij Fm.		ZPW-38	x	x	bad	rare	unidenfiable foram.
Eocene	Early	Ghazij Fm.		ZPW-37	x	x	bad	common	unidenfiable foram.
Eocene	Early	Ghazij Fm.		ZPW-36	x	x	bad	rare	unidenfiable foram.
Eocene	Early	Ghazij Fm.		ZPW-35	x	x	bad	common	unidenfiable foram.
Eocene	Early	Ghazij Fm.		ZPW-34	x	x	bad	rare	unidenfiable foram.
Eocene	Early	Ghazij Fm.		ZPW-33	x	x	bad	rare	unidenfiable foram.
Eocene	Early	Ghazij Fm.		ZPW-32	x	x	bad	rare	unidenfiable foram.
Eocene	Early	Ghazij Fm.		ZPW-31	x	x	bad	rare	unidenfiable foram.
Eocene	Early	Ghazij Fm.		ZPW-30	x	x	bad	rare	unidenfiable foram.
Eocene	Early	Ghazij Fm.		ZPW-29	NF	NF			unidenfiable foram.
Eocene	Early	Ghazij Fm.		ZPW-28	x	x	bad	rare	unidenfiable foram.
Eocene	Early	Ghazij Fm.		ZPW-27	NF	NF			
Eocene	Early	Ghazij Fm.		ZPW-26	50432	192	well	abundant	
Eocene	Early	Ghazij Fm.		ZPW-25	NF	NF			
Eocene	Early	Ghazij Fm.		ZPW-24	352512	1024	well	abundant	
Eocene	Early	Ghazij Fm.		ZPW-23	541445	7680	well	abundant	
Paleocene	Late	Dunghan Fm.		ZPW-22	38976	1600	poor	abundant	
Paleocene	Late	Dunghan Fm.		ZPW-21	14080	3520	well	abundant	
Paleocene	Late	Dunghan Fm.		ZPW-20	43180	6460	well	abundant	
Paleocene	Late	Dunghan Fm.		ZPW-19	47872	12800	good	abundant	
Paleocene	Late	Dunghan Fm.		ZPW-18	32064	2560	good	abundant	
Paleocene	Late	Dunghan Fm.		ZPW-17	101632	224320	well	abundant	
Paleocene	Middle	Dunghan Fm.		ZPW-16	22720	4480	well	abundant	
Paleocene	Middle	Dunghan Fm.		ZPW-15	3920	880	well	common	
Paleocene	Middle	Dunghan Fm.		ZPW-14	NF				
Paleocene	Middle	Dunghan Fm.		ZPW-13	NF				
Paleocene	Middle	Dunghan Fm.		ZPW-12	NF				
Paleocene	Middle	Dunghan Fm.		ZPW-11	NF				
Paleocene	Middle	Dunghan Fm.		ZPW-10	NF		bad	rare	reworked foram. are present
Paleocene	Middle	Dunghan Fm.		ZPW-9	NF				
Paleocene	Middle	Dunghan Fm.		ZPW-8	NF				
Paleocene	Middle	Dunghan Fm.		ZPW-7	NF				
Paleocene	Middle	Dunghan Fm.		ZPW-6	NF				
Paleocene	Middle	Dunghan Fm.		ZPW-5	1.76	0.112	good	rare	
Paleocene	Middle	Dunghan Fm.		ZPW-4	NF				
Paleocene	Middle	Dunghan Fm.		ZPW-3	NF				
Paleocene	Middle	Dunghan Fm.		ZPW-2	NF				
Paleocene	Middle	Dunghan Fm.		ZPW-1	0.53	0.08	good	rare	

phtographed (See plates 1～15) using scanning electron microscope (SEM).

The generic classifications used in this study were mainly of Blow (1979), Stainforth *et al.*(1975) and Loeblich and Tappan (1988). For the identification and stratigraphic correlation of the planktonic foraminiferal species, a wide range of literature was used, but descriptions of particular value were those of Bolli (1957a; 1957b), Blow (1979), Postuma (1971), Stainforth *et al.* (1975), and Toumarkine *et al.* (1985).

6. Planktonic foraminiferal biostratigraphy

Out of a total of 70 samples collected in the field, only 18 samples yielded sufficient and well preserved planktonic foraminifers. The rest of the samples either are barren or contain poorly preserved and taxonomically indeterminable fossil microfauna. A total of seventy-seven species and subspecies belonging to fourteen genera were identified and their stratigraphic distribution is shown in Table 3.

The lowermost 25m of the Dunghan Formation produce very few and poorly preserved planktonic foraminifers. The succeeding 80m don't produce any planktonic foraminifers. The uppermost 30m produce common to abundant and well preserved planktonic foraminifers.

The planktonic foraminifera are found abundant and excellently well preserved in the lowermost 55m of the Ghazij Formation. The rest of the formation (790m thick) does not contain any determinable planktonic foraminifers.

The lowest 165m of the Kirthar Formation also produce no determinable planktonic foraminifers whereas the succeeding 70m consisting of marly shales contain a very rich assemblage of planktonic foraminifers. The uppermost 285m of the Kirthar Formation contain rare to few planktonic foraminifers with poor to fairly satisfactory preservation. Seventy seven planktonic foraminiferal species and subspecies belonging to fourteen genera are identified. The distribution of these species against eighteen samples taken from Dunghan, Ghazij and Kirthar Formations is shown in Table 3.

Four genera namely *Acarinina, Globigerina, Morozovella* and *Planorotalites* make about 85% of the total planktonic foraminiferal fauna. *Morozovella* is the dominant genus represented by twenty five species and subspecies. *Acarinina* and *Globigerina* are the next dominant genera. The genus *Planorotalites* restricts to the Dunghan Formation except one species which occur in Kirthar Formation.

The representatives of the nine genera namely *Chiloguembilina, Catapsydrax, Globigerinoides, Globigerinatheka, Globigrinita, Hantkenina, Hastigerina, Truncorotaloides* and *Turborotalia* appear for the first time in the upper part of the Kirthar Formation. Planispiral genus *Pseudohastigerina* shows its first appearance in the lower part of the Ghazij Formation and continues to the overlying Kirthar Formation. *Catapsydrax Globigerinoides* and *Hastigerina* are represented by single species whereas *Chiloguembilina, Globigrinita* and *Hantkenina* are represented each by two species. The genera *Truncorotaloides* and *Turborotalia* are represented each by three species.

6.1 Planktonic zonation

Nine biostratigraphic zones have been established in the Paleocene-Eocene sequence of the Zinda Pir section (Tables 3 and 4). There is an interval between the sixth and the seventh zones which contains some reworked planktonic foraminifers and does not produce any identifiable planktonic foraminifers. The nine zones are discussed below in stratigraphic order.

1) *Morozovella* angulata Interval Zone

Definition

The interval between the first occurrence of *M. angulata* to the first evolutionary appearance of *Planorotalites pseudomenardii*.

Characteristics

This zone is represented by samples ZPW-1 to ZPW-15 from the Dunghan Formation. Twelve planktonic foraminiferal species were identified from this zone. *Morozovella angulata* is the most distinctive species in this zone. Preservation is not so good. Four species, *Planorotalites pusilla pusilla, P. compressa, Morozovella uncinata* and *M. kolchidica*, restrict to this zone whereas other eight species, *Globigerina triloculinoides, M. aequa, M. angulata, M. conicotruncata, M. pseudobulloides, M. velascoensis, P. chapmani* and *P. ehrenbergi*, range up to the next zone.

2) *Planorotalites pseudomenardii* Partial Range Zone

Definition

The base of this zone is placed at horizon marking the first evolutionary appearance of *Planorotalites pseudomenardii*. The top of the zone is taken immediately prior to first occurrence of *Acarinina soldadoensis soldadoensis*.

Characteristics

This zone is represented by samples ZPW-16 to ZPW-18 from the Dunghan Formation. Thirteen planktonic foraminiferal species were identified from this zone. Four species, *Planorotalites pseudomenardii, M. occlusa, M. acuta* and *A. mckannai*, appear for the first time at the base of the zone and range up to the next zones. *M. velascoensis* appears near the top of this zone and becomes a dominant species in overlying zone. Rest of the seven species, *Globigerina triloculinoides, M. aequa, M. angulata, M. conicotruncata, M. velascoensis, P. chapmani* and *P. ehrenbergi*, range up from the underlying *Morozovella angulata* Interval Zone and become more abundant in the next

Table 3 Stratigraphic distribution and range chart of planktonic foraminferal species in the Zinda Pir section, Sulaiman Range, Southern Indus Basin, Pakistan.

AGE	PALEOCENE									EOCENE								
	Middle			Late						Early				Middle				Late
FORMATION	Dunghan Fm.										Ghazij Fm.			Kirthar Fm.				
PLANKTONIC FORAMINIFERAL ZONES	*Morozovella angulata* Interval Zone			*Planorotalites pseudomenardii* PRZ			*Morozovella velascoensis* IZ			*Morozovella subbotinae* IZ		*M. f. formosa* IZ	*M. aragonensis* IZ	*M. spinulosa / Truncorotaloides topilensis* TRZ			*Catapsydrax howei* IZ	*G. officinalis* IZ
Samples / Species	ZPW-1	ZPW-5	ZPW-15	ZPW-16	ZPW-17	ZPW-18	ZPW-19	ZPW-20	ZPW-21	ZPW-22	ZPW-23	ZPW-24	ZPW-26	ZPW-61	ZPW-62	ZPW-63	ZPW-65	ZPW-70
Acarinina broedermanni											•	•	•					
A. collactea														•		•		
A. irrorata											•							
A. mckannai				•		•	•	•	•	•	•	•	•					
A. nitida							•	•	•	•	•	•	•					
A. primitiva							•	•	•	•	•							
A. pseudotopilensis									•	•	•	•						
A. pentacamerata													•					
A. soldadoensis soldadoensis							•	•	•	•	•	•	•					
A. soldadoensis angulosa												•	•					
A. triplex											•							
Chiloguembilina martini															•			
C. woodi															•			
Catapsydrax howei														•	•	•	•	
Globigerina baylissi																	•	
G. inaquispira											•	•	•					
G. officinalis															•	•	•	•
G. ouachitaensis																	•	
G. prolata												•	•	•				
G. linaperta									•	•	•	•		•				
G. triloculinoides	•	•	•	•	•	•	•	•	•									
G. varianta													•		•	•		
G. velascoensis								•										
G. yeguaensis														•	•	•		
Globigerinoides higginsi														•	•	•	•	
Globigerinatheka mexicana barri														•				
G. mexicana mexicana														•				
G. mexicana kugleri														•				
G. index tropicalis														•				
Globigerinita africana														•				
G. echinata														•				
Hantkenina dumblei																•		
H. mexicana																•		
Hastigerina' cf. bolivariana														•				
Morozovella acuta				•	•	•	•	•	•	•								
M. aequa		•	•	•	•	•	•	•	•	•								
M. angulata	•	•	•	•	•	•	•	•										
M. apanthesma							•	•										
M. aspensis											•							
M. aragonensis												•						
M. conicotruncata		•	•	•	•	•	•	•										
M. esnaensis											•							
M. formosa formosa												•						
M. formosa gracilis											•	•						
M. kolchidica			•															
M. lehneri														•				
M. lensiformis												•						
M. marginodendata										•	•							
M. occlusa				•	•	•	•	•	•									
M. parva					•	•	•	•	•									
M. pseudobulloides		•	•	•	•													
M. quadrata													•					
M. quetra											•	•						
M. spinulosa														•	•	•		
M. subbotinae										•	•							
M. uncinata		•																
M. velascoensis		•	•	•	•	•	•	•	•									
M. whitei											•	•	•					
M. wilcoxensis							•	•	•		•	•						
Planorotalites chapmani		•		•	•	•	•	•										
P. compressa	•	•																
P. ehrenbergi		•		•	•	•	•		•									
P. elongata							•		•									
P. palmerae															•			
P. pseudomenardii				•	•	•	•	•	•									
P. pusilla pusilla	•	•	•															
Pseudohastigerina danvilensis														•	•			
P. micra														•	•	•		
P. sharkriverensis														•		•		
P. pseudoiota													•					
P. wilcoxensis										•	•		•					
Turborotalia cerroazulensis pomeroli														•	•	•		
T. frontosa															•	•		
T. planoconica														•				
Truncorotaloides libyaensis															•		•	
T. rohri														•	•	•		
T. topilensis														•	•	•		

Table 4 Planktonic foraminiferal zonation of the Paleocene-Eocene sequence of the Zinda Pir section, Sulaiman Range, Southern Indus Basin, Pakistan.

Formation	Member	Planktonic Foraminiferal Zones	Age	
Kirthar Fm.	Drazinda Mem.	*Globigerina officinalis* Interval Zone	Late	Eocene
		Catapsydrax howei Interval Zone	Middle	
	Pirkoh LS. & Marl Mem.	*Morozovella spinulosa / Truncorotaloides topilensis* Total-range Zone		
	Sirki Mem.	{Zone of rare and very poorly preserved, indeterminable planktonic foraminifers.}		
	Habib Rahi LS. Mem.			
Ghazij Fm.			Early	
		Morozovella aragonensis Interval Zone		
		Morozovella formosa formosa Interval Zone		
		Morozovella subbotinae Interval Zone		
Dunghan Fm.		*Morozovella velascoensis* Interval Zone	Late	Paleocene
		Planorotalites pseudomenardii Partial-range Zone		
		Morozovella angulata Interval Zone	Middle	

zone. Only one species, *M. pseudobulloides*, which ranges up from the underlying zone disappears in the lower part of this zone.

3) *Morozovella velascoensis Interval Zone*

Definition

The base of the zone is taken with the first occurrence of the Acarinina soldadoensis soldadoensis whereas the top of the zone is marked by the last occurrence of *Morozovella velascoensis*.

Characteristics

This zone is represented by samples ZPW-19 to ZPW-21 from the Dunghan Formation. A total of twenty-one planktonic foraminiferal species were recorded from this zone. Three species *P. elongata, M. apanthesma* and *Globigerina velascoensis* restrict to this zone only. Nine species *Globigerina triloculinoides, M. angulata, M. conicotruncata, M. occlusa, M. parva. M. velascoensis, P. chapmani, P. ehrenbergi* and *Planorotalites pseudomenardii* which range up from the lower zone all disappear near the top of this zone.

Seven species, *A. nitida, A. primitiva, A. pseudotopilesis, A. soldadoensis soldadoensis, G. linaperta* and *M. wilcoxensis*, appear for the first time in this zone and range up to the next zones. Three species, *A. mckannai, M. aequa* and *M. acuta*, which appear in the lower zone and extend into the next zone.

4) *Morozovella subbotinae* Interval Zone

Definition

Interval from the extinction of the *M. velascoensis* to the first appearance of *M. aragonensis*.

Characteristics

This zone is represented by samples ZPW-22 from uppermost part of the Dunghan Formation and ZPW-23 from the lowermost part of the overlying Ghazij Formation.

This zone contains a very rich planktonic foraminiferal assemblage which occurs with excellent state of preservation. Twenty-one species were identified from this zone. Nine species, *A. nitida, A. primitiva, A. mckannai, A. pseudotopilesis, A. soldadoensis soldadoensis, G. linaperta, M. acuta, M. aequa,* and *M. wilcoxensis* range up from the underlying zone and among them, *M. acuta* and *M. aequa* disappear in the lower part of the zone.

Twelve species, *A. broedermanni, A. irrorata, A. triplex, G. inaquispira, M. aspensis, M. esnaensis, M. formosa gracilis, M. marginodentata, M. quetra, M. subbotinae, M. whitei* and *Pseudohastigerina wilcoxensis*, appear for the first time in this zone and among them six species, *A. irrorata, A. triplex, M. aspensis, M. esnaensis, M. marginodentata* and *M. subbotinae*, restrict to this zone whereas the remaining six range up to the next zones.

5) *Morozovella formosa formosa* Interval Zone

Definition

Interval from the first occurrence of *M. aragonensis* to the first appearance of *A. pentacamerata*.

Characteristics

This zone is represented by sample ZPW-24 from the lower part of the Ghazij Formation which produces abundant and well preserved planktonic foraminifers. It is characterized by the abundant occurrence of *M. aragonensis* and other stratigraphically important species such as *M. formosa formosa, M. formosa gracilis* and *M. lensiformis*.

Among seventeen planktonic foraminiferal species of *Acarinina, Globigerina, Morozovella* and *Pseudohastigerina* occurring in this zone, twelve range up from the underlying zone whereas three appear for the first time in this zone. Eight species extend up to the overlying zone and three species, *M. formosa formosa, M. aragonensis* and *M. lensiformis* are restricted in this zone.

6) *Morozovella aragonensis* Interval Zone

Definition

The base of this zone is taken as the first occurrence of *A. pentacamerata* which appears just above the extinction horizonof the *M. aragonensis*. The top of the zone is undefined as there is zone of indeterminable foraminifers immediately above this horizon.

Characteristics

This zone is represented by sample ZPW-26 and is characterized by the presence of *A. pentacamerata, A. broedermanni, A. nitida, G. inaquispira, G. varianta, M. quadrata* and *M. wilcoxensis. A. pentacamerata* is the most abundant and distinctive species in this zone.

Among fourteen species which occur in this zone, only three of them extend up to the next zone whereas rest of the eleven disappear in this zone.

7) *Morozovella spinulosa* / *Truncorataloides topilensis* Total-Range Zone
Definition

Total range of the nominate species.

Characteristics

This zone is represented by samples ZPW-61 to ZPW-63 from the upper part of the Kirthar Formation. This zone is characterized by the abundance of *T. topilensis* and *M. spinulosa*. The other important species are *M. lehneri, T. rohri, Turborotalia cerroazulensis pomeroli, H. mexicana, H. dumblei, Globigerinatheka mexcana barri, Globigerinatheka mexcana mexicana*, and *Globigerinatheka mexcana kugleri*.

The representatives of the nine genera, *Chiloguembilina, Catapsydrax, Globigerinita, Globigerinoides, Globigerinatheka, Hantkenina, Hastigerina, Truncorotaloides* and *Turborotalia*, appear for the first time in this zone. Thirty-two species and subspecies belonging to fourteen genera are identified and recorded in this zone which make it a zone containing the richest assemblage of the succession. The preservation is very well. The species of *Truncorotaloides* and Morozovella dominate the other planktonic foraminiferal genera. The genera *Chiloguembilina, Globigerinita, Globigerinatheka, Hantkenina, Hastigerina* and *Pseudohastigerina*, are restricted to this zone.

8) *Catapsydrax* howei Interval Zone
Definition

The base of the zone is taken as extinction of *M. spinulosa* and the last occurrence of *Catapsydrax howei* is taken as top.

Characteristics

This zone is represented by sample ZPW-65 which contains poorly preserved planktonic foraminifers. It is characterized by the presence of *A. bullbrooki, Catapsydrax howei, G. baylissi, G. officinalis, G. ouchitaensis, Globigerinoides higginsi* and *T. libyaensis*.

9) *Globigerina officinalis* Interval Zone
Definition :

The base of the zone is taken as the extinction of *Catapsydrax howei* whereas top of the zone is undefined because of the unconformity met above this zone.

Characteristics:

This zone is represented by sample ZPW-70 from the uppermost part of the Kirthar Formation which is separated from the overlying Siwalik Group of Miocene age through an unconformable contact. Most of the fauna found from this sample consists of reworked Middle Paleocene planktonic foraminifers. The only well preserved and abundantly occurring species is *Globigerina officinalis*.

6.2 Age and correlation

Dunghan Formation :

A total of 22 samples were collected from the Dunghan Formation which contain abundant and well preserved planktonic foraminifers. Four zones namely, *M. angulata* Interval Zone of the uppermost part of the Middle Paleocene, *P. pseudomenardii* Partial-Range Zone and *M. velascoensis* Interval Zone of the Late Paleocene and *M. subbotina* Interval Zone of the Early Eocene (Tables 3, 4). *M. subbotina* Interval Zone which extends to the overlying Ghazij Formation belonges to the Early Eocene. Therefore Middle Paleocene to Early Eocene age is assigned to the Dunghan Formation.

Ghazij Formation :

A total of 28 samples were collected and then processed in laboratory for planktonic foraminifers. Only three samples out of 28, produced abundant and well preserved planktonic foraminifers. These three samples were collected from the lowermost 50m which consists of marly shales. Rest of the 25 samples are either barren or produce very poorly preserved indeterminable planktonic foraminifers. Three biostratigraphic zones namely *M. subbotina* Interval Zone, *M. formosa formosa* Interval Zone and *M. aragonensis* Interval Zone (Tables 3 & 4) are recognized in this formation. Early Eocene age is assigned to the lower part of the Ghazij Formation.

Kirthar Formation:

A total of 29 samples were collected from all the four members of the Kirthar Formation (Fig. 3 & 4), among them only five samples produce planktonic foraminifers where as others don't contain any determinable planktonic foraminifers. The samples taken from the marly part of Pir Koh Limestone and Marl Member and lowermost part of the Drazinda Member contain abundant to common and well preserved planktonic foraminifers. The uppermost sample taken from the topmost marly part of the Drazinda Member contain very poor foraminifers mixed with reworked Paleocene planktonic foraminifers. Three planktonic foraminiferal zones, *Truncorotaloides topilensis* / *G. spinulosa* Tolal-Range Zone, *Catapsydrax howei* Interval Zone and *Globigerina officinalis* Interval Zone (Tables 3 & 4), has been recognized. The *Truncorotaloides topilensis* / *G. spinulosa* Tolal-range Zone and *Catapsydrax howei* Interval Zone belong to Middle Eocene whereas *Globigerina officinalis* Interval Zone belongs to the earliest part of the Early Eocene. Therefore Middle Eocene age is assigned to the Pir Koh and Marl Member whereas Drazinda Member of the Kirhtar Formation is assigned late Middle Eocene to early late Eocene.

6.3 Correlation between the established zones herein and those of others :

The planktonic foraminiferal zones established in the Zinda Pir section can be correlated locally with already established zones of Samanta (1973) and Dorreen (1974) in Rakhi Nala and Gaj River sections respectively (Table 5), in the Southern Indus Basin.

The planktonic foraminiferal assemblages recovered from the Zinda Pir section show a close resemblance with those of the Rakhi Nala which is situated 55km to the south of the study area. *Morozovella angulata* Interval Zone, *Planorotalites pseudomenardii* Partial-Range Zone and *Morozovella velascoensis* Interval Zone of the present study can be correlated with *Globorotalia angulata* and *Globorotalia velascoensis* zones of Samanta (1973) and Dorreen (1974) as shown in Table 5. However, in contrast to *Globorotalia aequa* Zone of Samanta (1973) which he has established in the Late Paleocene and looks inappropriate, the writer has errected *M. sobbotinae* Interval Zone in the Lower Eocene. Based on the occurrence and stratigraphic positions of the planktonic foraminiferal species, like *M. subbotinae, M. marginodenta, M. aequa, M. acuta* and *M. formosa gracilis* and first appearance of the planispiral species *Pseudohastigerina wilcoxensis* (See plates), *M. sobbotinae* Interval Zone is established in the Lower Eocene which is followed by the *M. formosa formosa* Interval Zone. These two zones are equivalent to the part of *G. aequa* and *G. formossa formossa* Zones of Samanta (1973) and *G. Rex* of Dorreen (1974) respectively.

M. aragonensis Zone can be correlated with the lower parts of the *G. espensis / G. esnaensis* and *G. aragonensis* zones of the Samanta (1973) and Dorreen (1974) respectively. *M. spinulosa / T. topilensis* and *Catapsydrax howei* Zones are collectively equivalent to *Globigerapsis Kugleri* Zone of Dorreen (1974) and *G. crassata / T. topilensis* and *T. rohri* zones of Samanta (1973). *Globigerina officinalis* Zone recognized in the Late Eocene is correlative with *Globigerina officinalis* Zone of the Samanta (1973) and with *G. cerroazulensis* Zone of Dorreen (1974) respectively.

Correlation of the proposed zones with those of the Bolli (1957 ; 1966), Toumarkine *et al.* (1985), Blow (1979) and Berggren *et al.* (1995) is shown in Table 6.

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Table 5 Correlation of the planktonic foraminiferal zonation of the Paleocene - Eocene sequence of the Zinda Pir section with those of others in the Southern Indus Basin, Pakistan.

Samanta (1973) Rakhi Nala Section	Dorreen (1974) Gaj River Section	This study Zinda Pir Section	Age	
Globigerina officinalis Zone	*G. cerroazulensis* Zone	*Globigerina officinalis* Interval Zone	Late	Eocene
T. rohri Zone	*Globigerapsis. kugleri* Zone	*Catapsydrax howei* Interval Zone	Middle	
G. crassata / T. topilensis Zone		*M. spinulosa / T. topilensis* Total-range Zone		
(No determinable planktonic foraminifers)	*Hantkenina dumblei* Zone	{Zone of rare and very poorly preserved, indeterminable planktonic foraminifers.}		
G. aspensis/ G. esnaensis Zone	*G. aragonensis* Zone	*M. aragonensis* Interval Zone	Early	
G. formosa formosa Zone	*G. rex* Zone	*M. formosa formosa* Interval Zone		
		M. subbotinae Interval Zone		
Globorotalia aequa Zone	*G. velascoensis* Zone	*M. velascoensis* Interval Zone	Late	Paleocene
G. velascoensis Zone		*Planorotalites pseudomenardii* Partial-range Zone		
G. angulata Zone	*G. angulata* Zone	*Morozovella angulata* Interval Zone	Middle	
(No determinable planktonic foraminifers)	*Globorotalia pseudobulloides* Zone			

Table 6 Correlation of the Paleocene to Eocene planktonic foraminiferal zones in the Zinda Pir area, Southern Indus Basin, Pakistan with those of Bolli (1957 ; 1966), Toumarkine *et al*. (1985), Blow (1979) and Berggren *et al*. (1995).

Age		Bolli (1957;1966) and Bolli & Saunders (1985)	Blow (1979)		Berggren et al. (1995)			This study
EOCENE	LATE	*G. semiinvoluta*	P15	*Porticulasphaera. semiinvoluta*	P15	*Porticulasphaera. semiinvoluta*		*Globigerina officinalis* Interval Zone
	MIDDLE	*T. rohri*	P14	*G. (M.) spinulosa spinulosa*	P14	*T. rohri - M. spinulosa PRZ*		*Catapsydrax howei* Interval Zone
		O. beckmanni	P13	*Globigerapsis beckmanni*	P13	*Globigerapsis beckmanni TRZ*		*M. spinulosa / T. topilensis TRZ*
		M. lehneri	P12	*G.(M.) lehneri*	P12	*M. lehneri PRZ*		{Zone of rare and very poorly preserved, indeterminable planktonic foraminifers.}
		G. s. subconglobata	P11	*Globigerapsis kugleri/ S. frontosa boweri*	P11	*Gb. kugleri/ M. aragonensis CRZ*		
		H. nuttali	P10	*S. frontosa frontosa/ G. (T.) pseudomayeri*	P10	*Hantkenina nuttali IZ*		
	EARLY	*A. pentacamerata*	P9	*G. (A.) aspensis/ G. lozanoi prolata*	P9	*P. palmerae - H. nuttali IZ*		
					P8	*M. aragonensis PRZ*		
		M. aragonensis	P8b	*G.(M.)aragonensis/ G.(M). formosa*	P7	*M. aragonensis/ M. formosa CRZ*		*M. aragonensis* Interval Zone
		M. formosa formosa	P8a	*G.(M.) formosa/ G.(M.)lensiformis*	P6	*M.subbotinae - PRZ*	*M. formosa/ M. lensiformis- M. aragonensis ISZ (P6b)*	*M. formosa formosa IZ*
		M. subbotinae	P7	*G. (A.) wilcoxensis berggreni*			*M. velascoensis- M. formosa formosa/ M. lensiformis- ISZ (P6a)*	*M. subbotinae IZ*
		M. edgari						
PALEOCENE	LATE	*M.velascoensis*	P6	*G. (M.) subbotinae subbotinae - G.(M.) velascoensis acuta*	P5	*M. velascoensis PRZ*		*M. velascoensis IZ*
			P5	*Muricoglobigerina s. soldadoensis/ Globorotalia (M.)velascoensis pasionensis*	P4	*G.pseudomenardii TRZ*	*Acarinina. soldadoensis- Gl. pseudomenardii CRSZ (P4c)*	
		P.pseudomenardii	P4	*G. (G.) pseudomenarii*			*Ac. subsphaerica- Ac. soldadoensis IRSZ (P4b)*	*P. pseudomenardii PRZ*
							Gl. pseudomenardii/ Ac. subsphaerica CRSZ (P4a)	
	MIDDLE	*P. pusilla pusilla*	P3	*G.(M.) angulata angulata*	P3	*M. angulataGlobanomalina pseudomenardii IZ*	*Igorina albeari- Globanomalina pseudomenardii ISZ(P3b)*	*M. angulata IZ*
		M. angulata					*M. angulata-Igorina albeari ISZ (P3a)*	

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Appendix (A): Faunal reference list

The classification followed here is based on Blow (1979), Stainforth *et al.* (1975), Toumarkine *et al.* (1985) and, Loeblich and Tappan (1988). The planktonic foraminifers reported here are already well established in paleontological literature, thus the reader is reffered to Subbotina (1953), Bolli (1957a,b), El-Naggar (1966), Blow (1979), Stainforth *et al.* (1975) and Toumarkine *et al.* (1985). The synonymies of the planktonic foraminifers described here, are restricted to only the orignal descriptions. SEM photomicrographs for the biostratigraphically important species of planktonic foraminifera are figured in plates 1-15.

Chiloguembelina martini (Pijpers)

Textularia martini Pijpers, 1933, p. 57, figs. 6-10.

Chiloguembelina woodi Samanta

Chiloguembelina woodi Samanta, 1973, p. 432-433, pl. 15, figs. 15-16.

Globigerina baylissi Samanta --------- pl. 2, figs. 3a-c.

Globigerina baylissi Samanta, 1973, p.436, pl.2, fig 4-6.

Globigerina inaquispira Subbotina --- pl. 2, figs. 1a-c.

Globigerina inaquispira Subbotina, 1953, p. 69, pl. 6, fig. 1a-4c.

Globigerina officinalis Subbotina ------ pl. 1, figs. 1a-c.

Globigerina officinalis Subbotina,1953, p. 78, pl. 11, fig. 1a-2c, 6a-7c, 5a-c.

Globigerina ouchitaensis Howe & Wallace ---------------------------------- pl. 1, figs. 2a-c.

Globigerina ouchitaensis Howe & Wallace, 1932, p.74, pl. 10, figs. 7a-b.

Globigerina prolata Bolli ---------------- pl. 2, figs. 2a-c.

Globigerina prolata Bolli, 1957a, p. 72. pl. 15, figs. 24-26.

Globigerina linaperta Finlay ----------- pl. 1, figs. 4a-c.

Globigerina linaperta Finlay, 1939a, p. 125, pl. 13, figs. 54-57.

Globigerina triloculinoides Plummer pl. 1, figs. 3a-c.

Globigerina triloculinoides Plummer, 1926, p.134-135, pl. 8, figs. 10a-c.

Globigerina varianta Subbotina ------ pl. 2, figs. 4a-c.

Globigerina varianta Subbotina, 1953, p. 63-64, pl. III, figs. 5a-7c, 9a-12c, pl. IV, figs. 1a-3c, pl. XV, fig. 1a-3c.

Globigerina velascoensis Cushman

Globigerina velascoensis Cushman, 1925c, p. 19, pl. 3, figs. 6a-c.

Globigerina yeguaensis Weinzierl & Applin

Globigerina yeguaensis Weinzierl & Applin, 1929, p. 408, pl. 43, figs. 1a-b.

Catapsydrax howei (Blow & Banner) pl. 4, figs. 2a-c.

Globigerinita howei Blow & Banner, 1962, p.109, fig. 11, x-xiv, pl. 14, fig. p-r.

Globigerinoides higginsi Bolli --------- pl. 4, figs. 3a-c.

Globigerinoides higginsi Bolli, 1957b, p. 164-165, pl. 36,

figs. 11a-13b.
Globigerinita africana Blow & Banner --- pl. 5, fig. 4a
Globigerinita africana Blow & Banner, 1962, p. 105 -106, pl. 15, figs. a-c, text fig. 11 (i-iv)
Globigerinita echinata (Bolli) -------- pl. 4, figs. 4a-c.
Catapsydrax echinatus Bolli, 1957, p. 165-166, pl. 37, figs. 2a-5b.
Globigerinatheka mexicana barri Bronnimann ---------------------------------- pl. 5, figs. 3a-b.
Globigerinatheka barri Bronnimann, 1952a, p. 27-28, text figs. 3a-c, g-h.
Globigerinatheka mexicana mexicana (Cushman) ---------------------------------- pl. 5, figs. 2a-c.
Globigerina mexicana Cushman, 1925b, p. 6, pl. 1, figs. 8a-b.
Globigerinatheka mexicana kugleri (Bolli, Loeblich & Tappan) ---------------------- pl. 5, figs. 1a-c.
Globigerapsis kugleri Bolli, Loeblich & Tappan, 1957, p. 34, pl. 6, figs. 6a-c.
Globigerinatheka index tropicalis (Blow & Banner)
Globigerapsis tropicalis Blow & Banner, 1962, p. 124, pl. 15, figs. d-e.
Hastigerina cf. *bolivarina* Petters (in Toumarkine et al. 1985) ---------------------- pl. 3, figs. 1a-c.
Globigerina wilsoni bolivariana Petters, 1954, p. 39, pl. 8, figs. 9a-c.
Acarinina broedermanni (Cushman and Bermudez) ---------------------------------- pl. 6, figs 4a-c.
Globorotalia (*Truncorotalia*) *broedermanni* Cushman and Bermudez, 1949, p. 40, pl. 7, figs. 22-24.
Acarinina collactea (Finlay)
Globorotalia collactea Finlay, 1939b, p. 37, pl. 29, figs. 164-165.
Acarinina irrorata (Loeblich and Tappan)
Globorotalia irrorata Loeblich and Tappan, 1957, p. 191, pl. 61, figs. 5a-c.
Acarinina mckannai (White) -------- pl. 6, figs. 2a-c.
Globigerina mckannai White, 1928, p. 194, pl. 27, fig. 16.
Acarinina nitida (Martin) -------------- pl. 6, figs 3a-c.
Globigerina nitida Martin, 1943, p. 115, pl. 7, fig. 1.
Acarinina primitiva (Finlay) ----------- pl. 8, figs. 4a-c.
Globoquadrina primitiva Finlay, 1939b, p. 291, pl. 8, figs. 129-134.
Acarinina pseudotopilensis Subbotina ---------------------------------- pl. 8, figs. 3a-c.
Acarinina pseudotopilensis Subbotina, 1953, p. 227-228, pl. 21, figs. 8-9; pl. 22.
Acarinina pentacamerata (Subbotina) pl. 6, figs 1a-c.
Globorotalia pentacamerata Subbotina, 1947, p. 128-9, pl. 7, fig. 24-26.
Acarinina soldadoensis soldadoensis (Bronnimann) --------------------------------- pl. 4, figs 1a-c.
Globigerina soldadoensis Bronnimann, 1952a, p. 7-9, pl. 1, figs. 1-9
Acarinina soldadoensis angulosa (Bolli) ---------------------------------- pl. 3, figs. 3a-c.
Globigerina soldadoensis angulosa Bolli, 1957a, p. 71, pl. 16 figs. 4-6
Acarinina triplex Subbotina -------- pl. 13, figs 4a-c.
Acarinina triplex Subbotina, 1953, p. 230, pl. 23, figs. 1a-c.; figs. 2a-5c.
Morozovella acuta (Toulmin) -------- pl. 12, figs 2a-c.
Globorotalia wilcoxensis Cushman & Ponton var. *acuta* Toulmin, 1941, p. 608, pl. 82, figs. 6-8.
Morozovella aequa (Cushman & Renz) ------------------------------- pl. 11, figs. 3a-c.
Globorotalia crassata (Cushman) var. *aequa* Cushman & Renz, 1942, p. 12, pl. 3, figs. 3.
Morozovella angulata (White) -------- pl. 7, figs. 4a-c.
Globigerina angulata White, 1928, p. 191-192, pl. 27, figs. 13a-c.
Morozovella apanthesma (Loeblich & Tappan) ---------------------------------- pl. 7, figs. 3a-c.
Globorotalia cf. *angulata* (White) Shifflett, 1948, p. 72, pl. 4, figs. 4a-c, 18a-c.
Morozovella aragonensis (Nuttall) --- pl. 10, figs. 3a-c.
Globorotalia aragonensis Nuttall, 1930, p. 288-289, pl. 24, figs. 6-8, 10-11.
Morozovella aspensis (Colom)
Globigerina aspensis Colom, 1954, p. 151-152, pl. 3, figs. 1-31.
Morozovella conicotruncata (Subbotina) ---------------------------------- pl. 7, figs. 2a-c.
Globorotalia conicotruncata Subbotina, 1947, p. 115 -117, pl. 4, fig. 11-13, pl. 9, figs. 9-11.
Morozovella esnaensis (LeRoy)
Globigerina esnaensis LeRoy, 1953, p. 31, pl. 6, figs. 8-10.
Morozovella formosa formosa (Bolli) pl. 10, figs. 1a-c.
Globorotalia formosa formosa Bolli, 1957a, p. 76, pl. 18, figs. 1-3.
Morozovella formosa gracilis (Bolli) pl. 10, figs. 2a-c.
Globorotalia formosa gracilis Bolli, 1957a, p. 75-76, pl. 18, figs. 4-6.
Morozovella kolchidica (Morozova) pl. 10, figs. 4a-c.
Globorotalia kolchidica Morozova, 1961, p. 17, pl. 2, figs. 2.
Morozovella lehneri (Cushman & Jarvis) ------------------------------- pl. 11, figs. 1a-c.
Globorotalia lehneri Cushman & Jarvis, 1929, p. 17, pl. 3, figs. 16a-3.
Morozovella lensiformis (Subbotina) pl. 11, figs. 4a-c.
Globorotalia lensiformis Subbotina, 1953, p. 214, pl. 18, figs. 4-5.
Morozovella marginodentata (Subbotina) ---------------------------------- pl. 9, figs. 1a-c.
Globorotalia marginodentata Subbotina, 1953, p. 212 -213, pl. 17, figs. 15a-16c, pl. 18, figs. 1-3.
Morozovella occlusa (Loeblich & Tappan)
Globorotalia occlusa Loeblich & Tappan 1957, p. 191, pl. 55, fig. 3, pl. 64, figs. 3a-c.
Morozovella parva (Rey) ------------- pl. 12, figs. 3a-c.
Globorotalia velascoensis (Cushman) var. *parva* Rey,

1955, p. 209, pl. 12, figs. 1a-b.
Morozovella pseudobulloides (Plummer) ---------------------------------- pl. 3, figs. 2a-c.
Globigerina pseudobulloides Plummer, 1926, p. 133-134, pl. 8, figs. 9a-c.
Morozovella quadrata (White) -------- pl. 7, figs. 1a-c.
Globigerina quadrata White, 1928, p. 195, pl. 27, figs. 18a-b.
Morozovella quetra (Bolli) -------------- pl. 8, figs. 2a-c.
Globorotalia quetra Bolli, 1957a, p. 79-80, pl. 19, figs. 1-6.
Morozovella spinulosa (Cushman) --- pl. 11, figs. 2a-c.
Globorotalia spinulosa Cushman, 1927, p. 114, pl. 23, figs. 4a-c.
Morozovella subbotinae (Morozova) pl. 9, figs. 2a-c.
Globorotalia subbotinae Morozova, 1939, p. 80, pl. 2, figs. 16-17.
Morozovella uncinata (Bolli)
Globorotalia uncinata Bolli, 1957a, p.74, pl. 17, figs. 13-15.
Morozovella velascoensis (Cushman) pl. 12, figs 1a-c.
Pulvinulina velascoensis Cushman, 1925c, p. 19,pl. 3, figs. 5a-c.
Morozovella whitei (Weiss)
Globorotalia whitei Weiss, 1955, p. 18-19. pl. 6, figs. 1-3
Morozovella wilcoxensis (Cushman & Ponton) ---------------------------------- pl. 8, figs. 1a-c.
Globorotalia wilcoxensis Cushman & Ponton, 1932, p. 71, pl. 9, figs. 10a-c.
Planorotalites chapmani (Parr) ------ pl. 14, figs. 2a-c.
Globorotalia chapmani Parr, 1938, p. 87, pl. 3, fig. 8-9b.
Planorotalites compressa (Plummer) --- pl. 14, fig. 4c.
Globorotalia compressa Plummer, 1926, p. 135, pl. 8, figs. 11a-c.
Planorotalites ehrenbergi (Bolli) --- Pl. 14, figs. 1a-c.
Globorotalia ehrenbergi Bolli, 1957a, p.77, pl. 20, figs. 18-20.
Planorotalites elongata (Glaessner) pl. 14, figs. 3a-c.
Globorotalia pseudoscitula var. *elongata* Glaessner, 1937, p. 33, figs. 3d-f.
Planorotalites palmarae (Cushman and Bermudez)
Globorotalia palmarae Cushman and Bermudez, 1949, p. 26, pl. 2, figs. 51-53.
Planorotalites pseudomenardii (Bolli) ------------------------------- pl. 12, figs. 4a-c.
Globorotalia pseudomenardii Bolli, 1957p. 77, pl. 20, figs. 14-17.
Planorotalites pusilla pusilla (Bolli) pl. 3, figs. 4a-c.
Globorotalia pusilla pusilla Bolli, 1957, p.78, pl. 20, fig. 8-10.
Turborotalia cerroazulensis pomeroli (Toumarkine & Bolli) ------------------- pl. 9, figs. 3a-c, 4a-c.
Globorotalia cerroazulensis pomeroli Toumarkine and Bolli, 1970, p. 140, pl. 1, fig. 13.
Turborotalia frontosa (Subbotina)
Globigerina frontosa Subbotina, 1953, p. 84, pl. 12, figs. 3a-c.
Turborotalia planoconica (Subbotina) ------------------------------- pl. 15, figs. 3a-c.
Globorotalia planoconica Subbotina, 1953, p. 210, pl. 17, figs. 4a-c.
Truncorotaloides libyaensis El Khoudary
Truncorotaloides libyaensis El Khoudary, 1977, p.330, pl.2, fig. 1
Truncorotaloides rohri Bronnimann & Bermudez ------------------------------- pl. 13, figs. 1a-c.
Truncorotaloides rohri Bronnimann & Bermudez 1953, p. 818-819, pl. 87, figs. 7-9.
Truncorotaloides topilensis (Cushman) -------------------------- pl. 13, figs. 2a-c, 3a-c.
Globigerina topilensis Cushman, 1925b, p. 7, pl. 1 fig.9.
Hantkenina dumblei Weinzierl & Applin ------------------------------- pl. 15, figs. 1a-c.
Hantkenina dumblei Weinzierl & Applin, 1929, p. 402, pl. 43, figs5a-b.
Hantkenina mexicana Cushman ------ pl. 15, figs. 2a-c.
Hantkenina mexicana Cushman, 1925c p. 3, pl. 2, fig. 2.
Pseudohastigerina danvilensis (Howe & Wallace)
Nonion danvilensis Howe & Wallace, 1932, p. 51-52, pl. 9, figs. 3a-b.
Pseudohastigerina micra (Cole)
Noniana micrus Cole, 1927, p. 22, pl. 12.
Pseudohastigerina pseudoiota (Hornibrook)
Globigerina pseudoiota Hornibrook, 1958a, p. 34, pl. 1, figs. 16-18.
Pseudohastigerina wilcoxensis (Cushman & Ponton) ------------------------------- pl. 15, figs. 4a-c.
Nonionwilcoxensis Cushman & Ponton, 1932, p. 64, pl. 8, figs. 11a-b. 41

パキスタンの南インダス堆積盆スライマン山脈ジンダピア地域における暁新-始新統の地質および浮遊性有孔虫生層序

M. Y. WARRAICH・名取博夫

要　旨

ジンダピア地域のソリナディ川には暁新世中期から始新世後期の浅海-深海成の堆積物が連続的に発達し，下位から Dunghan 層，Ghazij 層，Kirthar 層の 3 層に区分される．これらの地層の有孔虫化石分析により，14層77種・亜種の浮遊性有孔虫が同定され，これら地層は下位から *Morozovella angulata* Interval Zone, *Planorotalites pseudomenardii* Partial-Range Zone, *Morozovella formosa formosa* Interval Zone, *Morozovella aragonensis* Interval Zone, *Morozovella spinulosa* / *Truncorotaloides topilensis* Total-Range Zone, *Catapsydrax howei* Interval Zone, *Globigerina officinalis* Interval Zone の 9 帯に分帯される．

広域対比の結果，Dunghan 層は中部暁新-下部始新統，Ghazij 層は下部始新統，Kirthar 層は中部-上部始新統下部にそれぞれ対比される．

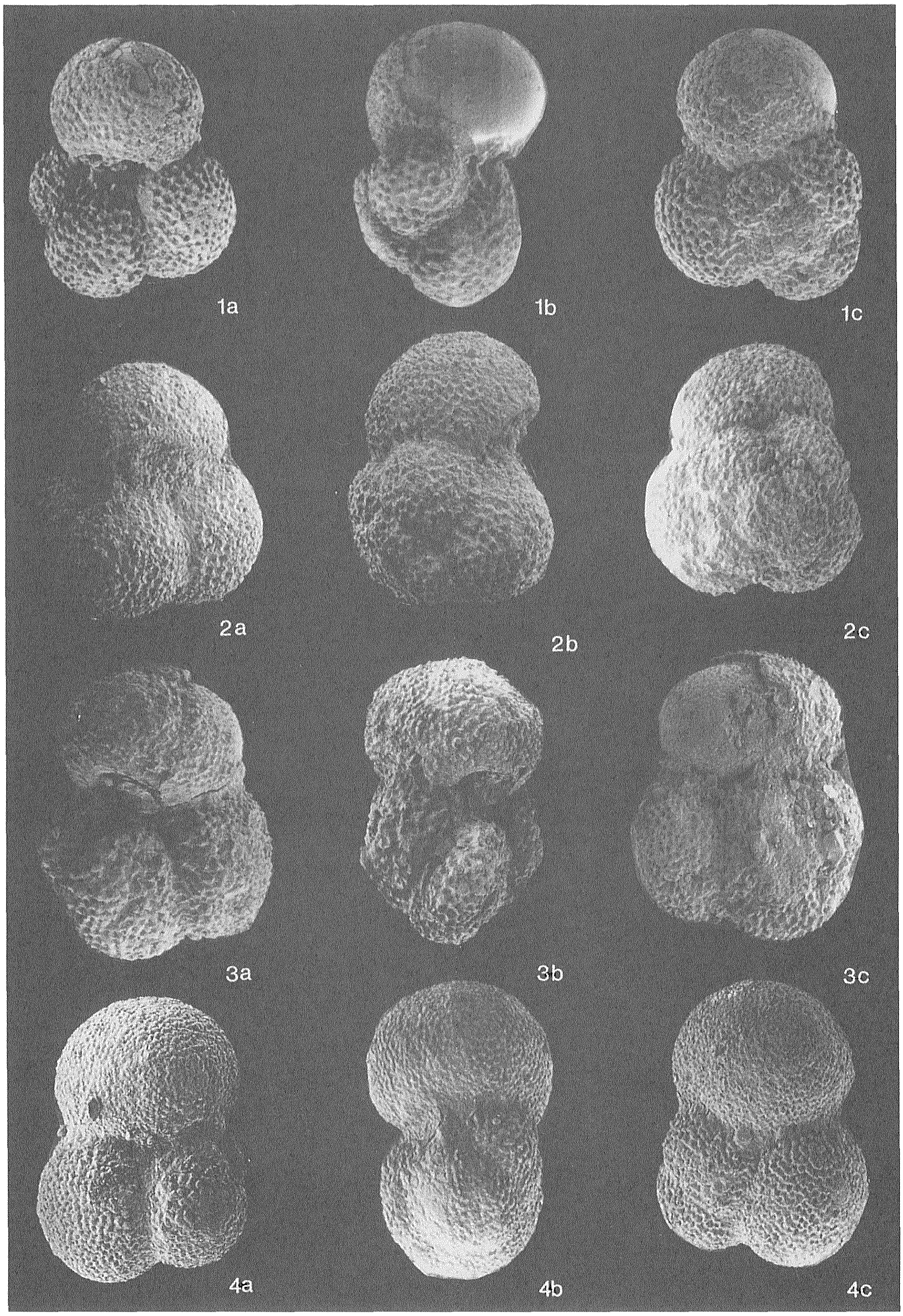

Plate 1 Paleocene-Eeocene planktonic foraminifera from the Zinda Pir section, Sulaiman Range, Southern Indus Basin, Pakistan. (All are scanning electron photomicrographs).

Figures:

1 a-c. *Globigerina officinalis* Subbotina, umbilical, side and spiral views, x450, sample ZPW-70.
2 a-c. *Globigerina ouchitaensis* Howe & Wallace, umbilical, side and spiral views, x350, sample ZPW-65.
3 a-c. *Globigerina triloculinoides* Plummer, umbilical, side and spiral views, x270, sample ZPW-15.
4 a-c. *Globigerina linaperta* Finlay, umbilical, side and spiral views, x350, sample ZPW-23

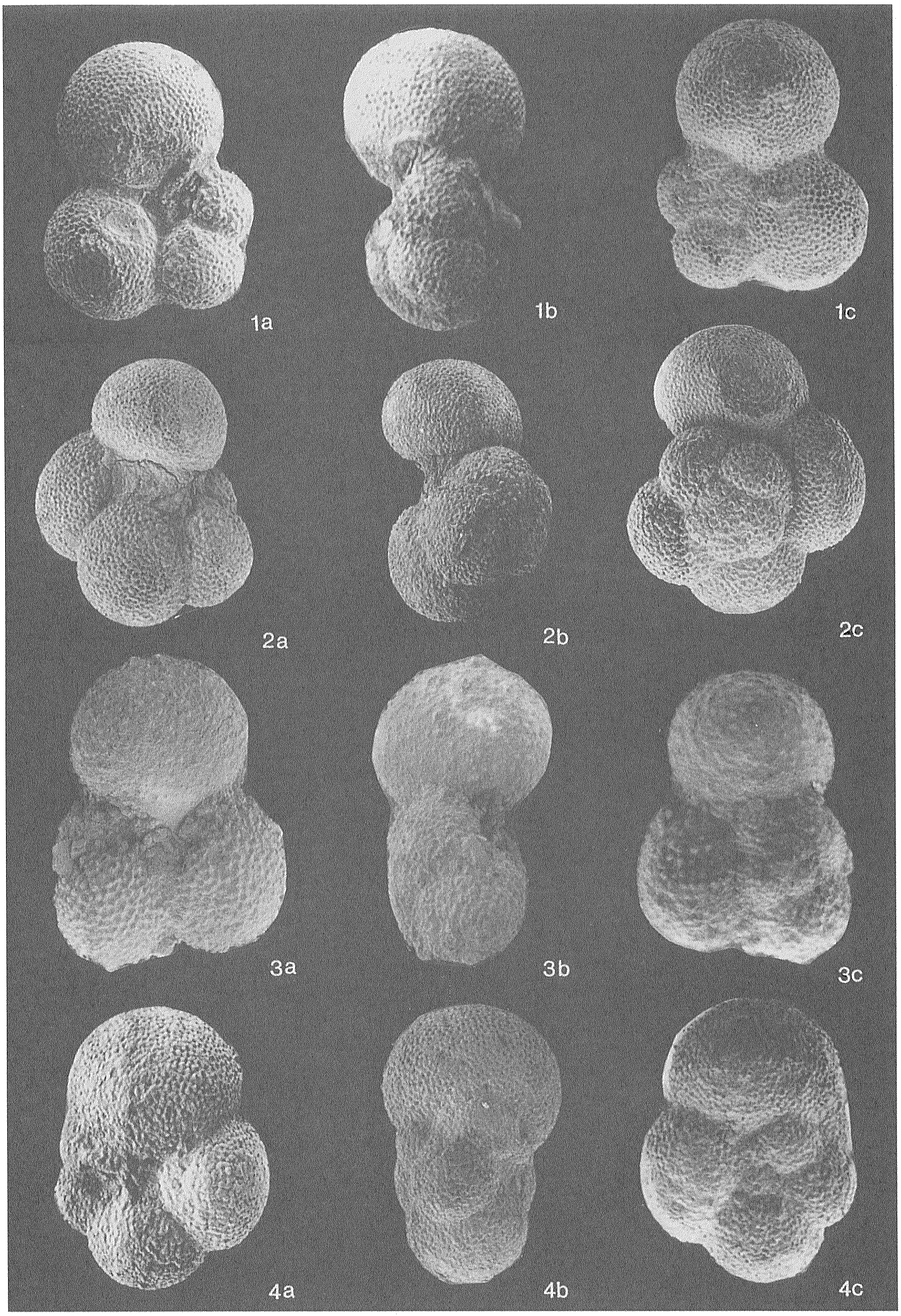

Plate 2 Paleocene-Eeocene planktonic foraminifera from the Zinda Pir section, Sulaiman Range, Southern Indus Basin, Pakistan. (All are scanning electron photomicrographs)

Figures :

1 a-c. *Globigerina inaquispira* Subbotina, umbilical, side and spiral views, x270, sample ZPW-24

2 a-c. *Globigerina prolata* Bolli, umbilical, side and spiral views, x230, sample ZPW-24

3 a-c. *Globigerina baylissi* Samanta, umbilical, side and spiral views, x350, sample ZPW-65

4 a-c. *Globigerina varianta* Subbotina, umbilical, side and spiral views, x350, sample ZPW-26

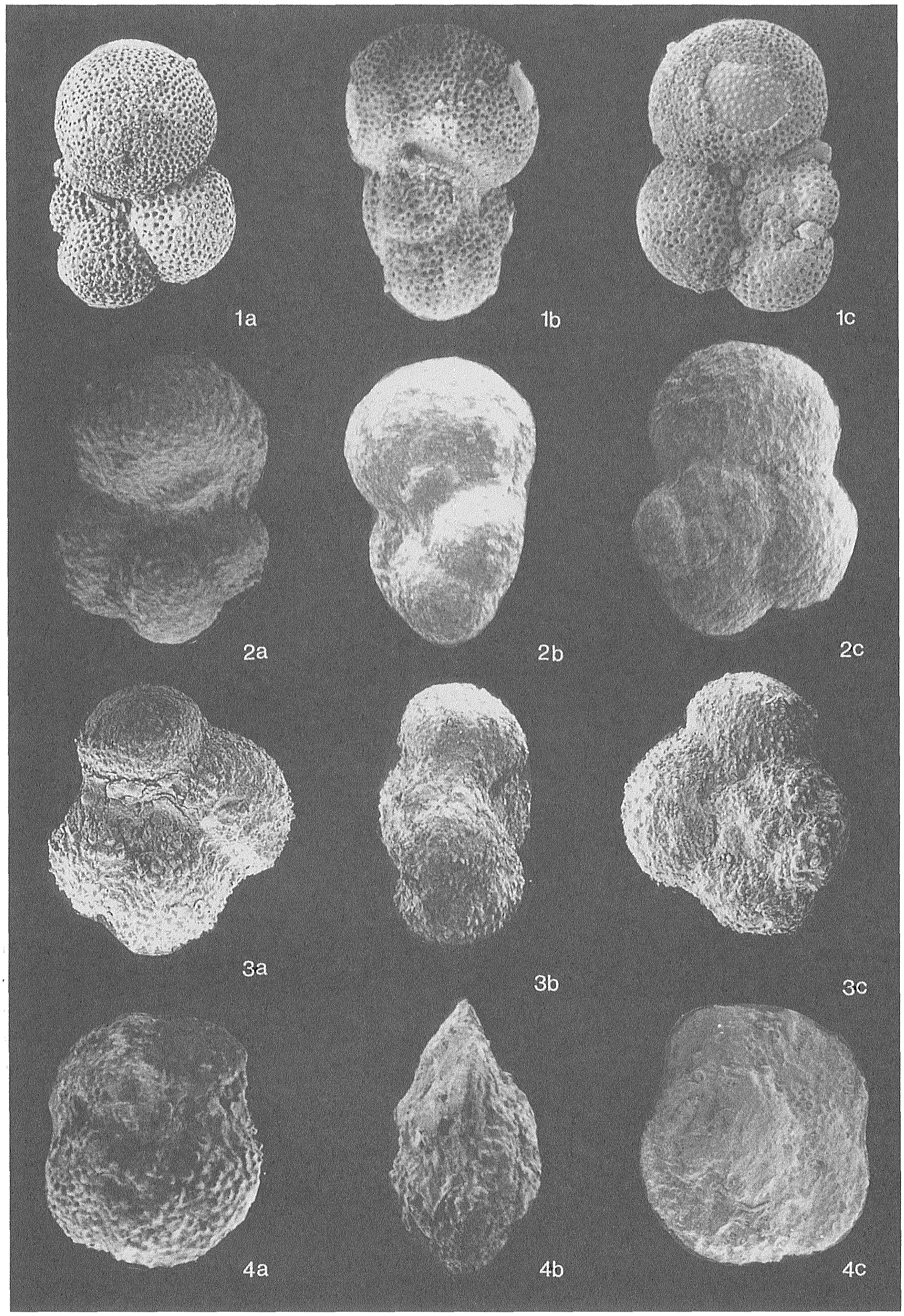

Plate 3 Paleocene-Eeocene planktonic foraminifera from the Zinda Pir section, Sulaiman Range, Southern Indus Basin, Pakistan. (All are scanning electron photomicrographs)

Figures:

1 a-c. *Hastigerina* cf. *bolivariana* (Petters), umbilical, side and spiral views, x300, sample ZPW-61
2 a-c. *Morozovella pseudobulloides* (Plummer), umbilical, side and spiral views, x550, sample ZPW-5
3 a-c. *Acarinina soldadoensis angulosa* (Bolli), umbilical, side and spiral views, x200, sample ZPW-23
4 a-c. *Planorolites pusilla pusila* (Bolli), umbilical, side and spiral views, x370, sample ZPW-15

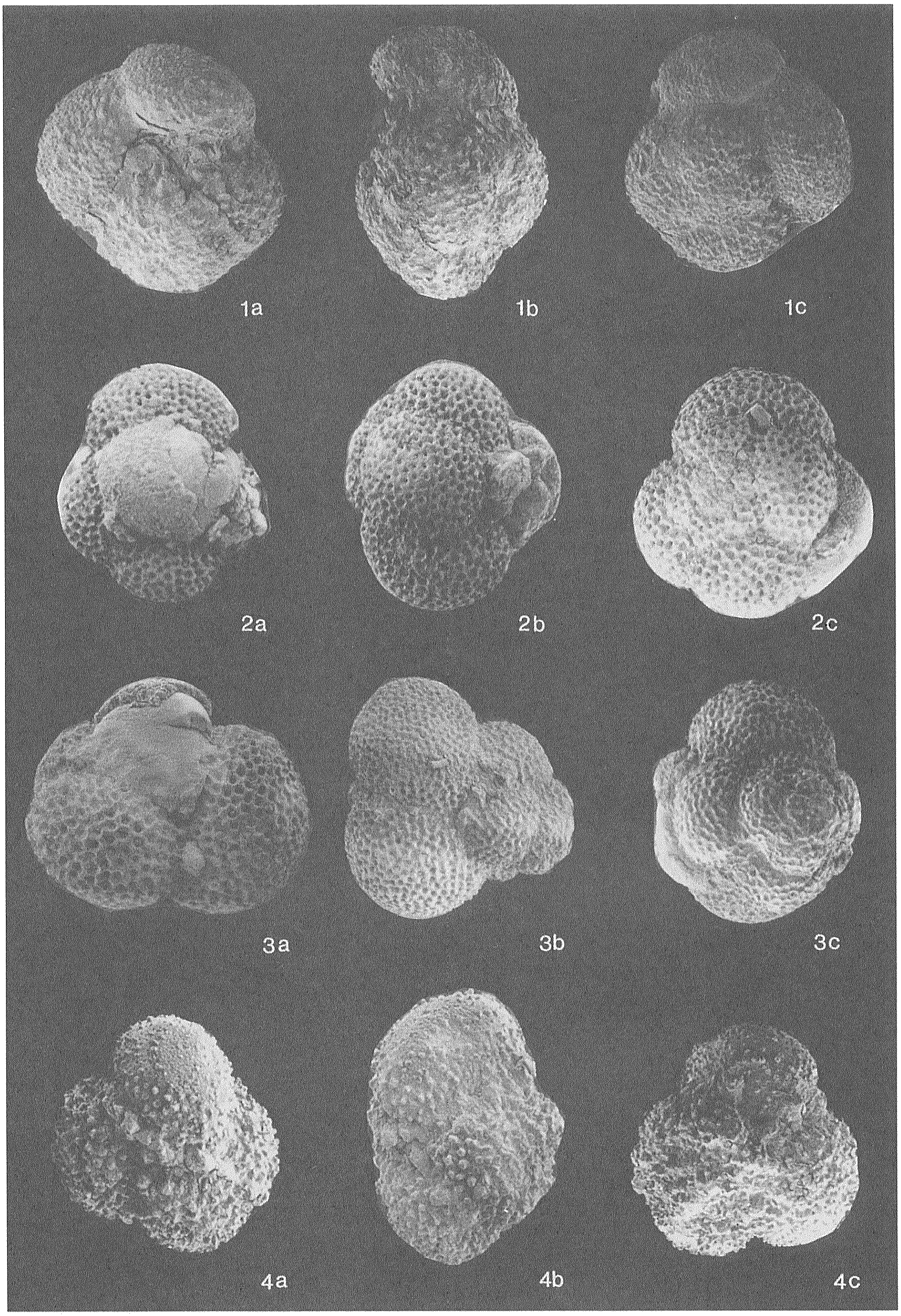

Plate 4 Paleocene-Eeocene planktonic foraminifera from the Zinda Pir section, Sulaiman Range, Southern Indus Basin, Pakistan. (All are scanning electron photomicrographs)

Figures:

1 a-c. *Acarinina soldadoensis soldadoensis* (Bronnimann), umbilical, side and spiral views, x250, sample ZPW-21

2 a-c. *Catapsydrax howei* (Blow & Banner), umbilical, side and spiral views, x350, sample ZPW-61

3 a-c. *Globigerinoides higgins* (Cushman), umbilical, side and spiral views, x300, sample ZPW-61

4 a-c. *Globigerinita echinata* (Bolli), umbilical, side and spiral views, x300, sample ZPW-61

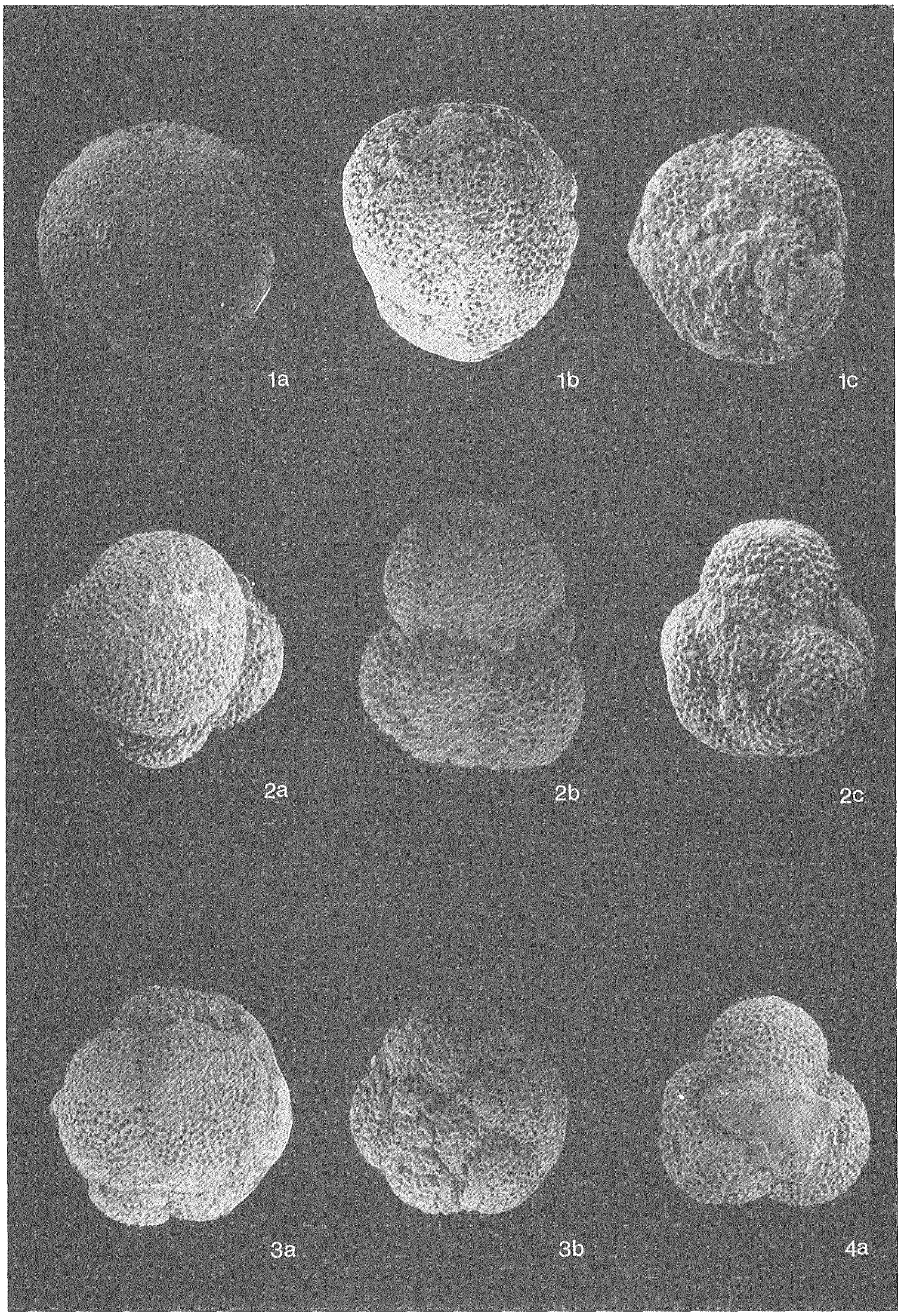

Plate 5 Paleocene-Eeocene planktonic foraminifera from the Zinda Pir section, Sulaiman Range, Southern Indus Basin, Pakistan. (All are scanning electron photomicrographs)

Figures :

1 a-c. *Globigerinatheka maxicana kugleri* (Bolli, Loeblich & Tappan), umbilical, side and spiral views, x270, sample ZPW-61

2 a-c. *Globigerinatheka maxicana maxicana* (Cushman), umbilical, side and spiral views, x330, sample ZPW-61

3 a-b. *Globigerinatheka maxicana barri* Bronnimann, umbilical, and spiral views, x200, sample ZPW-61

4 a. *Globigerinita africana* Blow & Banner, umbilical view, x300, sample ZPW-61

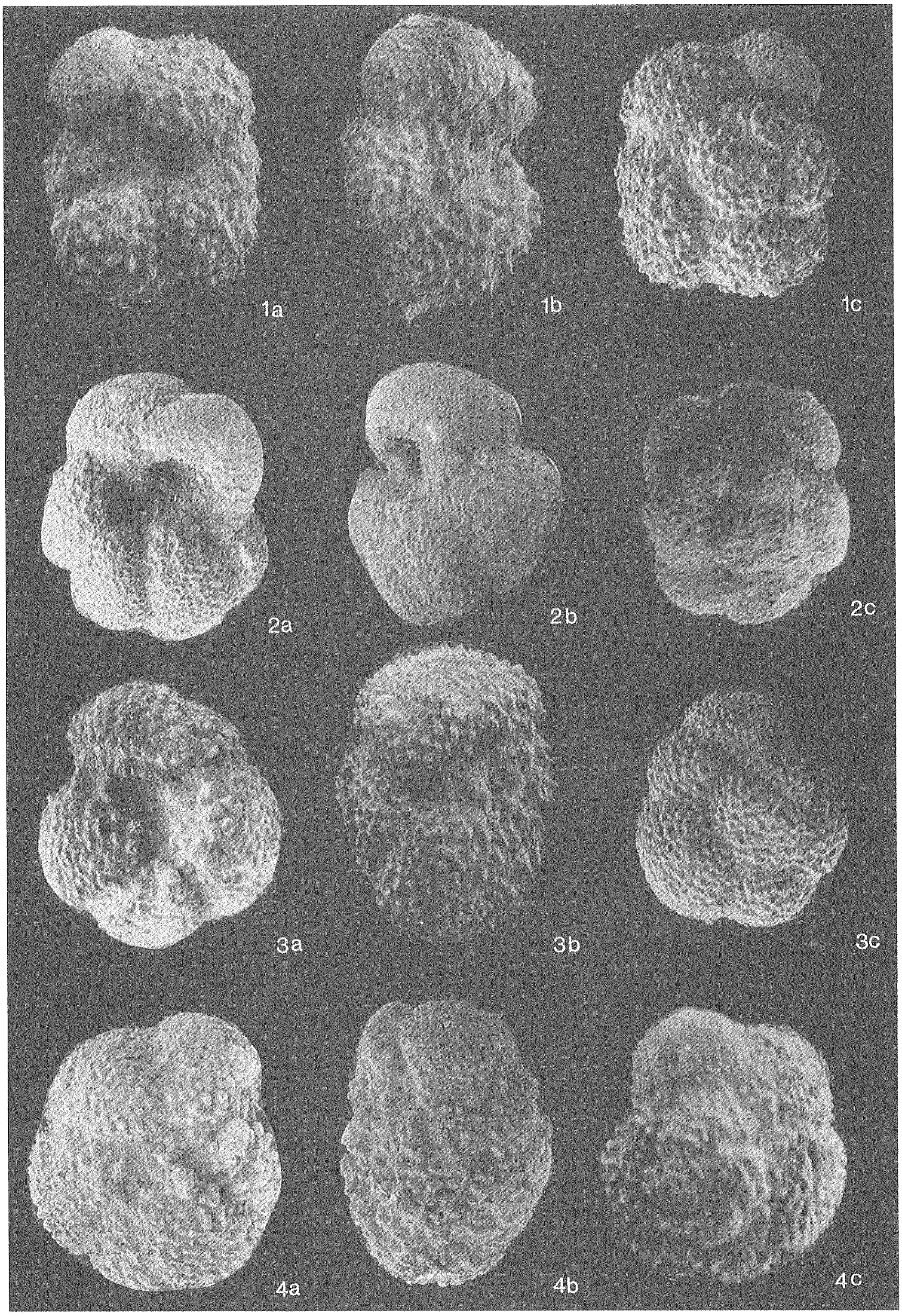

Plate 6 Paleocene-Eeocene planktonic foraminifera from the Zinda Pir section, Sulaiman Range, Southern Indus Basin, Pakistan. (All are scanning electron photomicrographs)

Figures :

1 a-c. *Acarinina pentacamerata* (Subbotina), umbilical, side and spiral views, x270, sample ZPW-26

2 a-c. *Acarinina mckannai* (White), umbilical, side and spiral views, x220, sample ZPW-23

3 a-c. *Acarinina nitida* (Martin), umbilical, side and spiral views, x300, sample ZPW-19

4 a-c. *Acarinina broedermanni* (Cushman and Bermudez), umbilical, side and spiral views, x400, sample ZPW -5

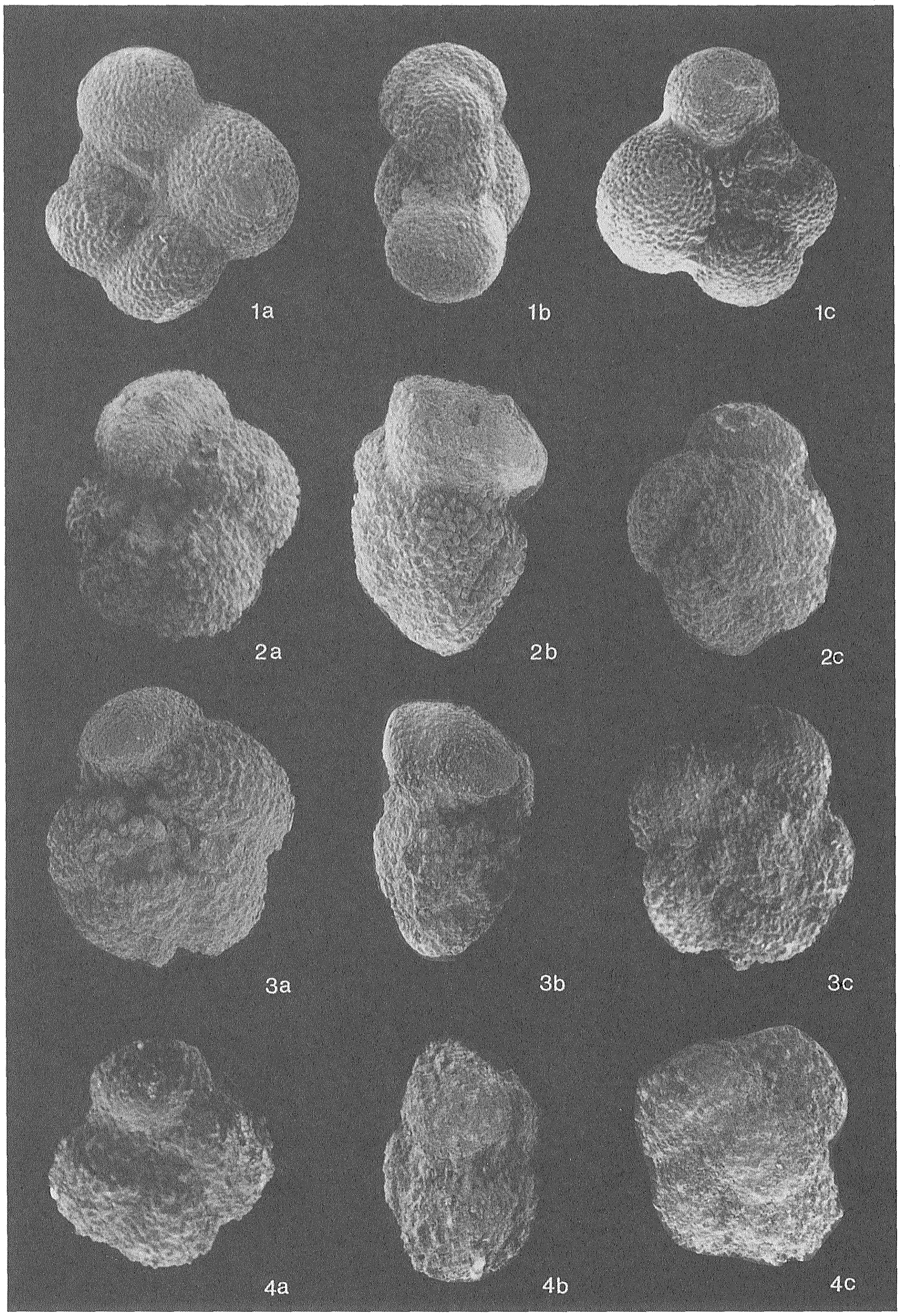

Plate 7 Paleocene-Eeocene planktonic foraminifera from the Zinda Pir section, Sulaiman Range, Southern Indus Basin, Pakistan. (All are scanning electron photomicrographs)

Figures:

1 a-c. *Morozovella quadrata* (White), umbilical, side and spiral views, x330, sample ZPW-26
2 a-c. *Morozovella conicotruncata* (Subbotina), umbilical, side and spiral views, x270, sample ZPW-16
3 a-c. *Morozovella apanthesma* (Loeblich and Tappan), umbilical, side and spiral views, x250, sample ZPW-19
4 a-c. *Morozovella angulata* (White), umbilical, side and spiral views, x400, sample ZPW-5

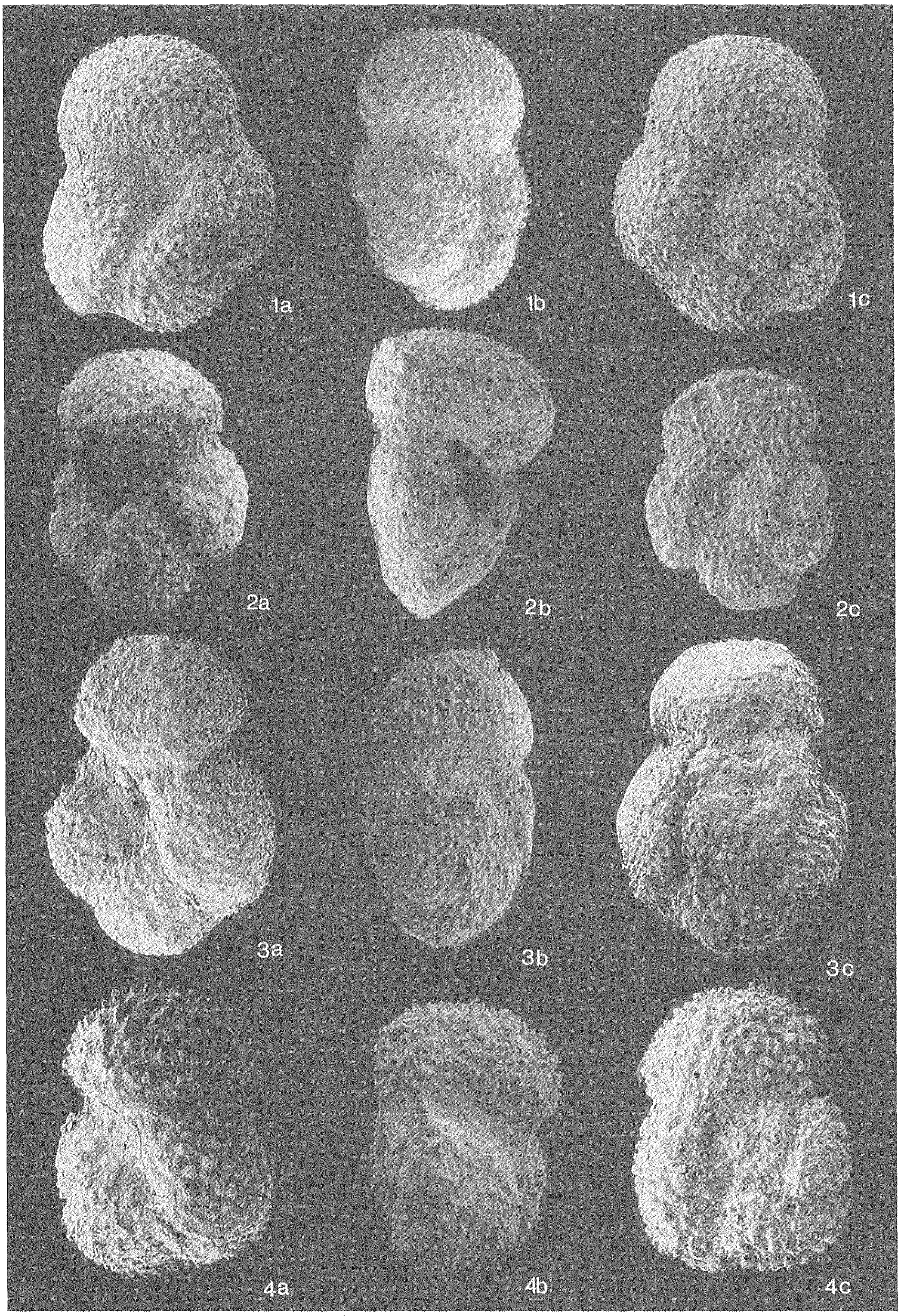

Plate 8 Paleocene-Eeocene planktonic foraminifera from the Zinda Pir section, Sulaiman Range, Southern Indus Basin, Pakistan. (All are scanning electron photomicrographs)

Figures:

1 a-c. *Morozovella wilcoxensis* (Cushman & Ponton), umbilical, side and spiral views, x230, sample ZPW-23

2 a-c. *Morozovella quetra* (Bolli), umbilical, side and spiral views, x300, sample ZPW-23

3 a-c. *Acarinina pseudotopilensis* (Subbotina), umbilical, side and spiral views, x220, sample ZPW-23

4 a-c. *Acarinina primitiva* (Finlay), umbilical, side and spiral views, x250, sample ZPW-23

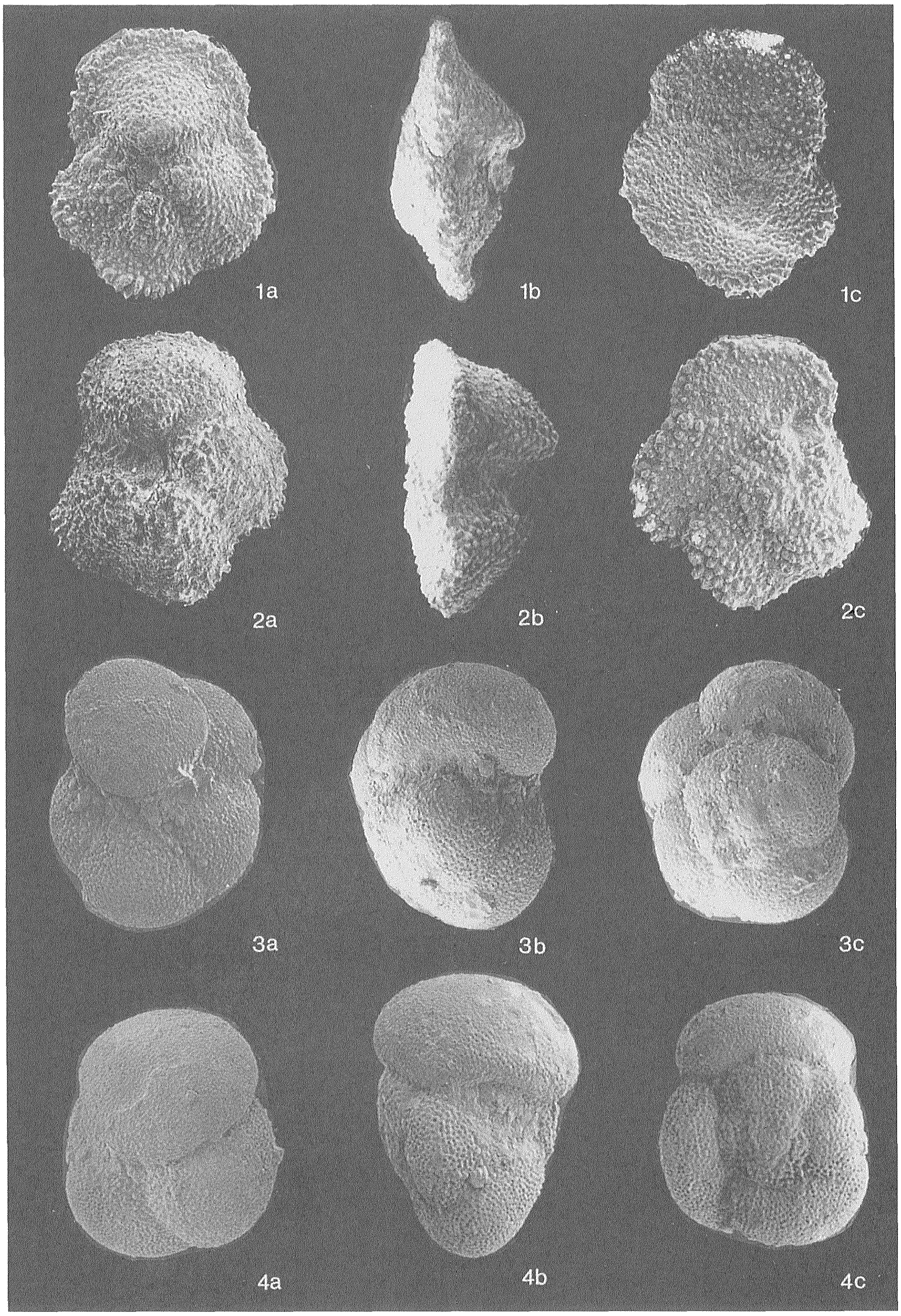

Plate 9 Paleocene-Eeocene planktonic foraminifera from the Zinda Pir section, Sulaiman Range, Southern Indus Basin, Pakistan. (All are scanning electron photomicrographs)

Figures:

1 a-c. *Morozovella marginodentata* (Subbotina), umbilical, side and spiral views, x250, sample ZPW-23

2 a-c. *Morozovella subbotinae* (Morozova), umbilical, side and spiral views, x270, sample ZPW-23

3 a-c. *Turborotalia cerroazulensis pomeroli* (Toumarkine & Bolli), umbilical, side and spiral views, x180, sample ZPW-61

4 a-c. *Turborotalia cerroazulensis pomeroli* (Toumarkine & Bolli), umbilical, side and spiral views, x180, sample ZPW-61

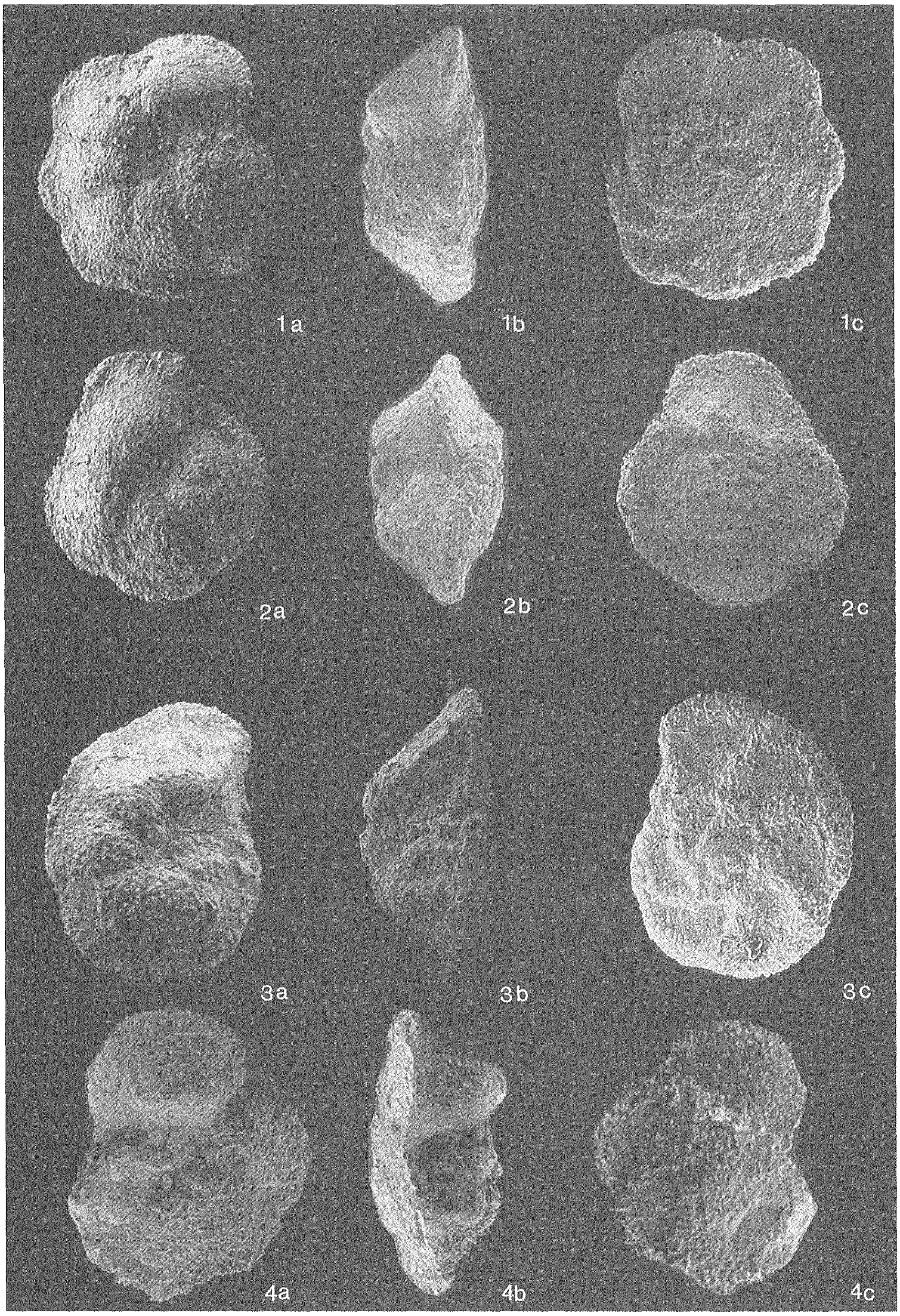

Plate 10 Paleocene-Eeocene planktonic foraminifera from the Zinda Pir section, Sulaiman Range, Southern Indus Basin, Pakistan. (All are scanning electron photomicrographs)

Figures:

1 a-c. *Morozovella formosa formosa* (Bolli), umbilical, side and spiral views, x170, sample ZPW-24
2 a-c. *Morozovella formosa gracilis* (Bolli), umbilical, side and spiral views, x170, sample ZPW-24
3 a-c. *Morozovella aragonensis* (Nuttall), umbilical, side and spiral views, x180, sample ZPW-24
4 a-c. *Morozovella kolchidica* (Morozova), umbilical, side and spiral views, x230, sample ZPW-15

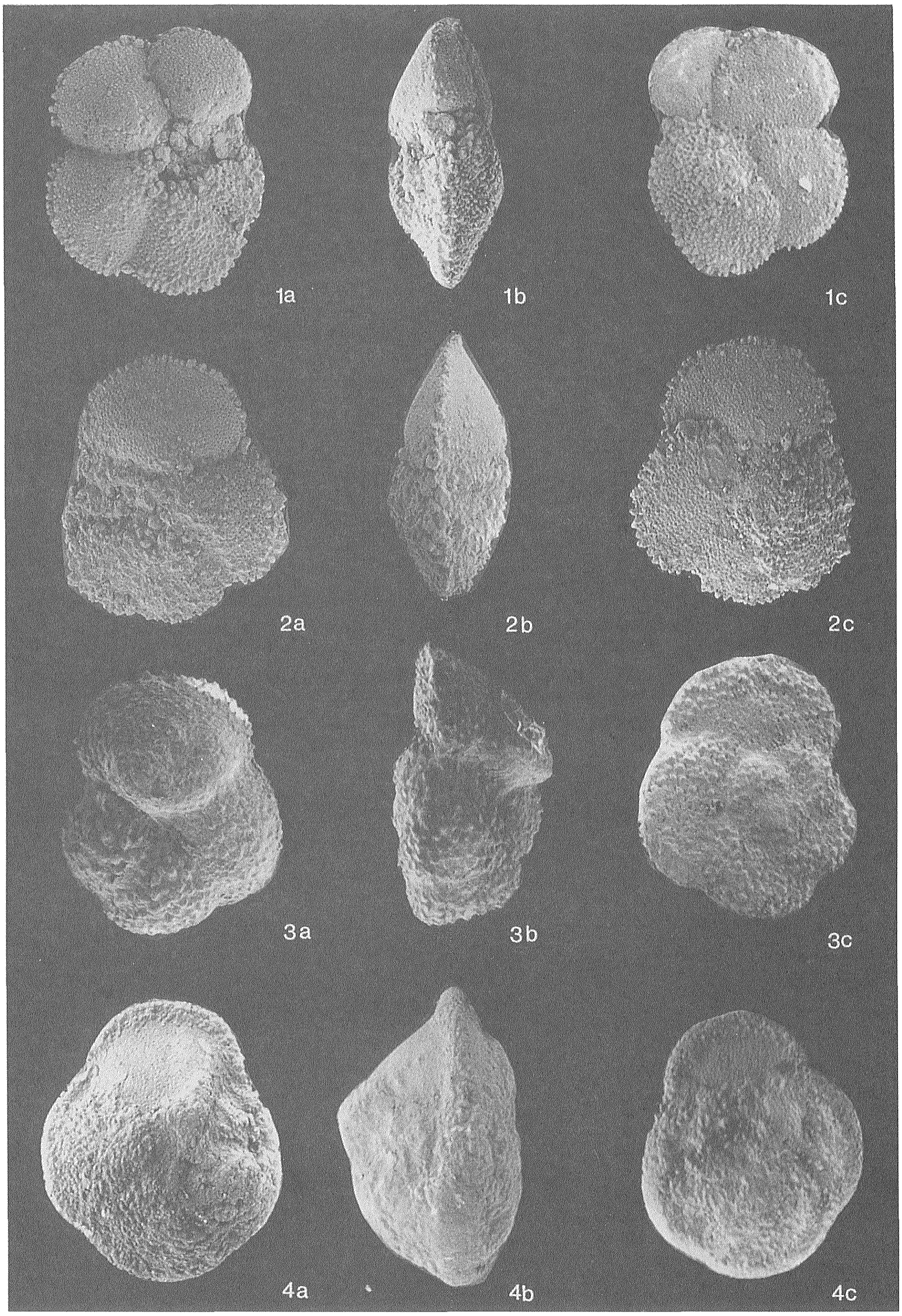

Plate 11 Paleocene-Eeocene planktonic foraminifera from the Zinda Pir section, Sulaiman Range, Southern Indus Basin, Pakistan. (All are scanning electron photomicrographs)

Figures:

1 a-c. *Morozovella lehneri* (Cushman & Jarvis), umbilical, side and spiral views, x200, sample ZPW-61
2 a-c. *Morozovella spinulosa* (Cushman), umbilical, side and spiral views, x190, sample ZPW-61
3 a-c. *Morozovella aequa* (Cushman & Renz), umbilical, side and spiral views, x170, sample ZPW-21
4 a-c. *Morozovella lensiformis* (Subbotina), umbilical, side and spiral views 200, sample ZPW-24

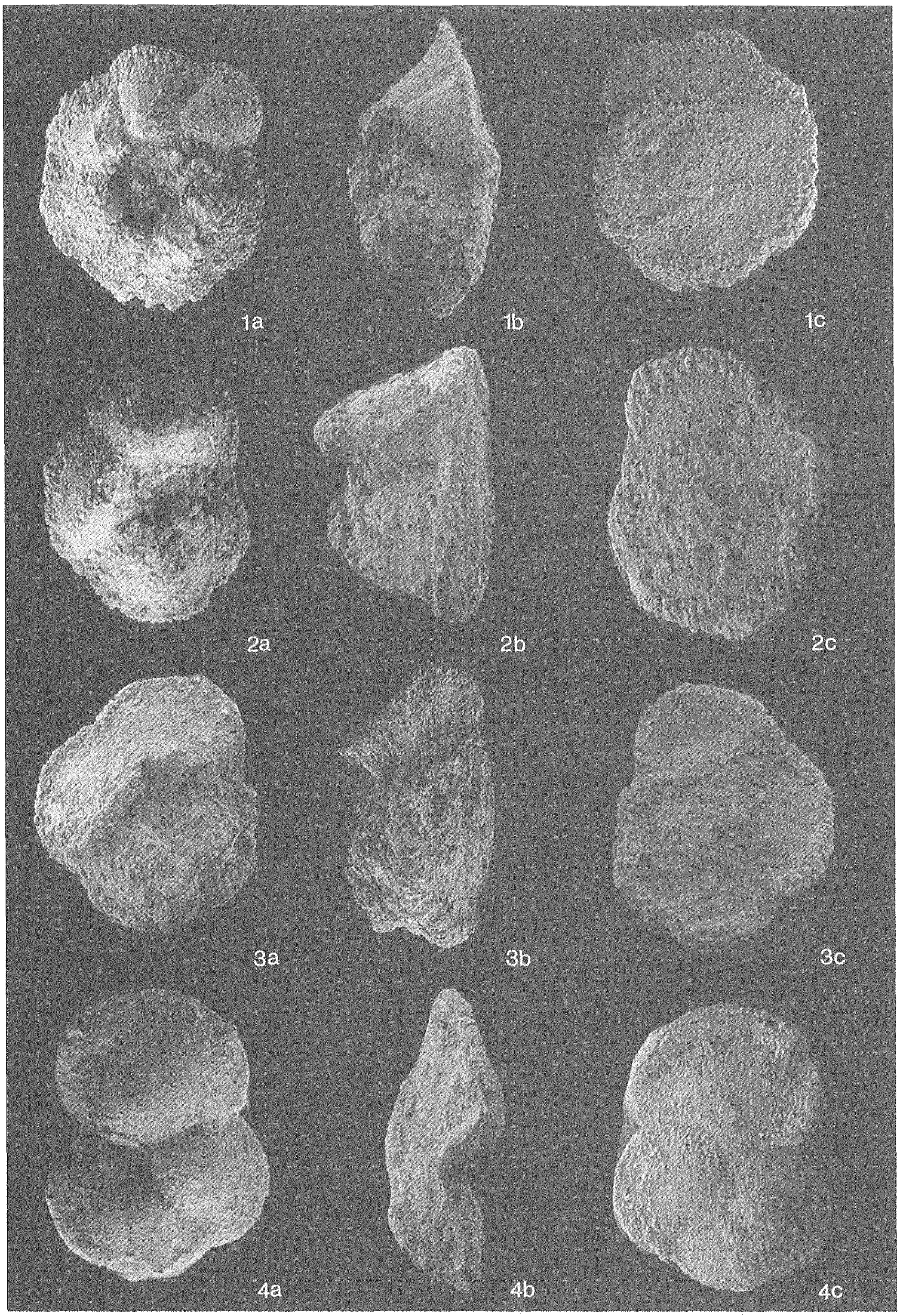

Plate 12 Paleocene-Eeocene planktonic foraminifera from the Zinda Pir section, Sulaiman Range, Southern Indus Basin, Pakistan. (All are scanning electron photomicrographs)

Figures:

1 a-c. *Morozovella velascoensis* (Cushman), umbilical, side and spiral views, x170, sample ZPW-19
2 a-c. *Morozovella acuta* (Toulmin), umbilical, side and spiral views, x200, sample ZPW-19
3 a-c. *Morozovella parva* (Rey), umbilical, side and spiral views, x190, sample ZPW-19
4 a-c. *Planorotalites pseudomenardii* (Bolli), umbilical, side and spiral views, x200, sample ZPW-17

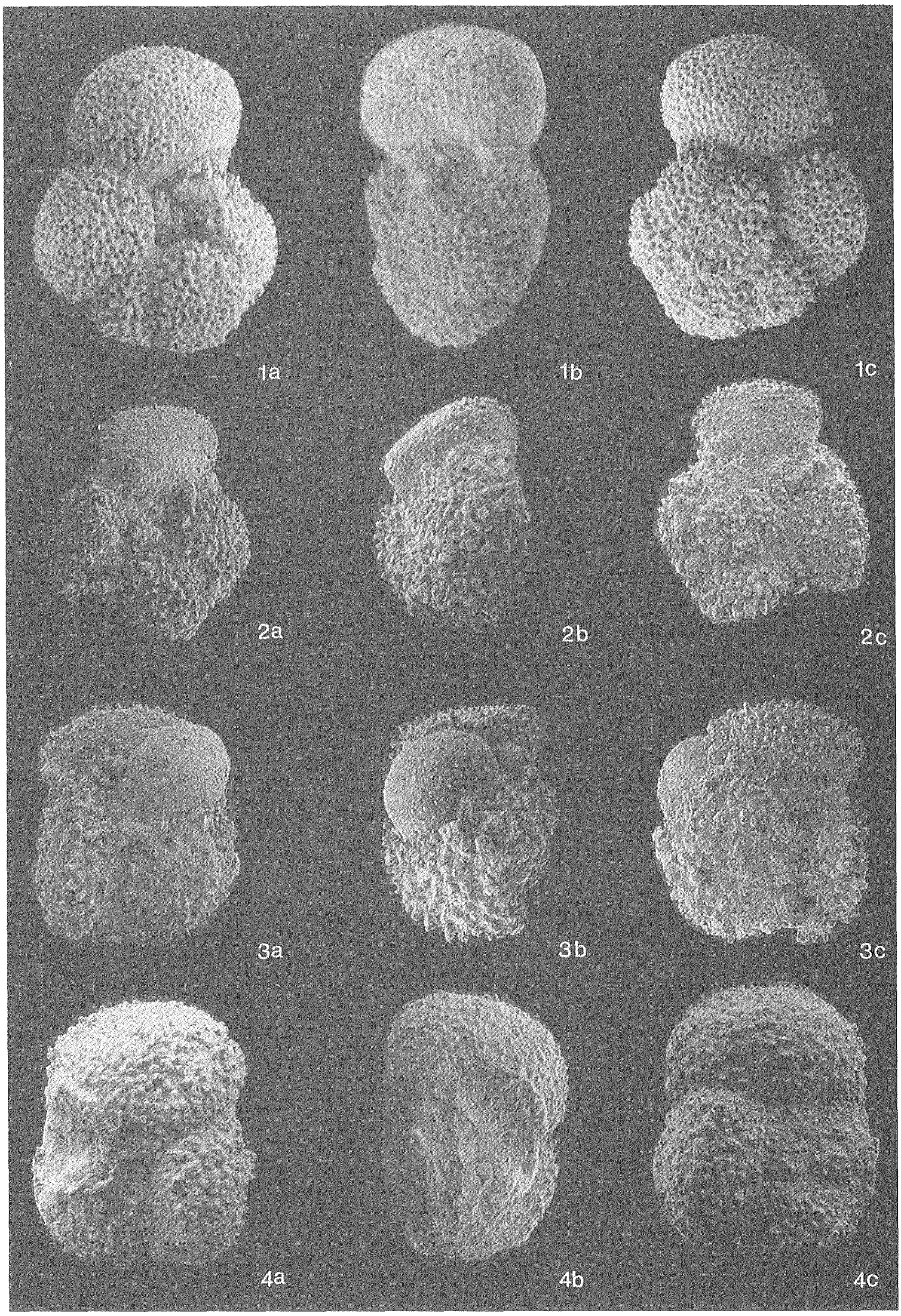

Plate 13 Paleocene-Eeocene planktonic foraminifera from the Zinda Pir section, Sulaiman Range, Southern Indus Basin, Pakistan. (All are scanning electron photomicrographs)

Figures:

1 a-c. *Truncorotaloides rohri* (Bronnimann & Bermudez), umbilical, side and spiral views, x270, sample ZPW-61

2 a-c. *Truncorotaloides topilensis* (Cushman), umbilical, side and spiral views, x200, sample ZPW-61

3 a-c. *Truncorotaloides topilensis* (Cushman), umbilical, side and spiral views, x220, sample ZPW-61

4 a-c. *Acarinina triplex* Subbotina, umbilical, side and spiral views, x200, sample ZPW-24

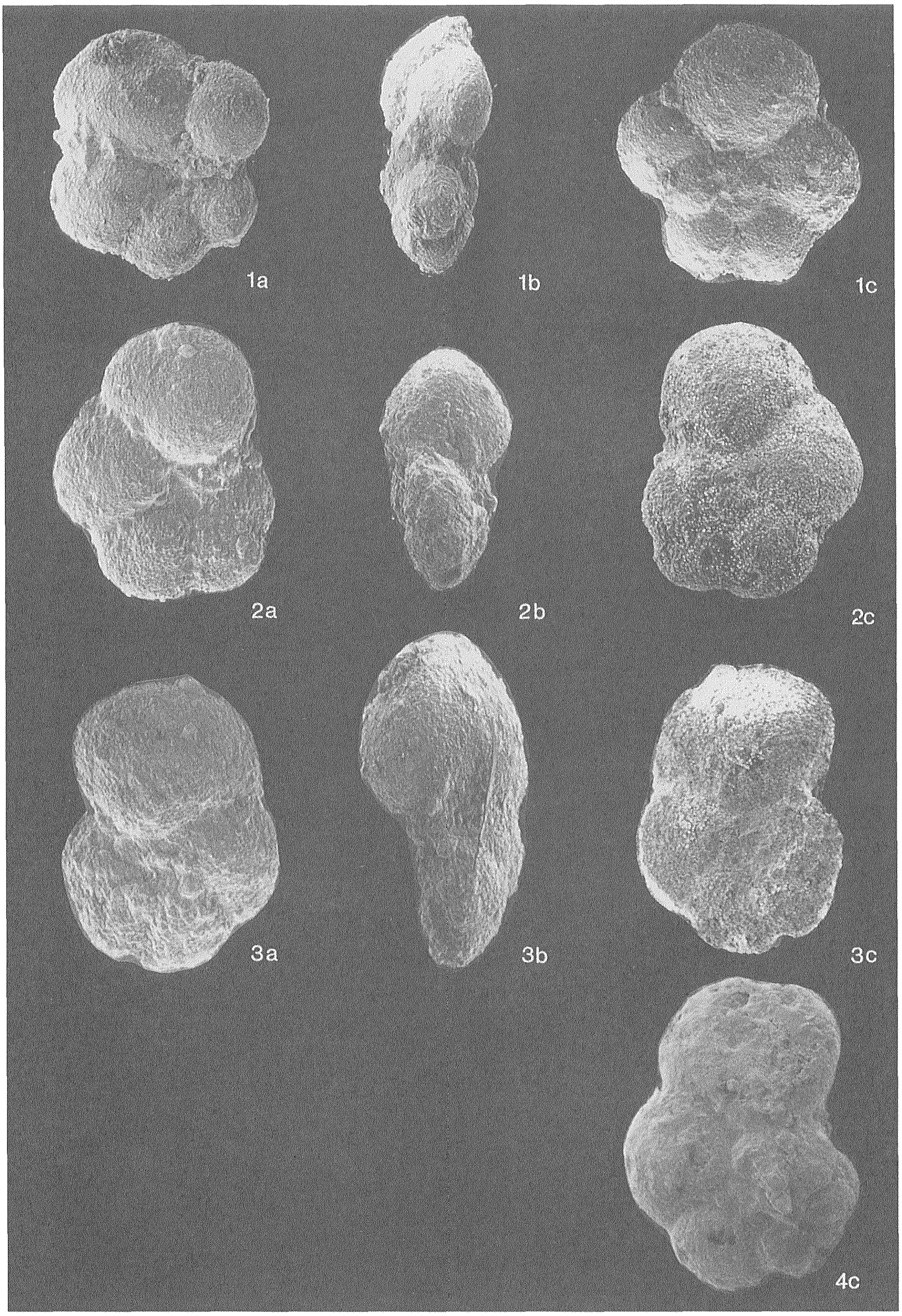

Plate 14 Paleocene-Eeocene planktonic foraminifera from the Zinda Pir section, Sulaiman Range, Southern Indus Basin, Pakistan. (All are scanning electron photomicrographs)

Figures:

1 a-c. *Planorotalites ehrenbergi* (Bolli), umbilical, side and spiral views, x180, sample ZPW-19
2 a-c. *Planorotalites chapmani* (Parr), umbilical, side and spiral views, x330, sample ZPW-19
3 a-c. *Planorotalites elongata* (Glaessner), umbilical, side and spiral views, x370, sample ZPW-19
4 c. *Planorotalites compressa* (Plummer), spiral view, x430, sample ZPW-15

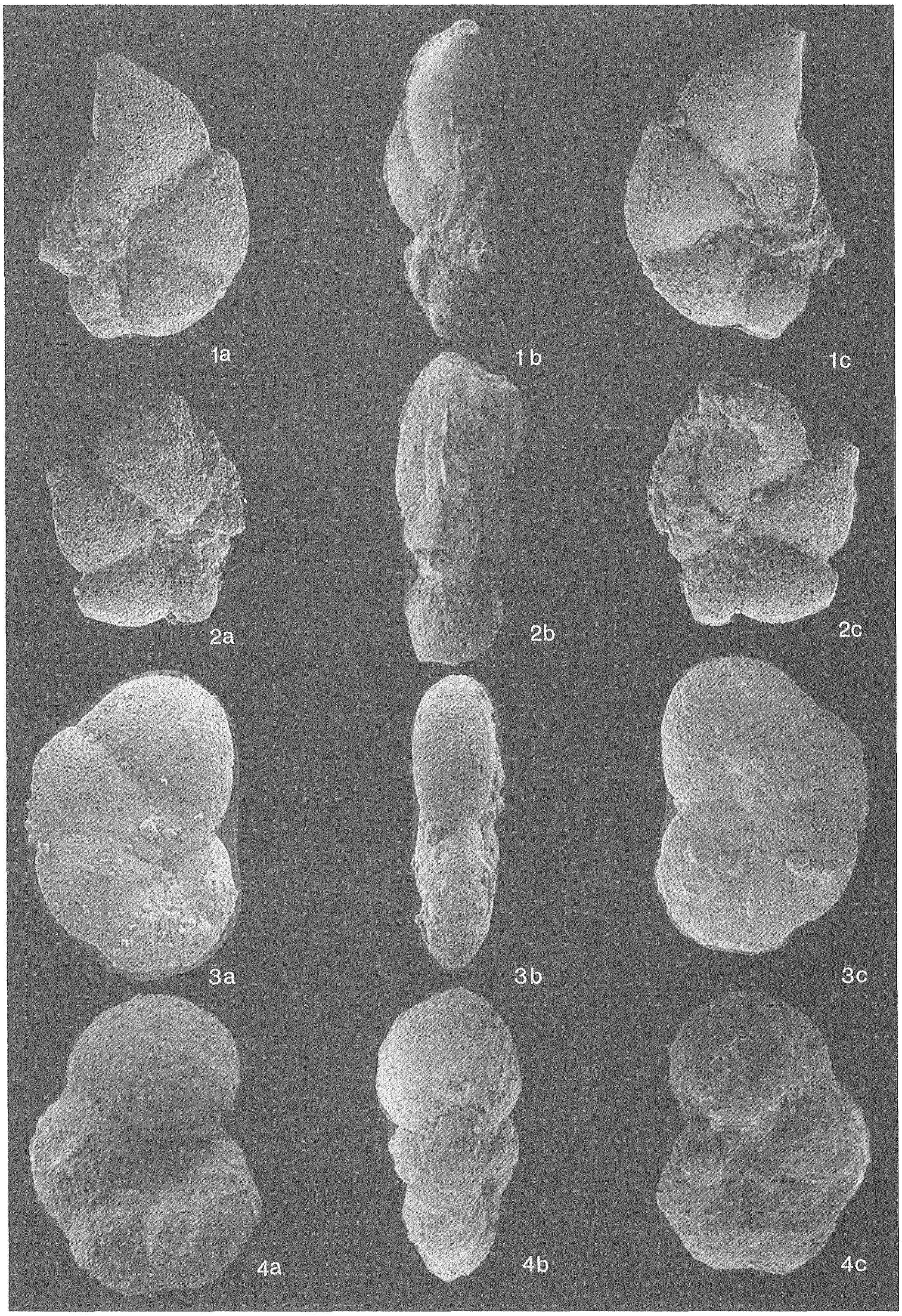

Plate 15 Paleocene-Eeocene planktonic foraminifera from the Zinda Pir section, Sulaiman Range, Southern Indus Basin, Pakistan. (All are scanning electron photomicrographs)

Figures:

1 a-c. *Hantkenina dumblei* (Weinzierl & Applin), umbilical, side and spiral views, x160, sample ZPW-63

2 a-c. *Hantkenina maxicana* (Cushman), umbilical, side and spiral views, x200, sample ZPW-63

3 a-c. *Turborotalia planoconica* (Subbotina), umbilical, side and spiral views, x230, sample ZPW-61

4 a-c. *Pseudohastigerina wilcoxensis* (Cushman & Ponton), umbilical, side and spiral view, x300, sample ZPW-22