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MID-PERMIAN (KUBERGANDIAN-MURGABIAN) BIVALVES FROM THE KHUFF FORMATION, OMAN: IMPLICATIONS FOR WORLD EVENTS AND CORRELATION

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Riassunto. Vengono descritte dieci specie di bivalvi, di cui sei identificate come nuove, appartenenti ai 10 generi, *Nuculopsis*, *Phestia*, *Edmondia*, *Dyasmya*, *Janeia ?*, *Liebia ?*, *Vnigripecten*, *Cyrtorostra*, *Schizodus* e *Astartella ?*. Esse provengono dalla parte basale della Formazione Khuff in Oman. Sono inoltre discussi: alcune forme apparentemente connesse con il genere *Dyasma*, i caratteri del genere *Janeia* e la classificazione degli aviculopectinidi.

La fauna in esame ha uno speciale significato in quanto associata alla trasgressione sopra la discordanza medio Permiana, che si rinviene in Medio Oriente ed in molte altre parti del mondo. Poiché questa trasgressione avviene dopo una vasta regressione per lo più rappresentata da una lacuna di sedimentazione o da depositi non marini, questa fauna dà un contributo significativo alla comprensione delle correlazioni globali per questo intervallo di tempo. Si osserva anche un importante mutamento globale della fauna. La fauna della parte inferiore della Khuff nel suo complesso è considerata non più antica del Kubergandiano o dei suoi equivalenti (Roadiano e Ufimiano "superiore" = Sheshminsk) ma, in base ai soli bivalvi potrebbe andare dal Kubergandiano al Murgabiano o essere il probabile equivalente del Kazaniano.

Abstract. Ten species, of which six are newly recognized, from ten genera, *Nuculopsis*, *Phestia*, *Edmondia*, *Dyasmya*, *Janeia ?*, *Liebia ?*, *Vnigripecten*, *Cyrtorostra*, *Schizodus* and *Astartella ?*, are described from the basal part of the Khuff Formation. Some forms apparently related to *Dyasmya* are discussed, along with the characters of *Janeia* and the classification of the aviculopectinids.

The fauna has a special significance because it is associated with a major mid-Permian transgressive unconformity found in the Middle East and many other parts of the world. Because the transgression succeeds a major regression which is widely represented by hiatus or non-marine deposits, the fauna contributes significantly to understanding the world correlation of the time. An important world-wide change in fauna also takes place. The fauna from the lower part of the Khuff is regarded as not older than Kubergandian or its equivalent (Roadian and "Upper" Ufimian = Sheshminsk) but from the bivalves alone might range from Kubergandian to Murgabian or it's probable equivalent the Kazanian.

Introduction.

Fossil brachiopods were described by Hudson and Sudbury (1959) from this area from what is now usually named the Khuff Formation. Hudson and Sudbury included in their paper identifications of bivalves from L.R.Cox. They named the unit, the Lusaba Limestone and considered it was Lower Permian and overlay the Haushi Formation. Hudson and Sudbury's collection is lodged in the Natural History Museum in London and the Haushi molluscan fauna was re-identified and discussed by Dickins and Shah (1979) with a note that the Lusaba fauna was distinctive. Subsequently Dickins (1992, 1997a) from further examination of Hudson and Sudbury's collection concluded the fauna was Upper Permian. Dickins and Shah regarded the Haushi molluscan fauna as equivalent to that of Stage B of the Permian of Western Australia which is found in the Perth, Carnarvon and Canning Basins and is thus considered to be Sterlitamkian (upper Sakmarian) - see Archbold and Dickins (1996). The occurrence of a closely related fauna includes Badhaura, Peninsular India, Kashmir, Himalayan India, Tibet and western Argentina (Dickins, 1997b). In recent work the unit containing the Haushi fauna has been named the Saiwan Formation. The Saiwan Formation overlies the Al Khlata Formation containing well authenticated glacial deposits (McClure, 1980; Braakman et al., 1982, Kruck and Thiele, 1983, Dickins, 1985). Its microflora is generally regarded as equivalent to palynological Stage 2 of Australia and thus belonging to the Asselian, the lowermost stage of the Permian (see Besems & Schuurman, 1987). The Haushi brachiopod fauna of Hudson and Sudbury has now been described fully by Angiolini et al. (1997) who concludes that it is upper Sakmarian.

The Saiwan Formation in southern Oman is overlain unconformably by the transgressive shales and sands of the Gharif Formation followed by the marine marls and limestones of the Upper Permian Khuff Formation. The hiatus in this area thus represents the Artinskian and Kungurian Stages. The Khuff is overlain with angular unconformity and a sharp boundary by

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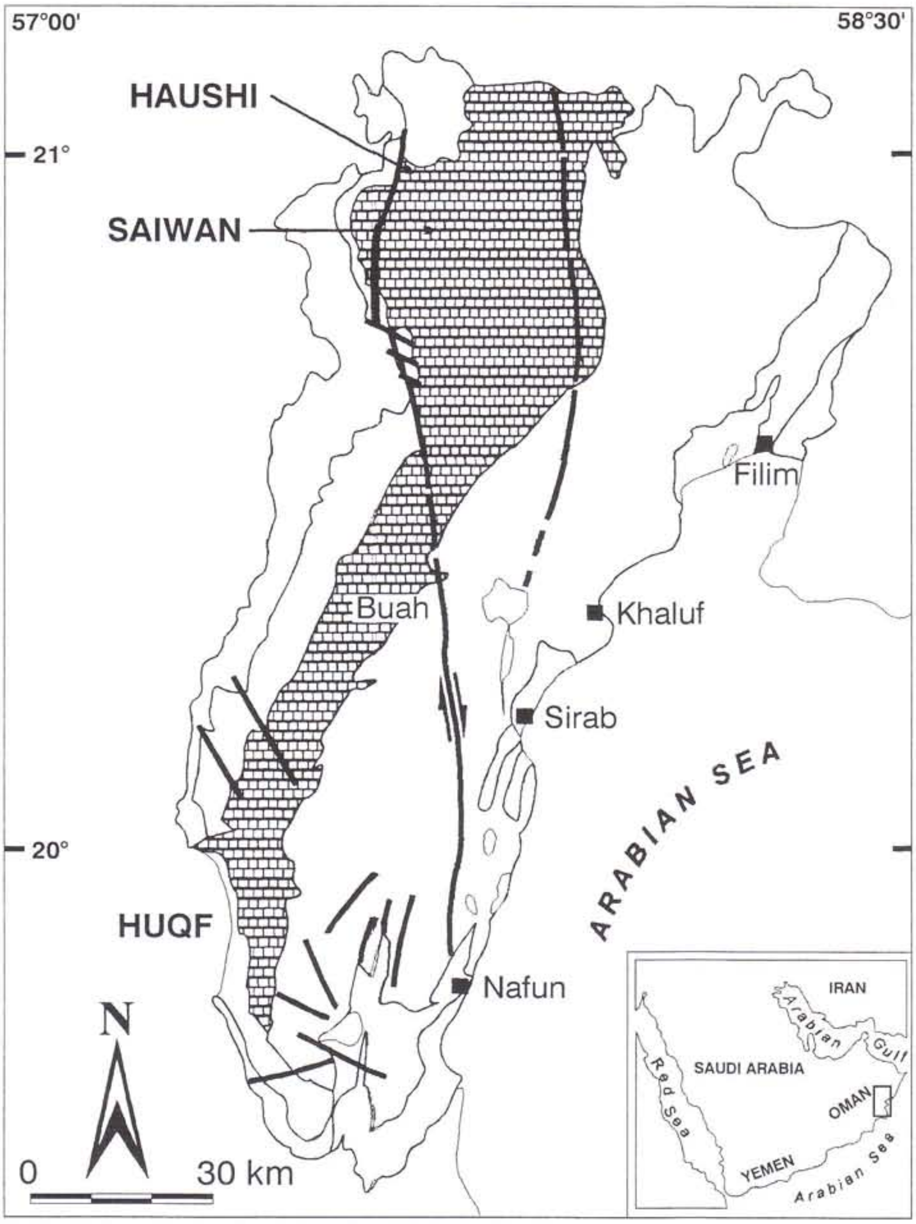


Fig. 1 - Geologic sketch map of the Haushi-Huqf area, Oman (modified from Broutin et al. 1995).

the Minjur Formation (Triassic to Jurassic ?) - Angiolini et al. (1998).

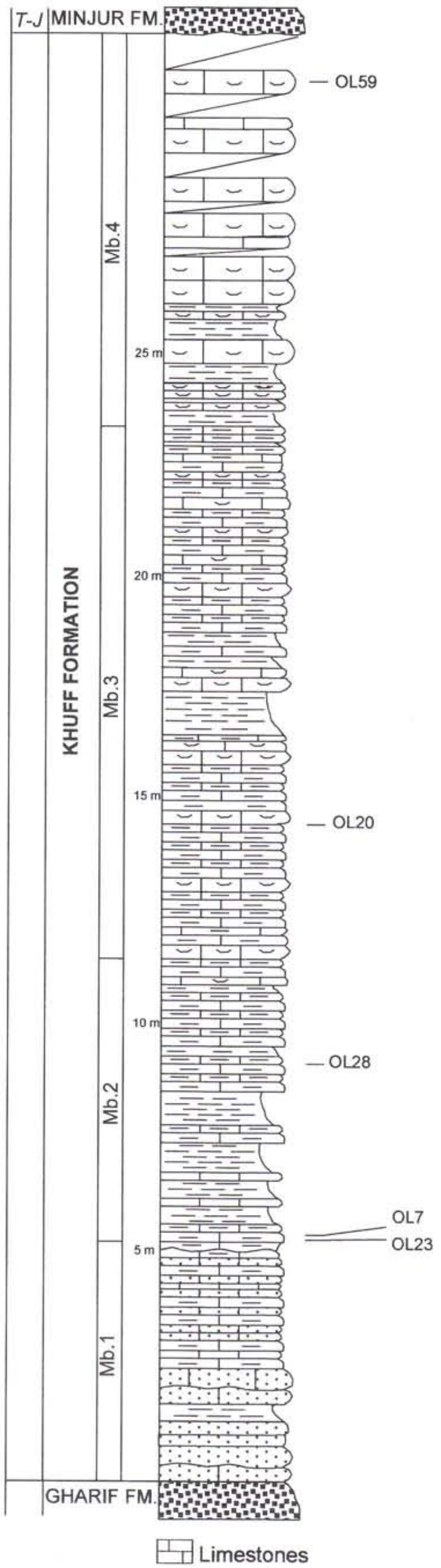
Considerable additional material from the Khuff has now been collected from the Lusaba area of southern Oman from the Peri-Tethys Expedition, January 1995 by J. Roger, J.P. Platel, J. Broutin, L. Angiolini, A. Baud, H. Bucher, J. Marcoux and H. Al Hashmi, supported by the Peri-Tethys Program and by IGCP Project 343. Information is available in Broutin et al. (1995) and Angiolini et al. (1998). The specimens were sent by Dr L. Angiolini of Università degli Studi di Milano, Dipartimento di Scienze della Terra. The accompanying figures showing the locality information (Fig. 1) and the sequence (Fig. 2) have been supplied by Dr Angiolini based on Angiolini et al. (1998).

The specimens numbered with the prefix PG and PL are lodged in the Natural History Museum, London and the MGL specimens in Musee de Geologie, Lausanne. From the information provided by Hudson and Sudbury (1959) and Dr Angiolini, the specimens are from the Wadi Lusaba area, immediately north-east of Haushi and east of the Haushi structure.

The ecology and relationships of the fauna.

In number of genera, ten altogether, the fauna is rather small. This compares, for example, with more than twenty genera of bivalves described by Gemmellaro (1887) from the Sosio beds of Sicily which contain the fusulinid *Neoschwagerina* indicating a similar or a slightly younger Murgabian age than the present assemblage. It does not, however differ very greatly from the fauna from the Phosphoria Formation of the Middle Rockies of the USA, from which Ciriacks (1963) describes some fourteen genera from a sequence apparently in part coeval with the present assemblage but ranging over a greater period of time.

The Oman fauna is, however, rather distinctive in that it largely lacks genera which are found in an arenacous sublittoral environment. These comprise especially *Oriocrassatella*, various schizodids and permophorids such as *Permophorus* itself. The exception is a single specimen of *Schizodus*. On the other hand, the fauna contains genera which are generally associated with a silt environment. These are *Nuculopsis*, *Phestia* and *Janeia* ? *Dyasma* is a burrowing form and *Edmondia* and *Astartella* tend to be ubiquitous. Pectinoids, in this case *Vnigripecten* and *Cyrtorostra*, tend to be found in different types of sediment and this appears to be a reflection of a free living existence (see Dickins, 1963). In forwarding the specimens (including also the gastropods), Dr Angiolini divided the sequence of the Khuff Formation into lower, middle and upper parts. No significant difference in the fauna of bivalves and gastropods is apparent in the three parts. This may indicate reworking of shells



from an adjacent location, or continuance of a rather uniform sediment supply as this assemblage might well be viable to a depth of not more than 30 m which is the thickness of the section represented. The occurrence of the molluscs is compatible with the interpretation of the depositional environment given for the brachiopods by Angiolini et al. (1998) and in many deepening down and especially shallowing up sequences which I have examined in the Permian, a low diversity chonetid association often with numerous specimens, is conspicuous at a very shallow marine level preceding an overlying highly burrowed estuarine or lagoonal sequence.

Dickins et al. (1989) have contended that the major world regression and hiatus associated with the Lower-Upper Permian boundary sequences has resulted in fewer marine deposits at this time which together with the unconformity which was often unrecognized, caused difficulties in correlation. While these difficulties are not entirely resolved there has been considerable progress on this problem. These are considered in Dickins (1997a) and Dickins et al. (1997). It is not proposed to repeat this work here. Subsequently an important contribution has been made on this question in the middle Tethyan region (Karakorum) by Gaetani et al. (1995) and Angiolini (1995) and now in the Arabian Peninsula.

The subsequent transgressive deposits of the lower part of the Upper Permian can be recognized in many parts of the world and a feature of the faunas is their cosmopolitan character. This seems to reflect two features. The formation of numerous new basins allowed a more ready migration of faunas combined apparently with a widespread mild climate reflected in the water temperatures. The more equable water temperatures though may, indeed, reflect the more widespread interconnection of marine basins leading to a greater exchange of water of different temperature, influencing perhaps in turn the world climate. This cosmopolitan character in shown in the Oman bivalve assemblage which on one hand seems closest to that found in the northern Russian Region and on the other to the central and southern United States. This is discussed further under the section on the age and significance of the fauna. Although this may seem surprising it is not less surprising than finding the interchange of fauna occurring at this time between Australia and the northern regions of Russia where Australian species and genera appear in the Russian sequence and also apparent reverse migrations (Dickins et al. 1989, Dickins, 1993, 1997a).

Fig. 2 - Section of the Khuff Fm. in the Haushi area. OL samples represent levels with bivalves (modified from Angiolini et al., 1998). OL9 and OL3 have been collected in the scree.

Age and significance of the fauna.

The age is based on the relationship of *Vnigripecten subphosphaticus* which is close specifically to *V. phosphaticus* from the lower part of the Phosphoria Formation (Meade Peak Member) of central United States and of *Cyrtorostra* (*sensu stricto*) not known below the Upper Permian and characteristically appearing in the Phosphoria Formation and its equivalents. The Roadian - "Upper" Ufimian - Kubergandian age of the lower part of the Phosphoria Formation has been considered by Dickins et al. (1989), Dickins (1993, 1997a) and gets support from recent work (Leven, 1994; Ross et al. 1994; Kotlyar, 1997).

This correlation is also supported by the similarity of *Phestia lusabaensis* sp. nov. to *Phestia kazanensis* (Verneuil) as recorded by Muromtseva (1984) from the Lev-Vorkutsk Suite of the Pechora Basin of the northern Urals. Although Muromtseva regards this suite as Kungurian, the bivalve fauna indicates that it is Upper Permian and the equivalent of "upper" Ufimian-Kazanian (Dickins, 1993). *Edmondia hudsoni* sp. nov. is also close to *Edmondia phosphatica* Girty as figured by Ciriacks (1963) from the Meade Peak Member of the Phosphoria Formation.

In the Phosphoria and the Roadian of the United States, the forms allied to those from Oman are associated with a diverse bivalve fauna which occurs in many parts of the world and represents a distinct change from the faunas of the Lower Permian (Dickins, 1993, 1997a). This level is especially marked by the widespread appearance of new genera and species from Spitzbergen and the northern Russian region, northern Canada and the United States to Japan, eastern Australia and New Zealand. This fauna includes forms of *Oriocrassatella* with a more complicated dentition not present in the Lower Permian, and similarly genera of pectinoids such as *Etheripecten*, *Vnigripecten*, *Hayasakapecten*, *Guizhopeceten* and *Cyrtorostra*, a complex of schizodids, pterioids forms such as *Bakewellia* and permophorids such as *Permophorus* itself. A similar generic assemblage is found in the Sosio beds of Sicily. This fauna which is not in sequence but is from blocks in younger beds (Upper Triassic - E. Flugel, pers. comm.). Although this is geographically the closest known occurrence of this assemblage to Oman, the species differ. It is not apparent that this results from a different environment but from the occurrence of the fusulinid *Neoschwagerina* fauna and the ammonoid *Waagenoceras*, the Sosio beds are Murgabian and perhaps differ somewhat in age from the Oman fauna.

At the specific level, *Phestia lusabaensis*, *Edmondia hudsoni* and *Vnigripecten subphosphaticus* suggest an age similar to the Meade Peak Member of lower part of the Phosphoria Formation (Roadian) and of the lowest part of the Upper Permian of the Pechora Basin of the northern Urals. Although I am reluctant to put too much weight on a small number of species, and have some reservation that the Oman species may range into younger (Murgabian-Kazanian) beds, there may be a discrepancy with a younger age based on the conodonts where only two species are involved (Angiolini et al., 1998).

In any conclusions about the age, however, some remarks about the current status of the Permian Time Scale seem desirable. A twofold subdivision into Lower and Upper Permian based on the Russian Type sequence has been used most commonly throughout the world. There has been a general but not complete agreement that for the world scale the Asselian, Sakmarian, Artinskian and Kungurian Stages can be used for the Lower Permian based on the Russian sequence. For the Upper Permian, although there is some consensus that a basic scheme of five stages can be recognized, there is no general agreement on the names of these stages or their arrangement, despite claims by some members of the Permian Subcommission (Jin Yugan et al., 1997). There is also strong dissent from the view expressed that the Guadalupian with its three subdivisions the Roadian, Wordian and Capitanian can serve as the basis for a "Middle" Permian Series for the World Scale. The reasons for this are that the Permian does not readily lend itself to a threefold subdivision, the faunas of the Guadalupian are too dissimilar to other parts of the world, and the boundaries of the subdivisions of the Guadalupian, the Roadian, the Wordian and the Capitanian and its top boundary are not readily recognizable even perhaps in parts of the U.S.A, let alone in other parts of the world. A decision on the five stages seems premature and there is a need to resolve some of the outstanding correlations problems which have recently been outlined by Dickins et al. (1997). That these problems can be resolved by conodonts alone as apparently contended by Jin Yugan et al. (1997), seems unlikely and the evidence already from the conodonts still remains to be adequately assessed. In these circumstances it would seem best to recognize the age of the Oman fauna in terms of the stages set out in Fig. 3. This has been followed in this paper and the traditional two-fold major subdivision of the Permian has been adhered to. In this context it may be noted that Archbold and Dickins (1996) have used a combination of the Russian and the Tethyan Scales for the Australian sequences.

The fauna is of particular importance in further establishing the significant events which are associated with the beginning of the Upper Permian (twofold subdivision based on the Russian type area) on a world wide scale. These have been described in Dickins (1997a) and Dickins, Yang Zunyi and Yin Honfu (1997). Because of the significance of the Khuff for hydrocarbons the mid-Permian regressive-transgressive is particularly well tabulated and it is truly remarkable. It is shown in many publications but especially in the chart (plate 1) of Powers et al. (1966) and in the information on the drilling through the Khuff in Edgell (1977) and Kashfi (1992). The Khuff and its equivalents extend over 1,000 km from the southern Arabian Peninsula to Turkey and Iraq into Iran as for as the Zagros Mountains or further. In southern Oman it is now shown to rest with a considerable hiatus on Lower Permian and in eastern Oman it rests with basalt at the base on pre-Permian (Blendinger, 1988). It's distribution is discordant with the Lower Permian and it rests as well on various different pre-Permian formations and in western Arabia extensively overlaps the pre-Cambrian shield.

A Kubergandian-Murgabian fauna at the base of the Khuff Formation establishes the age of the transgression. This transgression corresponds in time to major transgressions in many parts of the world following a major regression. It accompanies the beginning of major folding and a period of strong magmatic and volcanic activity - the Hunter-Bowen (Indosinian) Orogenic Phase. The extent of these events is tabulated in detail in (Dickins, 1997a, see also Dickins, 1992, fig. 5; Dickins, 1994, fig. 2) where the marked change in marine and terrestrial faunas is also discussed. Marked changes are found in many groups including bivalves, brachiopods, ammonoids, fusulinids, conodonts and tetrapods. The present fauna is particularly important because of the restricted number of marine faunas at this time.

Russian Platform-Urals	Tethyan Region	Texas Region
Tatarian	Midian	Capitanian
?	?	??
Kazarian	Murgabian	Wordian
"Upper" Ufimian	Kubergandian	Roadian
Kungurian	Bolorian	Leornadian

Fig. 3 - Correlation of stages of lowest part of the Upper Permian for the Russian, Tethyan and Texas sequences. ? indicates boundaries of lesser reliability and ?? without adequate evidence. The "Lower" Ufimian or Solikamsk is included in the Kungurian pending further consideration. The "Upper" Ufimian is the Sheshminsk.

Systematic descriptions

Superfamily *N u c u l a c e a* Gray 1824
Family *N u c u l i d a e* Gray, 1824
Genus *Nuculopsis* Girty 1911 (p. 134)

Type species. *Nuculopsis girtyi* Schenk 1934 (p. 30) - replacement name for *Nucula ventricosa* Hall 1858 proposed by Girty as type species - see Dickins (1963); McAlester (1968). For discussion of relationships of *Nuculopsis* see Dickins (1963).

Nuculopsis sp.

Pl. 1, fig. 1

Material. Figured and measured specimens and two other specimens PG 3526, Khuff Formation (Lusaba Limestone).

Description. This species is illustrated by one shell showing the external features. The beak is not particularly inrolled and a flattish area is formed on the dorsal part of the narrowest side of the shell ("anterior").

Dimensions (in mm).

	Lengt	Height	Thickness
Figured specimen "left valve"	5.5	4.5	1
Measured specimen "right valve"	5	4.5	1

Remarks. This shell is assigned to *Nuculopsis* only because of its general shape and therefore a comparison with other species is not warranted.

Family *N u c u l a n i d a e* Adams and Adams, 1858
Genus *Phestia* Chernyshew, 1951

Type species. *Leda inflatiformis* Chernyshew (1939, p. 116, pl. 29, fig. 1), by original designation of Chernyshew (1951).

Diagnosis and Remarks. See Dickins (1963, p. 36-37).

Phestia lusabaensis sp. nov.

Pl. 1, fig. 2-3

Material. Holotype MGL 74075, Paratype MGL 74076 and 9 other specimens, OL 9, Khuff Formation.

Diagnosis. Small, moderately elongated species with anterior in front of umbo prominent.

Description. Not especially distinctive. Ornament of growth lines of more or less equal prominence. Front of shell prominent and well rounded. Umbo from halfway or less from the front.

Dimensions (in mm).

	Length	Height	Thickness	Distance of Umbo from front
Holotype	9	4.5	1	3.5
Paratype	9 (approx)	5	1	4

Remarks. *Phestia lusabaensis* is close to *Phestia kazanensis* (Verneuil) (Muromsteva, 1984, p. 31, pl. 1, fig. 23, 24) from the Lev-Vorkutsk Suite of the Pechora basin of the northern Urals. It differs apparently in being slightly less elongated and less upturned at the back. It is perhaps slightly less close to *Phestia speluncaria* (Geinitz) (Muromtseva, 1984, p. 31, pl. 1, fig. 25-28) which is also from the Lev-Vorkutsk Suite but is less elongted and less triangular in shape. From its bivalve fauna most or all of the Lev-Vorkutsk Suite is lowermost Upper Permian (Dickins, 1993) and probably equivalent to the

Kap Starostin Formation of Spitzbergen. According to Dickins et al. (1989) the Kap Starostin is of Kubergandian age.

Superfamily *E d m o n d i a c e a* King, 1850

For the classification of the Edmondiacea and the Pholadomyacea see Morris et al. (1991).

Family *E d m o n d i i d a e* King, 1850
Genus *Edmondia* de Koninck, 1844

Type species. *Isocardia unioniformis* Phillips (1836, p. 209, pl. 5, fig. 18) by subsequent designation of Stoliczka (1871, p. xvi).

Remarks. The characters and relationships including the family relationships of *Edmondia* have been discussed recently by Morris et al. (1991).

Edmondia hudsoni sp. nov.

(Pl. 1, fig. 4-10

Material. Holotype MGL 74077 from OL 23, Paratype A MGL 74078 from OL 13 and Paratypes B MGL 74079 and eight other specimens from OL 9, Khuff Formation.

Diagnosis. Rather rectangular in shape with umbo rather high, a fair distance from the front of the shell and rather distinctly separated from the anterior part of the shell.

Description. The holotype is a bivalved specimen which shows some of the features of the hinge. The shell is equivalved and an internal lamellar plate seems to be present although this is not altogether clear.

Paratype A, also a bivalved specimen, shows the lamellate concentric external ornament. The posterior margin is rather straight and there is no gape.

Dimensions. (in mm)

	Length	Height	Thickness	Distance of Umbo from front
Holotype	22	18	12	9 (two valves)
Paratype A	29	21	13	11 (two valves)
Paratype B	28	19	5.5	11 (left valve)
Paratype C	20	15	5	8

Remarks. Although an internal lamellar plate is not definitely present, the quadrate shape gives a good indication that *Edmondia* is represented.

The species from Oman is close to *Edmondia phosphatica* Girty (Ciriacks, 1963, p. 74, pl. 11, fig. 12-15) from the Meade Peak Member of the Phosphoria Formation. Our holotype is somewhat more oval than the lectotype of Girty's species and less rounded viewed from the dorsal side. The Oman species is quite different to the species of *Edmondia* described by Gemmellaro (1887) from the Sosio beds of Sicily.

The species is named after R.G.S. Hudson who with Margaret Sudbury first described the fauna from the Lusaba Formation (= Khuff) in 1959.

Superfamily *P h o l a d o m y a c e a* King, 1844
Family *S a n g u i n o l i t i d a e* Miller, 1877
Subfamily *U n d u l o m y i n a e* Astafieva-Urbaitis, 1984
Genus *Dyasma* Morris, Dickins and Astafieva-Urbaitis, 1991

Type species. *Allorisma elegans* King, 1850 (p. 198. pl. 16. fig. 3-5.) by original designation (p. 77)

Dyasmya morrisi sp.nov.

Pl. 2, fig. 1-3

Material. The holotype, a bivalved specimen MGL 63170, Khuff Formation.

Diagnosis. Umbo arises distinctly above the hinge line, shell not extending far in front of umbo.

Description. A reasonably preserved bivalved shell with a straight hingeline and a flattish escutcheonal area as characteristic for the genus. The anterior margin does not extend far in front of the umbo and the shell is rather tumid towards the front in the region of the umbo. Only concentric ornament is visible. Some gape is present at the back.

Dimensions. (in mm)

Length	Height	Thickness
63	37	28 (two valves)

Remarks. The species is named after Dr N. J. Morris, lately Curator of Fossil Molluscs at the Natural History Museum, London, who was responsible for the name *Dyasmya*.

Species belonging or closely related to *Dyasmya* are common in the Permian and especially in the Upper

PLATE 1

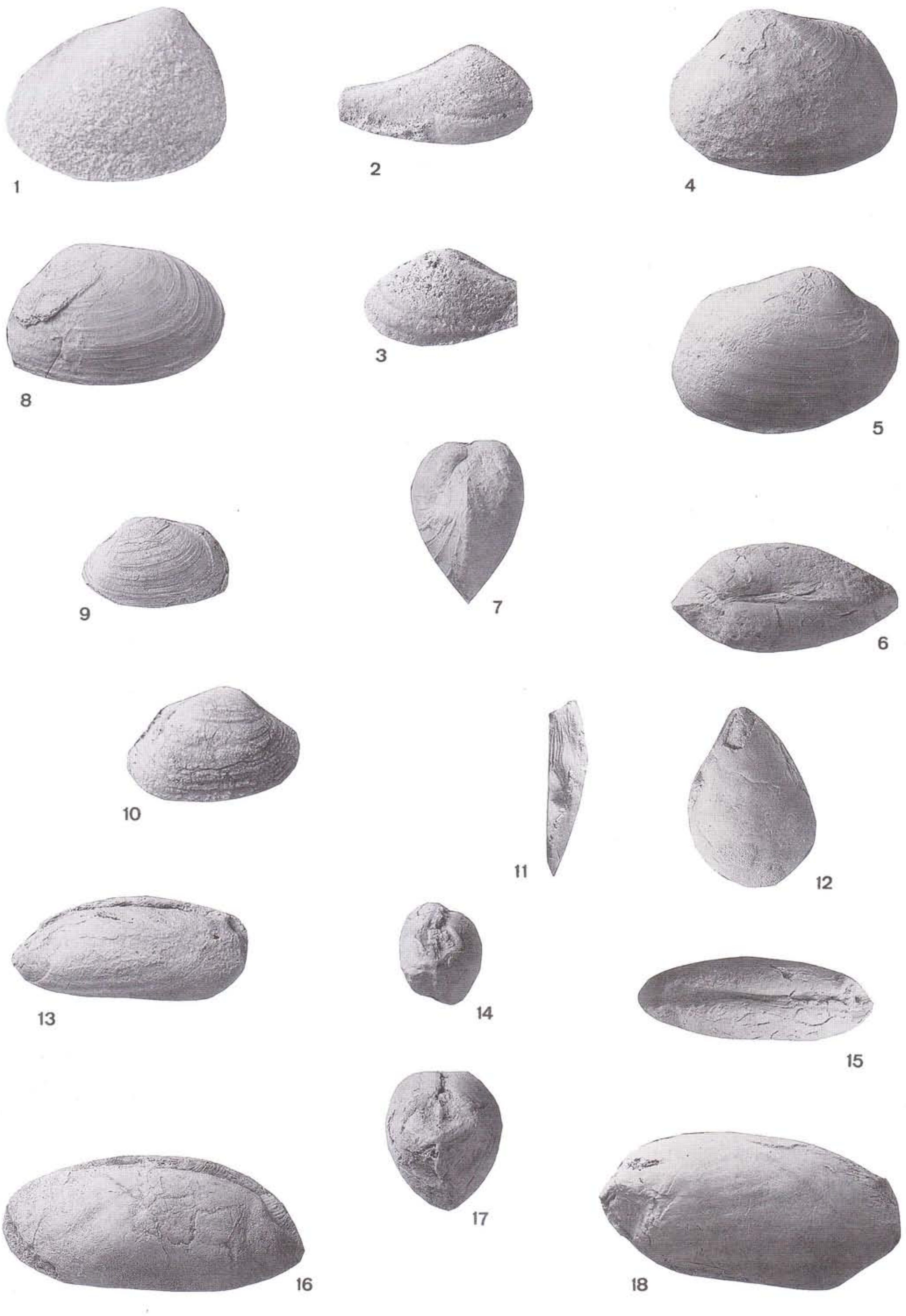
Fig. 1 - *Nuculopsis* sp., side view of "left valve" x 8.

Fig. 2-3 - *Phestia lusabaensis* sp. nov., Fig. 2, side view of holotype x 4 , Fig. 3, side view of paratype x 4.

Fig. 4-10 - *Edmondia hudsoni* sp. nov., Fig. 4-7, left and right valves and top and front views of holotype x 2; Fig. 8, left valve of Paratype A x 1 1/2, Fig. 9; left valve Paratype B x 1, Fig. 10; right valve Paratype C x 1 1/2.

Fig. 11-12 - *Liebia* ? sp., Fig. 11, front view x 2; Fig. 12, side view of left valve x 2.

Fig. 13-18 - *Janeia* ? *incertis* sp. nov., Fig. 13-15, left valve and front and top views of holotype x 1; Fig. 16, right valve of Paratype A x 1; Fig. 17-18, front view and left valve of Paratype B.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Permian of the northern hemisphere. Many are poorly described and often they are placed in *Sanguinolites* as a catch bag term or in other genera to which they are dubiously related. In the Upper Permian of the northern Russian region species have often been placed in *Praeundulomya* Dickins, 1957 described originally from the Lower Permian of Western Australia. My examination of Muromtseva's 1984 collection in Leningrad has failed to show any Upper Permian species with the two posterior grooves diagnostic of *Praeundulomya* or the elongated flat escutcheon relating *Praeundulomya* to *Wilkingia*. It has not been possible to relate *Dyasmya morrisi* to any described species.

Superfamily *Solemyacea* H. and A. Adams, 1857
Family *Solemyidae* Adams and Adams, 1857
Genus *Janeia* King, 1850

Type species. *Solemya primaeva* Phillips (1836, p.209), by original designation.

Remarks. The relationship of Permian Solemyidae have been discussed by Dickins (1963) and Logan (1967). King believed that *Janeia* had an internal ligament which is supported by Cox (Treatise 1969, p. N243) who states that "the impression of the internal ridge is seen on moulds of the type species which also bear indications of the chondrophore". In the Permian species described by Dickins and Logan and also in the specimens described here, an internal more or less vertical rib is present which, perhaps inter alia, serves as a buttress for the anterior adductor both in the Permian and living shells. What might be "indications of the chondrophore" are not clear. In the living solemyid genus *Acharax*, however, the ligament is totally external and in other Palaeozoic genera this appears also to be the case (Logan, 1967) so the position of the ligament in *Janeia* appears to be an unresolved problem.

Janeia ? incertis sp. nov.

Pl. 1, fig. 13-18

Material. Holotype MGL 74080, OL 13, Paratypes A MGL 74081 and B MGL 74082, OL 24 and 10 other specimens.

Diagnosis. Moderately elongated and obtuse in cross-section, slightly humped. Muscle buttresses not well developed. The umbo is low and well rounded.

Description. Although the posterior nymphs are not shown clearly on any of the specimens, apparently the ligament was external.

The dorsal margin anterior the umbo is also not clearly shown. If any gape were present it would have been small. The posterior adductor is large and placed more or less vertically with a low buttress ridge. The anterior adductor is well towards the front, round and with a low buttress at the rear. The shell is more or less equivalve.

Dimensions. (in mm)

	Length	Height (at umbo)	Thickness
Holotype	46	17	18 (two valves)
Paratype A	59	23	20 (two valves)
Paratype B	58	24	23 (two valves)

Remarks. Although solemyids are quite widespread in the Permian they often either fragmentary or poorly recognized and collected. There are few collections as well preserved as the specimens from the Oman fauna and no comparison with other species seems possible.

Superfamily *Ambonychiacea* S.A.Miller 1877
Family *Myalinidae* Frech 1891
Genus *Liebia* Waagen, 1881 (p. 292)

Type species. *Mytilus squamosus* J. de C. Sowerby, 1829 by subsequent designation of Cox (1936, p. 39).

Liebia ? sp.

Pl. 1. fig. 11-12

Material. Figured specimen PL 3489 and measured specimen PL 3490, Khuff Formation (Lusaba Limestone).

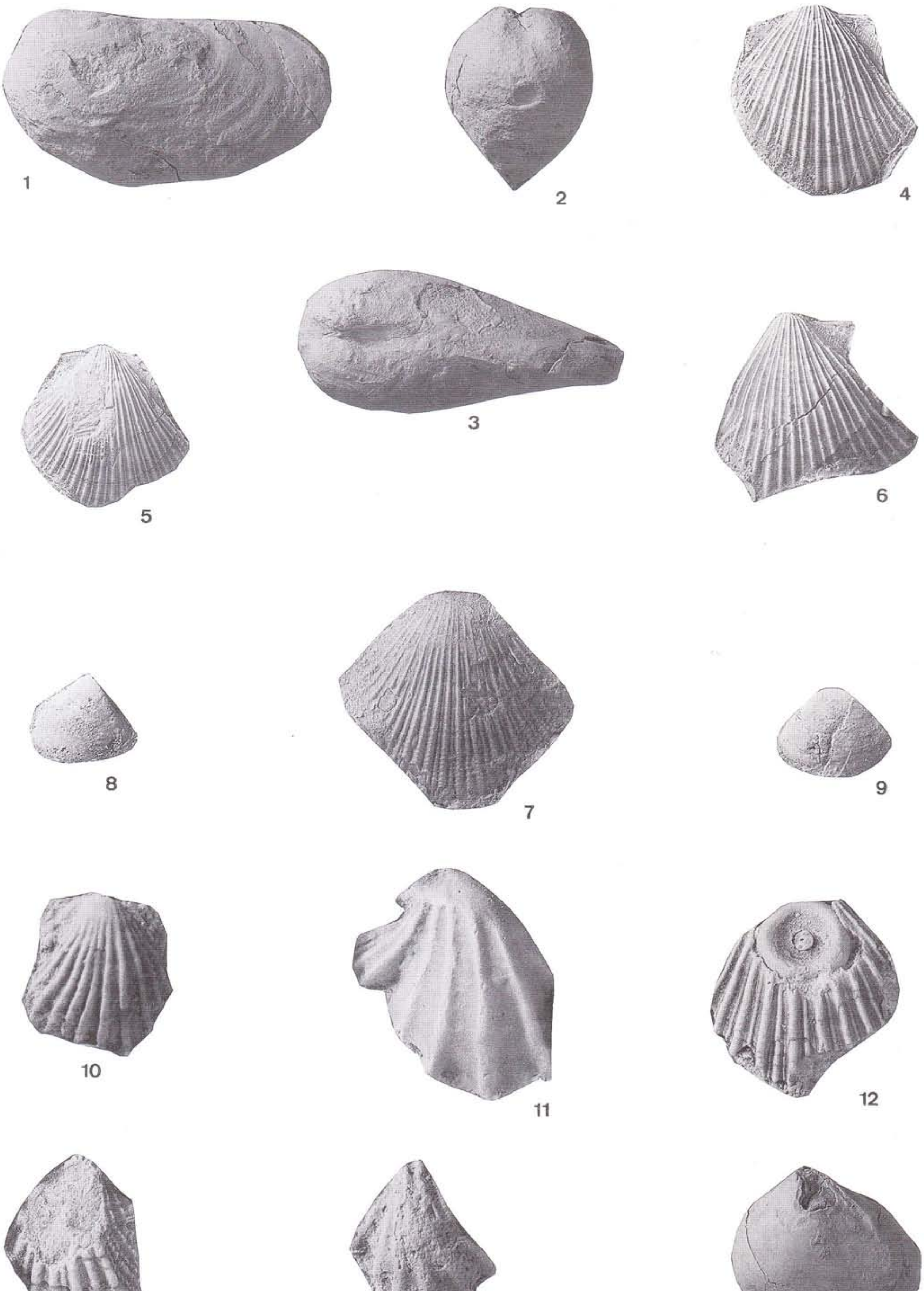
Description. Shell small, elongate and mytiliform, not very complex, but considerably thicker towards the top. Distinct growth lamellae on the anterior margin and a small auricle developed separated from the lower anterior margin by a broadly rounded curve, The external surface relatively smooth with concentric growth lines.

Dimensions (in mm).

	Length	Height	Thickness
Figured specimen	17	12	4 left valve
Measured specimen	18	12	3 left valve

PLATE 2

Fig. 1-3 - *Dyasmya morrisi* sp. nov., left valve and front and top views of holotype x 1.
Fig. 4-7 - *Vnigripecten subphosphaticus* sp. nov., left valves of holotype x 4 and Paratypes A x 2, B x 4 and C x 2.
Fig. 8-9 - *Astartella* ? sp., Fig 8, Figured specimen A, right valve x 8; Fig. 9 Figured specimen B, left valve x 8.
Fig. 10-14- *Cyrtorostra omanensis* sp. nov., Fig. 10, holotype left valve x 2; Fig. 11, Paratype A, right valve, external impression x 3; Fig. 12, left valve x 3; Fig. 13, Paratype B, left valve x 3; Fig. 14, Paratype C, left valve x 2.
Fig. 15 - *Schizodus* sp., Figured specimen left valve x 1.


1
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15

Remarks. No internal characters are available but the shape suggests the presence of *Liebia*.

Superfamily *Pectinacea* Rafinesque, 1815
Family *Aviculopectinidae*
Meek and Hayden, 1864

Remarks. Including the Aviculopectininae, the Pseudomonotinae, the Streblochondriinae, the Oxytominae and the Buchiinae, all within the family Aviculopectinidae has considerable merit in showing the relationships of these groups of forms and their phylogeny as discussed in detail in Dickins (1963). This proposal is, therefore followed here. Whether in this scheme *Cyrtorostra* should be placed in the Aviculopectinae or in a separate subfamily the Cyrtorostrinae = Family Cyrtorostridae Newell and Boyd, 1995, is a rather open question. *Cyrtorostra* resembles its apparent ancestor *Clavicosta* in its ornament and ribbing but differs in the biconvexity of the shell. In this latter respect it is close to the Streblochondriinae but differs in the strong character of its ribbing and spines along the external surface of the shell. The Oxytominae are also characteristically developed in the Jurassic and Cretaceous and there are few links known in the Triassic. Apart from Clavicosta, Cyrtorostra seems to have few links with other genera.

As indicated by Newell (1969, p. N346), *Cyrtorostra*, which appears in the Upper Permian, is probably derived from *Clavicosta* Newell, 1938 which occurs in the Carboniferous and the Lower Permian. The appearance of *Cyrtorostra* in the Upper Permian is shown well in the Phosphoria Formation of the western central United States and in the equivalent Road Canyon Formation of the Glass Mountains of Texas (see Ciriacks, 1963). Although the age of this level is given differently in earlier publications, its correlation has been discussed in Dickins et al. (1989) and Dickins (1993; 1997d) and an Ufimian-Roadian-Kubergandian age is accepted here.

Subfamily *Aviculopectinae* Meek and Hayden, 1864

Genus *Vnigripecten* Muromtseva, 1984

Type species. *Aviculopecten phosphaticus* Girty (1910, p. 43, pl. 4, fig. 11).

Remarks. Both left and right valves of the genus are very distinctive. The ornament of the left valve is made up prominent primary ribs with rather regular subdued secondary ribs. The right valves have strong spines along the dorsal margins. Shells of the genus are poorly known except at the mid-Permian (Ufimian-Roadian-Kubergandian) when they appear in widespread parts of the world.

Although earlier (Dickins, 1993) I had thought *Vnigripecten* might be a synonym of *Etheripecten* Waterhouse 1963, the holotype of the type species of *Etheripecten* has been refigured by Newell and Boyd (1995) which shows that in left valves the primary ribs are separated by numerous secondary ribs whereas in *Vnigripecten* the ribs are more or less of one order with few secondary ribs.

Vnigripecten subphosphaticus sp. nov.

Pl. 2, fig. 4-7

Material. Holotype MGL 74083, Paratypes A MGL 74084, B MGL 74085, and seven other specimens, OL 9 and Paratype C, PG 3517 from Khuff Formation.

Diagnosis. Differs little from *V. phosphaticus* Girty, the type species. Umbo seems a little sharper and the shell slightly inclined towards the front.

Description. Only left valves are included in the material. Pattern of primary and secondary ribs distinctive. Primary ribs relatively prominent and secondary ribs arise by intercalation and are relatively subdued. Indistinct beadlike protuberances are found where the growth lines cross the primary ribs. Number of primary ribs rather variable from thirteen to twenty. Shell moderately convex, slightly proscline and umbo rather sharp.

Dimensions (in mm).

All left valves	Length	Height	Thickness
Holotype	10	8	2 (approx.)
Paratype A	15	14	3
Paratype B	9	8	2
Paratype C	23	22	3 (approx.)

Remarks. Left valves closely resemble specimens of *V. phosphaticus* from the basal part of the Phosphoria Formation (Meade Peak Member) of central United States of Roadian (lowermost Upper Permian) age (Ciriacks, 1963). The species has also been described by Muromtseva (1984) from the northern Russian region where it recorded in the Ufimian-Kazanian from a wide area including the Kolyma Massive, the Omolon Massive, Novaya Zemlya, Verchoyan, Kharulakh and the Kanin Peninsula (see also Newell and Boyd, 1995).

There is not a clear answer on whether the Oman species should be placed in a separate species or in *Vnigripecten phosphaticus*.

Genus *Cyrtorostra* Branson, 1930

Type species. *Cyrtorostra varicostata* Branson (1930, p. 94, pl. 11, fig. 16-19) by original definition of Branson from the Phosphoria Formation, central U.S.A.

Diagnosis. See Ciriacks (1963); Newell and Boyd (1995).

Remarks. *Cyrtorostra* is distinguished from *Clavicosta* by the forward flexuring of the valves as distinct from *Clavicosta* in which the valves are upright. This is shown especially in the right valve. The hinge of right valve of *Cyrtorostra* is also modified to fit into the left valve. Ciriacks (1963, p. 57) notes that "the heavily folded and irregularly shaped right anterior auricle".

In the Permian sequence of the Carnarvon Basin, Western Australia, *Clavicosta* is found at the top of the Lower Permian where undescribed specimens occur in the Coolkilya Sandstone. *Cyrtorostra*, on the other hand is first apparently known from immediately younger beds of Ufimian age in the United States (for discussion of ages of these beds see Dickins et al., 1989).

Clavicosta also apparently occurs in Lower Permian beds close in age to the Coolkilya Sandstone at Fossil Head, Treachery Bay, Bonaparte Gulf Basin, Northern Territory, Australia, recorded as *Aviculopecten* (?) *hardmani*, 1897 by Etheridge Jnr. (1907, p. 7, pl. 2, fig. 12-14; pl. 3, pl. 5, fig. 5-9). The Coolkilya specimens may belong to Etheridge's species. Etheridge notes that "the external appearance of the left valve" is reminiscent of the *Oxytoma* group.

Cyrtorostra omanensis sp. nov.

Pl. 2, fig. 10-14

Material. Holotype PG 3484, Paratype A PG 3443, Paratype B PG 3481, Paratype C PG 3482, Paratype D PG 3487 and more than five other specimens, Khuff Formation (Lusaba Limestone).

Diagnosis. Small specimens with relatively few ribs and showing generic feature of anterior flexuring of the valves but not as strong as for example in the genotype.

Description. The holotype, a well preserved left valve, shows the shape and moderate anterior flexuring. Eleven primary ribs are visible with secondary ribs developed in between in a few instances. Paratype A is a right valve showing distinct flexuring and biconvexity. Five primary ribs over the valve and five on the anterior ear. Paratypes B,C and D are left valves showing variation in the flexuring and ribbing. In Paratype B intermediate ribs are well developed and incipient spines are found at the external margin. In Paratype C smaller ribs are shown to be developed on the posterior part of the valve.

Dimensions (in mm).

	Length	Height	Thickness
Holotype (left valve)	3.5	3.5	0.8
Paratype A (right valve)	7	7	1.5
Paratype B (left valve)	5	5 (approx.)	1
Paratype C (left valve)	6	7?	1.5
Paratype D (left valve)	4	4	1

Remarks. The oldest *Cyrtorostra* known to me occur in the collections I have examined at Cambridge from the Kap Starostin Formation of Spitzbergen and the specimens from the Assistance Formation of northern Canada described by Logan (1970) where in both places the beds appear to be of Ufimian-Kubergandian-Roadian age. A considerable number of species have been described and they range at least as high as the Dzhulfian. As Logan suggests, a review is long overdue and I am hesitant to refer the specimens from Oman to any existing species.

Superfamily *Trigoniacea* Lamarck, 1819

Family *Schizodidae* Newell and Boyd, 1975

Genus *Schizodus* de Verneuil and Murchison, 1844 (p.485)

Type species. *Axinus obscurus* J. de C. Sowerby (1821, p.12, pl. 314) by subsequent designation of de Verneuil (1845, p.308).

Schizodus sp.

(Pl. 2, fig. 15)

Material. One bivalved internal impression with the right valve squashed MGL 74086, OL 13, Khuff Formation.

Description. Typical schizodid shape with shell upright and somewhat longer than high. The anterior and posterior adductors are shown and the pallial line. A distinct anterior hinge buttress is present. The dentition is poorly preserved.

Dimensions. (in mm)

	Length	Height	Thickness
Left valve	36	30	10

Superfamily *Crassatellacea* Ferussac, 1822

Family *Astartidae* d'Orbigny, 1844

Genus *Astartella* Hall, 1858

Type species. *Astartella vera* Hall (1858, p. 715 , pl. 29, fig. 1a-e) by monotypy.

Astartella ? sp.

(Pl. 2, fig. 8-9)

Material. Figured specimen A MGL 74087 and B MGL 74088 and six other specimens, OL 13, Khuff Formation.

Description. Although no reliable information is available on the dentition, the shape gives a fairly reliable indication that *Astartella* is present. The umbo is humped over towards the front making a strong angle with anterior margin, typical of *Astartella*. The external ornament is poorly preserved.

Dimensions (in mm).

	Length	Height	Thickness
Figured specimen A (right valve)	10	8	1.5
Figured specimen B (Left valve)	11	9	2

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