Oligocene and Aquitanian Gastropod Faunas from the Sultanate of Oman and their biogeographic implications for the early western Indo-Pacific

by

MATHIAS HARZHAUSER

With a contribution by DIRK FEHSE
With 6 plates, 4 text-figures and 1 table

Zusammenfassung


Die geringen faunistischen Gemeinsamkeiten der omanischen Faunen mit gleichaltrigen Faunen aus Pakistan lassen vermuten, dass im östlichen Teil der Westlichen Tethys Region während des Oligozäns und des Aquitaniums zumindest zwei Bioprovinzen existierten. Für diese biogeographischen Einheiten werden die Begriffe Eastern-African-Arabian Province (EAAP) und Western Indian Province (WIP) vorgeschlagen.


Schlüsselwörter: Gastropoda, Oligozän, Aquitanium, Biogeographie, Arabien.

Summary

The Late Paleogene and Early Neogene gastropod faunas of the Duqm and Madrakah area in the Sultanate of Oman are described for the first time. The total fauna comprises 51 species-level taxa, derived from shallow marine, coral-dominated, bioklastic limestones of the Shuwayr and Warak Formation (Upper Oligocene) and the Ghubbarah Formation (Aquitanian).

The fauna is an important key for the biogeographic reconstruction of the Western Tethys region and turned out to be part of a discrete bioprovince with considerable influx from the Mediterranean-Iranian Province and some links to the Proto-Indo-Polynesian Province. The discreetness of this biogeographic entity is expressed by an endemism ratio of 42% representing 21 new species. Of these, Cantharidus elkeae, Solarillieta krobi, Waraka pulleri, Tenuecerithium omanicum, Cerithium lakenederi, Cerithium markusreuteri, Turritella steiningeri,

Address of the authors: MATHIAS HARZHAUSER, Naturhistorisches Museum Wien, Burgring 7, A-1010 Vienna, Austria. e-mail: mathias.harzhauser@nhm-wien.ac.at

DIRK FEHSE, Nißberg Str. 3, D-12524 Berlin. e-mail: dirk.fehse@FTK.rohde-schwarz.com

0375-0442/07/0280/0075 $ 23.85 © 2007 E. Schweizerbart'sche Verlagsbuchhandlung, D-70176 Stuttgart
Bayania omanispinosa, Projenneria sabaica, Varicospira zschizini, Strombus bernielandasi, Strombus gijskronenbergii, Lyria madrakabensis, Vasia arubianum, Cytharinella duymensis and Balda argensis are formally introduced as new species. Warakia is described as a new gastropod genus.

The rather low faunistic similarities of the Omani faunas with coeval Pakistani faunas suggest that at least two bioprovinces existed during the Oligocene and Aquitanian in the eastern part of the Western Tethys Region. The biogeographic terms Eastern-African-Arabian Province (EAAP) and Western Indian Province (WIP) are proposed for these bioprovinces.

The gastropod species from the Warak Formation – especially those which are shared with the Mediterranean-Iranian Province – allow to estimate a Late Oligocene age. The stratigraphic ranges of the taxa from the overlying Ghubbahar Formation represent an Aquitanian age for that unit. These age estimates diverge markedly from literature data, which propose a Miocene age for the Warak Formation and a Middle Miocene age for the Ghubbahar Formation.

**Key words:** Gastropoda, Oligocene, Aquitanian, Biogeography, Arabia.

1. **Introduction**

Our knowledge of the Oligocene and Early Miocene European gastropod faunas of the Western Tethys Region is relatively extensive. The key faunas are those from the northern Italian region such as the Veneto and Liguria described by Micheliotti (1861), Fuchs (1870), Rovereto (1900), and many others (see Harzhauser et al. 2002 for an extensive discussion). Especially the Aquitaine faunas, located on the western side of the Western Tethys, have recently received considerable attention (Lozouet 1998, 1999, Lozouet et al. 2001). Several Oligocene and Aquitanian faunas have been extensively treated from the central and eastern parts of the Western Tethys [e.g. Bulgaria (Karagiuleva 1964), Greece (Harzhauser 2004), Turkey (Stchepinsky 1939), Armenia (Abich 1882), Iran (Harzhauser 2004) and Pakistan (Vredenburg 1925, 1928)]. Hardly any information is available about coeval faunas from the southern shelf of the Western Tethys. Therefore, the current project attempts to extend our understanding of these assemblages along the eastern coast of the Sultanate of Oman on the Arabian Peninsula.

A gastropod fauna was collected during a fieldtrip that focused on Oligocene and Miocene shallow water carbonates of the Dhofar Group (Shuwayr Formation) and the Fars Group (Warak and Ghubbahar Formations) in the area of Madrakah and Duqm in the SE coastal zone of Oman (Text-fig. 1). The selection of the areas followed age indications and reports on fossil faunas in Platel et al. (1992) and Béchennec et al. (1993). The analysis of the marine fauna and the description of the depositional history along the south-eastern Arabian shelf provides the basis for the reconstruction of the biotic development along the southern coast of the Oligocene Tethys Ocean within the FWF-Project Biogeographic Differentiation and Biotic Gradients in the Western Indo-Pacific during the Late Oligocene to Early Miocene. The Omani faunas were expected to be keystones for the reconstruction of Oligocene biogeography in the eastern Western Tethys, as no Oligocene to Early Miocene Mollusc faunas have been satisfactorily reported so far from the Arabian peninsula.

2. **Geological Setting**

[based on logging in co-operation with Markus Reuter, Werner Piller (Univ. Graz, Austria) and Andreas Kroh (Natural History Museum Vienna)]

The investigated assemblages have been collected in two main areas along the eastern coast of central Oman (Text-fig. 1). These areas in the Madrakah district and the Duqm district are about 70 km apart but display highly similar depositional successions and quite homogeneous invertebrate assemblages. This faunistic similarity shows that the recorded sequences are representative for a large part of the south-eastern Arabian shelf during the Oligocene and Early Miocene (Aquitanian). A detailed discussion of the lithological successions will be given elsewhere by Reuter et al. (in prep.); therefore, only a brief introduction is presented here. Formation names follow the lithostratigraphic concept of Platel et al. (1992).
2.1. Madrakah district

Madrakah cliffs (MC section; N 19º 01’ 31,36"; E 07º 48’ 25,61") – Shuwayr Formation

The section is situated close to the Masirah ophiolite zone and comprises carbonates of the Shuwayr Formation of more than 90 m thickness. In the basal part of the succession, marls predominate, yielding small coral colonies and scattered molluscs. Articulated bivalves occur in life position. The marls soon grade into bioclastic limestones with larger foraminifers (lepidocyclinids), molluscs, echinoids and coral branches (Acropora). Throughout the lower and middle part of the section, rooted horizons indicate repeated phases of emersion. The section is terminated by a several-meter-thick cap of dolomite, forming the geomorphologic plain of the Madrakah peninsula.
Gebel Madrahah (GF section; N 19° 02’ 19.11", E 57° 45’ 12.22") – Warak & Ghubbarah Formations

Following the Madrahah plain about 3 km E into the hinterland, the second investigated sedimentary succession is exposed at the Gebel Madrahah. Almost the entire section is composed of bioclastic limestones of the Warak Formation. Fossils are abundant and are preserved as calcitic pseudomorphs. Corals are represented mainly by branches of *Acropora*. The top of the section is formed by a prominent cap of dense floatstone with a diverse mollusc fauna characterised by strombid coquinas. The fauna of the top unit is largely silicified, which distinguishes this unit from the underlying beds with calcitic preservation. This cap is defined as Ghubbarah Formation in the geological map of the Duqm-Madrahah area (Platel et al. 1992).

2.2. Duqm district

Karmah Pass (D section; N 19° 30’ 37.36", E 57° 35’ 22.56") – Warak Formation

A short part of the Warak formation, of up to 30 m thickness, is exposed along the Karmah pass road. The rather monotonous lithological succession starts with two characteristic bioclastic limestone beds with in-situ patches of the bivalve *Kuphus*, *Xenophora* snails and various cerithids are common. Locally, mass-occurrences of the small-sized infaunal echinoid *Echinocyamus* occur. *Acropora* fragments and isolated large massive coral heads are found as well. Above follows a thick unit of white mudstones which are virtually unfossiliferous. Grainstones with small foraminifers and partly dolomitised packstones form the top of the succession. Macrofossils are rare in these diagenetically altered beds.

3. Composition and biostratigraphic implications

The total fauna comprises 51 species-level taxa (Table 1). Most of them (42) have been found in the *Acropora*-bearing limestones of the Warak Formation. All shells are preserved solely as calcitic pseudomorphs, which can be collected only if weathered out from the limestones. In contrast, only 5 species are documented from the much thicker Shuwayr Formation, where shells suffered from heavy dolomitization. About 12 species are identified from the limestones of the Ghubbarah Formation. These specimens are preserved mainly as silicone moulds, whilst the associated steinkerns usually lack distinctive features.

No reliable age estimates of the formations are available from the literature. The shallow marine carbonate facies is hard to date due to the lack of planktonic foraminifera. Age correlations range broadly from Oligocene to Middle Miocene (Platel et al. 1992). Larger foraminifers occur in the base of the Shuwayr Formation. There, *Eulepidina formosoides* (identification by David Bass) points to a latest Rupelian or Early Chattian age, enabling at least the lower stratigraphic boundary to be defined. Hence, lacking any other biostratigraphic tools, the mollusc faunas are used to estimate the age of the overlying deposits.

3.1. Shuwayr and Warak Formations

The latest Rupelian to Early Chattian Shuwayr Formation represents the basal part of the investigated succession (Text-fig. 2). This unit bears a very small gastropod fauna which is of little biostratigraphic value. The overlying Warak Formation yielded 42 gastropod species which allow a more detailed age estimate. Eliminating the 17 new species, which are unknown from any other locality, about 25 species remain for a biostratigraphic interpretation. Of these, 10 species are known so far only from Oligocene faunas of France, Italy, Iran and/or Pakistan [e.g. *Terebra perturrita* Sacco 1891, *Consorsis protensus* (Michelotti 1861), *Rhinoclavis submelanoides* (Michelotti 1861), *Rhinoclavis vogifinni* (Michelotti 1861), *Gouyma balachaniannessis* (Vredenburg 1928), *Seraphs* cf. *subconvolutus* (d’Orbigny 1852), *Capulus aniceps* (Michelotti 1861), *Distorsio aff. cancellina* (Lamarck 1803), *Turritella (Hausstator) conofasciata* (Sacco 1895)]. Eight species appear during the Oligocene and persist either into the Aquitanian [*Tectarius elegans* (Faujas 1817), *Campanile pseudobolus* (Grateloup 1832), *Globularia cf. compressa* (Basterot 1825)] or into the Burdigalian [*Pyrazinus monstrosus* (Grateloup 1847), *Melongena lami* (Basterot 1825)] or even into the Middle Miocene [*Grandolabium plicatum* (Bruguière 1792), *Terebralia bidentata* (Defrance in Grateloup 1832), *Athleta* cf. *ficulina* (Lamarck 1811)]. At least 7 species, however, are known so far only from the Early Miocene [*Tectus loryi* (d’Archiac &
<table>
<thead>
<tr>
<th>Taxon</th>
<th>Shuwayt Fm.</th>
<th>Warak Fm.</th>
<th>Ghubbarah Fm.</th>
<th>EAP</th>
<th>MIP</th>
<th>EEAP</th>
<th>WIP</th>
<th>PIPP</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Tecta longis</em> (d’Archiac &amp; Haim 1853)</td>
<td>×</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Cantharidus</em> (Borera) elkeae n.sp.</td>
<td>×</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Solarrella krobi</em> n.sp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Warasia pilieri</em> n.sp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Globularia</em> cf. <em>compresa</em> (Basterot 1826)</td>
<td>×</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Pachycentrum</em> harrisi (Pannekoek 1936)</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tenacicerithium</em> omaniacum n.sp.</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Campanile pseudoobesus</em> (Grateloup 1832)</td>
<td>×</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Campanile</em> gigas (Martin 1882)</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Cerithium</em> archaici <em>Vredenburg</em> 1928</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Cerithium</em> markurenieri n.sp.</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Cerithium</em> lakeneneri n.sp.</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Cerithium rube Sowerby 1840</em></td>
<td>×</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Cerithium</em> cf. <em>propoena</em> (Martin 1916)</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Rhinoeclavis</em> submelanoides (Michelotti 1861)</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Rhinoeclavis</em> voglinoi (Michelotti 1861)</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Goarnya</em> baldastianensis (<em>Vredenburg</em> 1928)</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Goarnya</em> delboi (Michelotti 1861)</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Pyrazinosius</em> monstruosus (Grateloup 1847)</td>
<td>×</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Gratulalbium</em> pliacum (Bruguiere 1792)</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Terebralia</em> bidentata (Defrance in Grateloup 1832)</td>
<td>×</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Bayania</em> omanisimosa n.sp.</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Turrissella</em> steiningeri n.sp.</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Turrissella</em> sp. 1</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Turrissella</em> (Hautator) conofasciata (Sacco 1895)</td>
<td>×</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Turrissella</em> (Hautator) cf. sedanaensis (Martin 1905)</td>
<td>×</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tectarius</em> elegans (Faujas 1817)</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Xenophora</em> cf. <em>deshayesi</em> (Michelotti 1847)</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Projenneria</em> salata* Fehsen* n.sp.</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Varicoprora</em> zunzini* n.sp.</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Varicoprora</em> morax (Martin 1916)</td>
<td>×</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Dalmanubra</em> subphilatisius (d’Orbigny 1852)</td>
<td>×</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Strombus</em> gigasrenbergi* n.sp.</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Strombus</em> bernsteinaensis* n.sp.</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Seraphi</em> cf. <em>scolosubitus</em> (d’Orbigny 1852)</td>
<td>×</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Capulus</em> anceris (Michelotti 1861)</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Distinos</em> aff. <em>cancellina</em> (Lamarck 1802)</td>
<td>×</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Melongena</em> lainei (Basterot 1825)</td>
<td>×</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Lyria</em> madrakahensis* n.sp.</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Athleta</em> cf. <em>fuscula</em> (Lamarck 1811)</td>
<td>×</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Vasum</em> omanicama* n.sp.</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Cancellia</em> n.sp.</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Mitra</em> cf. <em>dulcenae</em> Basterot 1825</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Crassapora</em> n.sp.</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Terebraria</em> perturrita* <em>Saco</em> 1891</td>
<td>×</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Conus</em> n.sp. 1 (aff. <em>grateloup</em> d’Orbigny 1852)</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Conus</em> n.sp. 2 (aff. <em>antiquus</em> Lamarck 1810)</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Conorhizy protensus</em> (Michelotti 1861)</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Cyclicella</em> dagnensis* n.sp.</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Bulla</em> argausensis* n.sp.</td>
<td>×</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Haimé 1853), *Campanile gigas* (Martin 1881), *Cerithium archiaci* Vredenburg 1928, *Cerithium rude* Sowerby 1840, *Turritella (Haustor)* cf. *sedanensis* (Martin 1905), *Varicospira mordax* (Martin 1916), *Cerithium cf. progensis* (Martin 1916). Interestingly, these species belong exclusively to the Pakistani or Indonesian faunas, deriving from areas where Oligocene faunas are poorly known or absent. Based on this data set, the Warak fauna is most likely of Late Oligocene age. These species originated during the Oligocene and became part of the Indonesian faunas during the Early Miocene.

### 3.2. Ghubbarah Formation

The fauna of 12 gastropod species consists of at least 5 new species. Of these, *Warakia pillerii* n.sp. and *Cantharidus elkeae* n.sp. have close relatives in the Early Miocene faunas of Borneo and Java (see discussion in the systematic part). *Dilatidlabrum sublattissimus* (d’Orbigny 1852), *Campanile pseudoobeliscus* (Grateloup 1832) and *Gourmya delbosi* (Michelotti 1861) appear during the Oligocene and persist into the Aquitanian (Lozo et al. 2001, Harzhauser 2004). Similarly, *Cerithium rude* Sowerby 1840, which is recorded herein from the Warak Formation, seems to range from the Late Oligocene to the Miocene. Two further species are known so far exclusively from the Miocene: *Mitra cf. dufresnei* Basterot 1825 is an Aquitanian to Burdigalian species in the Western Tethys, whereas *Pachycrommadium harrisii* (Pannekoek 1936) is an Early to Late Miocene
species of the Proto-Indo-Pacific. This pattern would, thus, fit best to an Aquitanian age for the Ghubbarah fauna (Text-fig. 2). A Burdigalian to Langhian age, as suggested by Plate et al. (1992), is not supported by our data.

4. Biogeography

The Late Paleogene and Early Neogene marine faunas of Oman lived along the southern coast of the Western Tethys Ocean. At that time, a broad connection still existed between the Mediterranean basins and the Indo-Pacific basins, via the Mesopotamian trough and the Zagros zone (Rögl 1998). The composition of the faunas of the northern Tethys coast are fairly well documented by a chain of classical localities starting in the French Adour Basin (Atlantic) in the west via Liguria, the Veneto region and the Turin Mountains in northern Italy, the Greek Mesohellenic Trough and the Turkish Sivas Basin down to the Iranian Esfahan-Sirjan and Qom basins and Pakistan in the east (Harzhauser 2004 and references therein). In contrast, the faunas from the southern Tethys are almost unknown. Only scattered reports on usually poorly preserved faunas from Israel, Somalia and Kenya are available (Azzaroli 1958, Cox 1930, 1934).

Harzhauser et al. (2002) proposed a biogeographic scheme for the Oligocene and Early Miocene of the Western Tethys Region based on molluscs. The Western Tethys Region – being part of the huge Tethys Realm – covered the area of the modern Mediterranean, including also the European Atlantic coast with the Bay of Biscay as its northern limit. The Western Tethys Region reached to Pakistan, Somalia and Zanzibar in the east and the south and was bordered by a major biogeographic unit inhabited by the Indo-Malayan faunas. This is called herein the Proto-Indo-Polynesian Province (PIPP) of the Proto-Indo-West Pacific Region.

The Western Tethys Region was composed of the Mediterranean-Iranian Province (MIP) in its core area. In the west, the Eastern-Atlantic Province (EAP) was already forming a transitional zone to the faunas in the North Sea. For the eastern part of the Western Tethys Region, Harzhauser et al. (2002) proposed a single large province contributed by the faunas of Pakistan (Vredenburg 1925-28, Iqbal 1980) and those of the coast of Eastern Africa described by Azzaroli (1958) from Somalia and from Kenya by Cox (1930). Although the Pakistani and Omani areas share several taxa that are unknown from the MIP [e.g.: Tectus loryi (d’Archiac & Haime 1853),

Text-fig. 3. Relation of the herein-documented Omani gastropod assemblage with Oligocene and Early Miocene gastropod faunas of adjacent bioprovinces. Values show how many percent of the Omani taxa are also found in the reference faunas (EAP: East-African-Arabian Province, EAP: Eastern-Atlantic Province, MIP: Mediterranean-Iranian Province, WIP: Western-Indian Province, PIPP: Proto-Indo-Polynesian Province).
Cerithium archiaci Vredenburg 1928, Cerithium rude Sowerby 1840, Gourmya baluchistanensis (Vredenburg 1928), the general faunistic similarity is quite low (Text-fig. 3). Instead, the Omanian fauna shows a higher affinity with MIP-faunas, sharing about 40% of the species. Moreover, the high percentage of endemics (42%) - with the strombids as the most conspicuous elements – points to a discrete biogeographic entity. This pattern requires a separation of the eastern part of the Western Tethys Region into two provinces called Western Indian Province (WIP) and Eastern African-Arabian Province (EAAP) herein.

The low number of PIPP elements in the Oligocene of the Omanian faunas [e.g. Warakia, Pachycroanum harrisii (Pannekoek 1936), Campanile gigas (Martin 1882), Varicospira mordax (Martin 1916), Cerithium cf. progensis (Martin 1916), Cerithium rude Sowerby 1840] is probably an artefact due to the lack of Oligocene faunas in the Indonesian region. The connection to the Miocene PIPP faunas might therefore rather be documented by closely related species pairs. Such suggested species pairs are formed by the Omanian Oligocene Stombus bernielandaei n.sp. and Cantihelius elutea n.sp. and the Miocene Stombus proconvitatus Finlay 1921 and Cantihelius erinaceus Beets 1941 from Borneo, respectively. Tectus loryi (d’Archiac & Haim 1853) and Warakia pilleri n.sp. and their younger PIPP counterparts Tectus cognatus (Sowerby 1840) and Warakia estoni (Martin 1916) are two further examples.

5. Paleocology

Both the taxonomic composition of the gastropod fauna and the co-occurring biota clearly indicate a very shallow marine depositional environment for all formations. In general, the Shuwayr and Warak formations are characterized by quite similar faunas and lithologies. The only exception is the somewhat marly base of the Shuwayr formation, where Solariella? krohi n.sp. occurs. This species is accompanied by Spondylus sp., Chlamys sp., ostreids, bryoides, lepidocyclins, and numerous fragments of astropectenids and other echinoderms, pointing to a shallow sublittoral setting of few tens of metres water depth. Even shallower, largely intertidal taxa, such as Pyrazinus monstrosus (Grateloup 1847) are present in the overlying bioclastic limestones and dolomitized mudstones. Modern Pyrazus ebenus (Bruguieré, 1792), the closest relative of the fossil Pyrazinus monstrosus, is an intertidal animal dwelling in mangroves and Zosteria flats (Vohra 1965). The broad spectrum of taxa of the Warak Formation allows to recognise several shallow marine environments, such as patch reefs or coral reefs, sea grass meadows and littoral mangrove flats.

At Gebel Madrakah, the Acropora-bearing limestones are dominated by Cerithium rude Sowerby 1840, Cerithium markusreuteri n.sp., Cerithium archiaci Vredenburg 1928, Tectus loryi d’Archiac & Haim 1853 and Stombus bernielandaei n.sp. These species are usually well preserved and appear in large numbers. Others, such as Campanile gigas (Martin 1881) and Pyrazinus monstrosus (Grateloup 1847), are less abundant and display strongly corroded shells. Obviously, the cerithids and the small strombid formed large populations in the loose Acropora carpets. Several modern Indo-Pacific Cerithium species are recorded by Houbriek (1992) to occur in similar shallow water habitats with sand-rubble substrates. In contrast, the poorly preserved Pyrazinus and Campanile may have been transported from the adjacent coastal area. This is supported by the data on their living relatives, which do not favour coral-associated habitats; an example is the extant Australian Campanile symbolicum (Iredale), which is reported by Houbriek (1981a) to live in shallow subtidal sandy habitats in 1–4 m water depth. Terebratalia bidentata (Defrance in Grateloup 1832) may well be derived from a nearby mangrove flat, because modern Terebratalia prefer mangrove swamps in the intertidal zone (Houbriek 1991).

Carbonate sand flats with scattered sea grasses and/or algae within the Acropora carpets are indicated by the assemblages in the basaltic parts of the Karmah pass section at Duqm and at Shuwayr on the Madrakah Peninsula. There, Rhinoclavis submelanoidei (Michelotti), Tenuicerithium omanicum n.sp., Bayania omanipinosa n.sp. and Campanile pseudooebelicus (Grateloup) are common. Modern plesiotochids, related to Tenuicerithium, live on algae in sheltered pools and in sea grasses (Houbriek 1990, Ludbrook 1984), whilst Rhinoclavis species are infaunal sand dwellers (Houbriek 1992).

The fauna of the Ghubbahar Formation differs in its composition from the previous faunas. The most remarkable feature is the abundance of the large strombid Stombus gigikronenbergi n.sp. and of the giant conch Dilatlabrum sublattissimus (d’Orbiigny). Colonies of such large (> 20 cm) strombids are found today in sea grass meadows and sheltered lagoons, where they live partly buried in the soft substrate (Bandel & Wedler 1987).
Indeed, coral carpets, as typical for the Warak Formation seem to be rare in the Ghubbarah Formation. Acropora branches are less abundant. Isolated massive corals may have been the habitat of Goury na delbosi (Michelotti), corresponding to its sole extant relative Goury na goury (Crosse 1861), which is described by Houbri c (1981b) as a herbivorous grazer on rocks in coral reef slopes between 5 and 30 m depth.

In conclusion, all assemblages are marine from partly coral-, partly sea grass-dominated shallow sublittoral to intertidal environments. Coastal areas might have been covered by mangroves. None of the taxa suggest any freshwater influx or considerable fluctuations in salinity. Instead, this area of the Arabian shelf experienced quite stable marine conditions, with repeated but short phases of emersion.

6. Systematic Palaeontology

The systematic arrangement of higher taxa largely follows the proposal of Bouc he & Rocco (2005) and Lezou et al. (2001). Abbreviations: w = width, h = height, NHMW = Natural History Museum Wien.

Class Gastropoda Cuvier 1797
Subclass Orthogastropoda Ponder & Lindberg 1996
Superorder Vetigastropoda Salvini-Plawen & Haszprunar 1987
Superfamily Trochoidea Rafinesque 1815
Family Trochidae Rafinesque 1815
Subfamily Trochinae Rafinesque 1815
Tribe Trochini Rafinesque 1815
Genus Tectus Montfort 1810

Type species: Tectus mauritianus Gmelin 1791. Recent, Indo-Pacific.

Tectus loryi (d’Archiac & Haime 1853)

Plate 1, figs. 1–3

1853 Tectus cognatus d’Archiac & Haime, p. 290, pl. 26, fig. 18 (non Tectus cognatus Sowerby 1840).
1853 Tectus loryi d’Archiac & Haime, p. 290, pl. 26, fig. 17.

Material: 15 specimens (NHMW 2006e0231/0221-0224) from Gebel Madrakah (Warak Fm.).

Remarks: d’Archiac & Haime (1853) based their Tectus loryi on a juvenile shell, neglecting the strong change of sculpture between juvenile (Plate 1, fig. 3) and adult teleoconch whorls (Plate 1, fig. 1). As pointed out by Vredenburg (1928), this large Tectus differs from the younger Tectus cognatus (Sowerby 1840) by the coarser and fewer granules and by the lower number of spirals (4 instead of 5). Its western Tethyan relative, Tectus lucastianus (Brongniart 1823) differs in its cyrtoconoid spire and the coarser granules which are arranged in only 3 spirals.

Tectus loryi appears during the Oligocene along the southern Tethys coast (Warak Formation, Oman) and is a common fossil in the Lower Miocene of Pakistan (Gāj Formation; Vredenburg 1928).

Tribe Cantharidini Gray 1857
Genus Cantharidus Montfort 1810
Subgenus Beranae Beets 1941

Type species: Cantharidus (Beranae) erinaceus Beets 1941. Miocene, Borneo.
Cantharidus (Beraea) elkeae n.sp.

Plate 1, figs. 4–5

Material: 2 specimens and 1 silicone-mould from Gebel Madrakah (Warak and Ghubbarah formations).
Holotype: Plate 1, fig. 5; NHMW 2006z0231/0013, h.: 11.1 mm, w.: 14.2 mm.
Paratype: Plate 1, fig. 4; NHMW 2006z0231/0012, w.: 8.3 mm, h.: 8.7 mm.
Stratum typicum: Acropora bearing bioclastic limestones of the Warak Fm.
Type locality: Gebel Madrakah, Oman.
Age: Oligocene (Chattian).
Name: In honour of my beloved wife Elke Harzhauser.

Diagnosis: Tall cantharidinid trochid with flat to slightly concave whors and an apabral row of spiny nodes along the lower suture on the third and fourth teleoconch whorl.
Description: Small-sized trochoid shell of 5 teleoconch whors with flat to slightly cyrtoconoid whors. The protoconch is unknown. Flanks of whors are weakly concave and sculptured with 8-9 densely spaced spiral threads. These are crossed by delicate, strongly inclined prosocline growth lines. On the second and third preserved teleoconch whorl, a row of beads develops along the lower suture, becoming prominent spiny nodes on the fourth whorl (15), weakening again on the bodywhorl. Thin and shallow suture. Base of bodywhorl sharply delaminated from remainder shell, covered with dense spiral threads. Aperture not present in material.
Discussion: Only very few trochids with this strange spiny sutural sculpture are described in the literature. Cantharidus (Beraea) erinaceus Beets 1941 from the Miocene of Mangkalihat (Borneo) is quite similar concerning the overall outline and sculpture. A clear difference is the tendency of that species to produce a prominent row of spines or tubercles along the upper suture in addition to the weaker lower one. Cantharidus (Beraea) sp. from the Miocene of the Mariana Islands (Ladd 1966) lacks the lower nodes and displays a much coarser spiral sculpture. Juvinimus? sawitae Beets 1942 (Miocene, Borneo) is smaller, very slender and develops well-separated whors. Cantharidus (Beraea) elkeae is known so far only from the Oligocene and Aquitanian of the Warak and Ghubbarah Formations in Oman.

Family Calliostomatidae Thiele 1924
Subfamily Solariellinae Powell 1951
Genus Solariella Wood 1842

Sauria? krobi n.sp.
Plate 1, figs. 6–7

Material: 9 specimens from Madrakah cliff (Shuwayr Fm.).
Holotype: Plate 1, fig. 6, NHMW 2006z0232/0004, h.: 8.5 mm, w.: 12.5 mm.
Paratype: Plate 1, fig. 7, NHMW 2006z0232/0003, h.: 8 mm, w.: 12.5 mm.
Stratum typicum: shallow marine marls of the Shuwayr Fm.
Type locality: Madrakah cliff (MC section, base), Oman.
Age: Oligocene (late Rupelian or Chattian).
Name: In honor of Andreas Kroh, Paleontologist at the Natural History Museum Vienna.

Diagnosis: Small-sized, depressed trochid shell with strongly convex whors of circular cross-section and wide-spaced, delicate spiral ribbing. Very broad and deep umbilicus with spiral threads, lacking an umbilical cord or nodes.
Description: Depressed trochid shell containing 3 strongly convex teleoconch whors with incised sutures. The protoconch is poorly preserved, consisting of about one whorl, with a large elevated nucleus. The surface is covered by thin spiral ribs that are separated by broader interspaces. The penultimate whorl bears 8 spirals, increasing to 21 spirals on the bodywhorl (including base and umbilicus). Spirals are more or less of equal strength; only the lower, sutural 2 tend to be slightly stronger. Similarly, the 2 spirals on the bodywhorl are slightly more pronounced than those at the base. Interspaces increase in width towards the base. The umbilicus is
very broad and deep, covered by similar spirals as seen on the bodywhorl. No umbilical cord is developed. Well-preserved shells display remnants of a dense pattern of faint axial threads in the interspaces between the ribs without crossing them. The aperture is lacking in most specimens but appears circular in outline.

Discussion: The generic affiliation is supported by the paucispiral, apparently smooth protoconch with the large nucleus as described by Landau et al. (2003) and Marshall (1999) for Pliocene and Recent species of Solarilla. Nevertheless, given the general poor preservation, the generic affiliation remains doubtful. Among the modern solarielline, Solarilla plicatula (Murdock & Suter 1906) from New Zealand as described by Marshall (1999) is highly reminiscent in outline, ornamentation and umbilical ornament but is much smaller. A sexual dimorphism, as reported by Marshall (1999) for S. plicatula, is missing (at least within the small number of shells). Within the fossil faunas, "Delphinula oligocaenica Cossmann & Lambert 1884" from the Oligocene of France differs considerably by its much smaller size and rapidly increasing bodywhorl. "Torinia buddha Noetling 1895" (in Noetling 1895, 1901) differs in its less convex whorls and a strongly depressed, conical outline; its bodywhorl increases much slower in width. Solariella multistriata (Fuchs 1870) is smaller, develops a narrow umbilicus and differs by its circum-umbilical row of nodes.

Superorder Caenogastropoda Cox 1960
Order Architaenioglossa HALLER 1892
Superfamily Ampullinoidea COSSMANN 1918

Family Ampullinidae COSSMANN 1918

Genus Warakia n. gen.

Type species: Warakia pilleri n. sp., Oligocene, Oman.
Name: After the Oligocene Warak Formation.

Diagnosis: Large-sized ampullinid with heavy, bulbous columnar callus and a shoulder row of spiny nodes; inner lip callus weakly convex, almost flat with several prominent ridges. Surface smooth except for slightly prosocline axial plicae on the apical part of the whorls and the aforementioned nodes.

Discussion: The unusual combination of features, such as the large size, the shoulder nodes and the extreme and sculptured callus, distinguish Warakia from other ampullinids. Warakia is typically found in coral-associated shallow marine faunas. Deshayesia Raulin 1844 from the European Eocene and Oligocene is a probably closely related genus. The various Deshayesia species described by Hébert & Renevier (1855), Vinasca de Regny (1896), Boussac (1911), and Cossmann (1925) develop neritid-like dentitions on the columnar callus, being reminiscent of the callus ornament of Warakia. Deshayesia, however, is clearly distinguished from Warakia by its smaller size, the higher shell outline, the higher number of sculptural elements on the columnar callus, the slit-like pseudumbilicus and by the absence of surface sculpture such as spines or axial plicae. Moreover, Deshayesia develops a thick parietal callus whereas Warakia develops the maximum swelling in the middle of the columnar callus. The outer lip of Deshayesia is well defined and forms an inflated termination.

Nanggulania Martin 1914 from the Middle Eocene of Java bears a superficial similarity but differs in the presence of a weak spiral sculpture, a pseudumbilicus and an expanded outer lip. The callus develops only weak wrinkles and is less prominent.

Occurrence: This genus is represented by its type species in the Oligocene and Aquitanian of Oman and by Warakia eastonii (Martin 1916, p. 260) in the Miocene of Java (Text-fig. 4). Warakia seems to be a typical Proto-Indo-Pacific element.

Warakia pilleri n. sp.
Plate 1, figs. 8-10


Material: 5 specimens from Gebel Madrakah (Warak and Ghubbarah formations).
Holotype: Plate 1, fig. 9, NHMW 2006o0231/0016, w.: 32, h.: 27.5 mm.
**Paratype**: Plate 1, fig. 8, NHMW 2006/0231/0015, w.: 26.5 mm, h.: 24.5 mm.

**Paratype** (silicone mould): Plate 1, fig. 10, NHMW 2006/0231/0014, w.: 40 mm.

**Stratum typicum**: *Acropora* bearing bioclastic limestones of the Warak Fm.

**Type locality**: Gebel Madrakah, Oman.

**Age**: Late Oligocene ( Chattian) to Early Miocene (Aquitanian).

**Name**: In honor of Werner Piller, who has been my teacher, mentor and friend for many years.

**Diagnosis**: Large-sized ampullinid with a shoulder ornamented with axially elongated nodes and a strongly thickened columellar callus bearing 4–5 prominent ridges and a prominent parietal swelling.

**Description**: A large-sized ampullinid shell consisting of 5 convex whorls with incised sutures. Bodywhorl increases rapidly in width with and has a pronounced convexity in its middle part. The bodywhorl passes rather abruptly into the base forming a slight angulation. Surface covered by slightly prosocline growth lines which culminate in distinct axial plicae in the adapical part of the whorls. A row of spiny, slightly axially elongated, nodes decorates the last and the penultimate whorls at the shoulder. The height of the spines decreases towards the aperture, which is narrowed in its lower half by a prominent, bulbous columellar callus and a thick parietal pad. The callus passes into an almost flat callus swelling with up to 5, blunt axial ridges. Of these, the middle ones are most prominent, whereas the upper two are weaker and more closely interspaced. The outer lip is not thickened and lacks denticles.

![Image of Warakia eastoni](image.png)


**Discussion**: *Warakia pilleri* differs from the congeneric *Warakia eastoni* (Martin 1916) [= *Neritina (Clithon) Eastoni* Martin 1916] from the Early Miocene of Java by the coarser columellar sculpture (Text-fig. 4). The spire of *Warakia eastoni* is hardly protruding from the broad and flat subsutural ramp and the species lacks the bulbous columellar callus. Furthermore, the angulation of *Warakia pilleri* forms a marked transition between the subsutural ramp and the strongly convex body whorl. In contrast, this angulation is less pronounced in *Warakia eastoni*. Despite these differences, a close relation between both species is evident.

The species is common in *Acropora* bearing deposits of the Omanian Oligocene and Aquitanian. In size and shape it is highly reminiscent of various Oligocene and Miocene *Globularia* species and seems to have been repeatedly misidentified by mapping geologists (e.g. *Globularia carlei* in Plate et al. 1992).

**Genus Globularia Swainson 1840**

**Type species**: *Ampullaria sigaretina* Lamarck 1804. Eocene, Paris Basin.
Globularia cf. compressa (Basterot 1825)

? 1825 *Ampullaria compressa* Basterot, p. 34, pl. 4, fig. 17.
? 2001 *Globularia compressa* – Lozouet et al., p. 21, pl. 18, fig. 10.

**Material:** 3 fragmentary shells from Gebel Madrakah (Warak Fm.), NHMW 2006e0231/0075.

**Discussion:** Three fragments of subadult specimens are available (max. height 15 mm). Their straight-sided columellar callus distinguishes the specimens from the Miocene Pakistani and South-Indian *Globularia carlei* (Finlay 1927) [= *Natica callosa* Sowerby 1840], which has a strongly sigmoidal columellar area. The same feature allows a separation from the Oligocene European *Globularia gibberosa-santistephani*-complex (see Baldi 1973). A clear identification, however, is almost impossible based on such fragmentary material.

The oldest Oligocene representatives of the otherwise typical Early Miocene *Globularia compressa* are known from France and Hungary (Lozouet 1986a).

**Genus* Pachycrommium* Woodring 1928**

*Type species:* *Amaura saginata* Böhm 1895. Miocene, Florida.

*Pachycrommium bairisi* (Pannekoek 1936)

Plate 6, fig. 6

1936 *Ampullina (Ampullopria) bairisi* Pannekoek, p. 58, pl. 3, figs. 38–39.
1948 *Pachycrommium bairisi* – Cox, p. 19, pl. 1, figs. 4a–b.

**Material:** 1 silicone mould from Gebel Madrakah (Ghubbarah Fm.), NHMW 2006e0231/0061, h.: 46 mm.

**Discussion:** The species is characterised by its flat subsutural ramp and the globular, inflated body whorl which is contrasted by a relatively high and slender spire. *Pachycrommium oweni* (d’Archiac & Haim 1853) from the Oligocene and Early Miocene of Pakistan and Iran (own observation) is more elongate and lacks the inflated bodywhorl. *Pachycrommium eburnoides* (Grateloup 1847) from the Late Oligocene and Early Miocene of France differs clearly by its channelled suture.

*Pachycrommium bairisi* was described from the Early Miocene of Java (Pannekoek 1936) and seems to have persisted throughout the Miocene in Borneo (Cox 1948). The occurrence in the Omanian Ghubbarah Formation is thus a hint to a Miocene age of that formation.

**Superfamily Campaniloidea Douville 1904**

**Family* Plesiotrochidae* Houbrick 1990**

**Genus* Tenuicerithium* Cossmann 1896**

*Type species:* *Cerithium fragile* Deshayes 1833. Eocene, Paris Basin.

*Tenuicerithium omanicum* n. sp.

Plate 3, fig 3

**Material:** 5 specimens from Shuwayr (Warak Fm.).
**Holotype:** Plate 3, fig. 3, NHMW 2006e0236/0005, h.: 14.5 mm, w.: 6 mm.
**Paratype:** NHMW 2006e0236/0002, w.: 7 mm.
**Paratype:** NHMW 2006e0236/0004, h.: 14 mm, w.: 6 mm.
**Locality:** Shuwayr, Oman.
**Type specimen:** *Acropora* bearing bioclastic limestones of the Warak Fm.
**Age:** Oligocene (Late Rupelian or Chattian).
**Name:** After the Sultanate of Oman.

**Diagnosis:** Small-sized pagoidiform shell with prominent keel at c. 1/4th of the whorl height, separating a broad, concave ramp; above drop-like axial-nodes on early whorls grade into spiny nodes on late whorls; a spiral thread, coinciding with the angulation and crossing also the spines, forms a delicate keel.
Description: Small-sized, slender, turriculate, pagodiform shell of more than 9 teleoconch whorls with an apical angle of 30°. A marked angulation appears close to the lower suture on early whorls, moving into the lower third of the whorls during growth. This sharp angulation separates a flat to slightly concave subsutural ramp from a slightly convex lower part of the whorl. Drop-like, widely-spaced axial swellings cover the ramp, terminating in spiny nodes at the angulation. The nodes start as rounded knobs on the early whorls and grade into spiny nodes on the final whorls. Six to seven sharp spiral threads cover the ramp; an even more prominent thread coincides with the keel-like angulation, running also across the spines. Additionally, three threads appear below the angulation. Secondary spiral threads are intercalated increasing the total number of spirals to 11 on the base of the body whorl, where they grade into sharp ridges. Sutures and adaxial spiral threads are wavy on the final whorls. The aperture is elongate ovoid with narrow angled adapical channel; inner lip is narrow and well defined. The anterior channel is not preserved.

Discussion: The Eocene representatives of Tenuiceritium, such as T. fragile (Deshayes 1833) and T. costulatum (Lamarck 1804), lack the keel and develop a weaker angulation of the whorls. Others, such as T. boernesi (Deshayes 1864), T. crassiscostatum (Deshayes 1864) and T. limbatum (Deshayes 1864), develop shorter whorls, display pronounced axial elements and have a broader apical angle [see Deshayes 1864, Coissmann & Pissarro 1911].

Somewhat similar morphologies are also developed by representatives of the related genus Pleisticrothus Fischer 1878. Pleisticrothus saubontensis (Vignal 1911) is the only species that develops a comparable slender pagodiform shell among Pleisticrothus but lacks the sharp keel and the spiny nodes of Tenuiceritium omanicum. Pleisticrothus cf. stephanensis (Coissmann & Peyrot 1922) from the Oligocene of Iran (Harzhauser 2004) is very similar concerning sculpture and in respect to the position of the angulation but develops an expanded bodywhorl. The type of Pleisticrothus stephanensis (Coissmann & Peyrot 1922) from the Early Miocene of France differs by its broad shape and in respect to the position of the angulation but develops an expanded bodywhorl. The French Early Miocene Pleisticrothus fallax (Grateloup 1832) is less pagodiform, broader and lacks the sharp angulation [see Vignal 1911, Coissmann & Peyrot 1922 and Lozouët et al. 2001 for descriptions].

Few comparable species are present in the Proto-Indo-Pacific faunas. Pleisticrothus semari (Beets 1941) from the Miocene of Java is much broader and the Late Neogene P. inopinatum (Coissmann 1910) from Java (Beets 1941) and Karikal in southeast India (Coissmann 1910) lacks the spiral sculpture, develops few but prominent varix-like axial ribs and has a shorter bodywhorl with a less conical base. The smaller Early Miocene Pleisticrothus talmanana Ladd 1972 from Eniwetok (Pacific) is broader and develops a second keel below the angulation of the whorls; its nodes are smaller and more numerous. Pleisticrothus sp. A in Ladd (1972) from the Pliocene of the same locality agrees in sculpture but is much broader.

Family Campanilidae Douvillé 1904

Genus Campanile Fischer 1884

Type species: Cerithium giganteum Lamarck 1804. Eocene, Paris Basin.

Campanile pseudoobeliscus (Grateloup 1832)

Plate 2, figs. 5–7

1832 Cerithium pseudo-obeliscus Grateloup, p. 282.
1847 Cerithium pseudo-obeliscus – Grateloup, pl. 17, fig. 12.
1870 Cerithium Menegazzii – Fuchs, p. 152, pl. 5, fig. 11.
1870 Cerithium tranitense – Fuchs, p. 176, pl. 5, fig. 10.
1882 Cerithium Charpentieri – Abich, p. 251, pl. 7, fig. 1.
1895a Telestoicium Charpentieri var. subgranosa Sacco, p. 57, pl. 3, fig. 42.
1895a Telestoicium Charpentieri var. ornata – Sacco, p. 57, pl. 3, fig. 43.
1895a Telestoicium Charpentieri var. tuberculatoconica Sacco, p. 57, pl. 3, fig. 44.
1922 Telestoicium pseudoobeliscus – Coissmann & Peyrot, p. 255, pl. 7, fig. 35.
1922 Telestoicium pseudoobeliscus var. spinato-conicum Coissmann & Peyrot, p. 256, pl. 6, fig. 16.
1928 Telestoicium charpentieri – Vredenburg, p. 364 pars, pl. 15, figs. 17–18, pl. 17, figs. 1–2, 6–9.
2001 Campanile pseudoobeliscus – Lozouët et al., p. 22, pl. 10, figs. 4a–7b.
2004 Campanile pseudoobeliscus – Harzhauser, p. 112, pl. 6, figs. 1, 4.
Material: 4 shells from Karmah Pass at Duqm (Warak Fm.), NHMW 2006a0231/0011-0012; 5 shells and 1 silicone mould from Gebel Madrakah (Warak and Ghubbarah formations), NHMW 2006a0231/0018.

Discussion: The specimens from Karmah Pass are strongly spinose and have a weaker spiral sculpture, thus approaching the morphology of “*Cerithium menegazzii* Fuchs 1870”. A similar shell was detected at Abadeh in the Iranian Esfahan-Sirjan Basin (Harzhauser 2004). At Gebel Madrakah, the shells are all weakly ornamented with small nodes and a dominant spiral sculpture, being thus reminiscent of the “ornata” morph described by Sacco (1895a). This tendency to produce distinct morphologies at certain localities may point to eco-morphotypes. A detailed discussion on this species is given in Harzhauser (2004).

*Campanile pseudoobeliscus* is a Western Tethyan species which is known from the Late Oligocene of France, Northern Italy, Bulgaria, Iran, and Pakistan. According to Lozouet et al. (2001) its distribution extends northwards into the North Sea Basin during the Late Oligocene. During the Aquitanian the species is still common along the Atlantic coast of France and in Italy and was also present in the Iranian Esfahan-Sirjan Basin. Its easternmost occurrence is the Gâj Formation of Pakistan (Vredenburg 1928).

*Campanile gigas* (Martin 1881)
Plate 2 figs. 1–2

1881 *Telescopium gigas* Martin, p. 117, pl. 6, fig. 4, pl. 7, fig. 1.

Material: 3 shells from Gebel Madrakah (Warak Fm.), NHMW 2006a0231/0007-0009.

Discussion: The species is represented by two strongly weathered shell fragments. They display a very weak convex bulge in the abapical third of the final teleoconch whorls and their base is sculptured by marked spiral threads. Despite their poor preservation, the shells correspond fully to *Campanile gigas*, which is characterised by an almost smooth columella (Martin 1899), a weak bulge in the lower part of the whorls and spiral threads on early teleoconch whorls (Beets 1941). Only one fragment of a very huge specimen shows a weak columellar fold.

*Campanile gigas* is reported from the Early Miocene of Java (Hoek OstenDE et al. 2002) and seems to persist up the Middle or Late Miocene in Borneo (Beets 1941).

Order Sorbeconcha Ponder & Lindberg 1997

Superfamily Cerithiodea Fleming 1822

Family Cerithiidae Fleming 1822

Subfamily Cerithiinae Fleming 1822

Genus Cerithium Bruguère 1789

Type species: *Cerithium adansonii* Bruguère 1792. Recent, Indo-Pacific.

*Cerithium archiaci* Vredenburg 1928

Plate 3, figs. 6–7, 14

1853 *Cerithium pseudocorrugatum var c – d’Archiac & Haime*, p. 299 (pars), pl. 28, fig. 7 (non *Cerithium pseudocorrugatum d’Orbigny 1852*).

1853 *Cerithium pseudocorrugatum var b – d’Archiac & Haime*, p. 299 (pars), pl. 28, fig. 8 (non *Cerithium pseudocorrugatum d’Orbigny 1852*).

1928 *Cerithium archiaci* Vredenburg, p. 356.

Material: 4 specimens from Gebel Madrakah (Warak Fm.), NHMW 2006a0231/0050-0051.

Description: A large-sized cerithiid, which might have attained a size of up to 7 cm (calculated from the preserved fragments). Short, convex teleoconch whorls with coarse, broad and rounded, straight to slightly prosocline axial ribs and varices located irregularly on the shell. The ribs are highly structured by about 10 spiral elements. The first primary spiral thread below the upper suture is somewhat isolated forming a sutural row of
nodes or tiny spines, accompanied by a weak secondary thread directly at the suture. Below, two delicate spiral threads occur, which cause a narrow concavity on the axial ribs. A pair of stronger primary spiral threads is located further. They form spirally elongated nodes or spines on the backs of the axial ribs, where they sometimes almost merge together. A second pair of almost amalgamated spiral threads is separated by a spiral groove, which is ornamented by indistinct spiral threads. Below, the whorls are constricted, bearing another secondary spiral thread. One specimen displays a delicate spiral thread with small granules along the lower suture on the last two teleoconch whorls. The bodywhorl looses the axial ribs but develops coarse primary and secondary spiral ribs with irregular knobs and nodes. The transition towards the base is marked by an angulation formed by a primary spiral rib, accompanied by a pronounced spiral depression below. A thick and strongly sculpture varix appears close to the expanding aperture which overlaps the lower half of the bodywhorl. The wing-like expansion of the inner lip as described by d’Archiac & Haime (1853) is only fragmentary preserved. Its lower tip is hardly separated from the base and forms a thin cover.

**Discussion:** This is a rarely reported species, which was probably often confused with *Cerithium pseudocornutatum* d’Orbigny 1852. The latter species, described by Sowerby (1840) as *Cerithium cornutatum* from the Miocene of Pakistan, has nothing in common with *Cerithium archiaci*. It is more slender, lacks the differentiated spiral sculpture and develops delicate axial ribs. *Cerithium cristatobirtum* Sacco 1895a, from the Oligocene of Dego in Italy, known so far only by a single fragment of the bodywhorl, is reminiscent of the Indo-Pacific species. The strong angulation of the bodywhorl, caused by a blunt spiral rib ornamented with nodes, distinguishes the Italian species clearly from *C. archiaci*. It develops an almost flat outline in the lower part of the whorl, whereas the bodywhorl of *Cerithium archiaci* is convex.

*Cerithium archiaci* is unknown from the Western Tethys; its occurrence is documented only from the Early Miocene of Pakistan. Thus, this is the first record of that species from the southern coast of the Tethys.

---

**Cerithium markusreuteri** n.sp.

*Plate 3, figs. 8–9*

**Material:** 2 shells from Gebel Madrakah (Warak Fm.).

**Holotype:** Plate 3, fig. 8, NHMW 200620231/0045, h.: 46 mm.

**Paratype:** Plate 3, fig. 9, NHMW 200620231/0044, h.: 31 mm.

**Stratum typicum:** Acropora bearing bioclastic limestones of the Warak Fm.

**Type locality:** Gebel Madrakah, Oman.

**Age:** Oligocene (Chattian).

**Name:** In honour of the geologist Markus Reuter, who collected the shells during our fieldtrip.

**Diagnosis:** Large-sized cerithiid with angulated whorls; widely spaced, coarse, spinose axial ribs crossed by 2 primary spiral ribs.

**Description:** Large-sized, broad turreted shells with angulated whorls with convex lower part and flat to slightly concave ramp in the upper third. Early teleoconch whorls bear up to 9 axial ribs with broad interspaces, becoming increasingly wider during growth (about double the width of the ribs). The axial ribs are strongly modulated by the spiral sculpture, consisting of three prominent spiral ribs on early whorls. Even in this early stage the lower two spiral ribs are better developed. Soon these two spirals predominate, causing the angulations of the whorl. The upper one forms small spines at the intersections with the axial ribs, whereas the lower rib yields spiny nodes. Aside from these primary spirals, a weaker spiral thread is developed along both sutures. About 4 much weaker secondary spiral threads are intercalated between each of these primary spirals. An additional very delicate spiral thread is intercalated between each pair of secondary threads. Varices are developed but hard to distinguish from the axial ribs. Only the varix of the bodywhorl is extremely thickened bearing 6 rounded spiral ribs. The base of the shell is separated from the convex bodywhorl by two coarse spiral ribs, marking an abrupt concavity which passes into the slightly twisted columnella. Siphonal canal narrow and deep.

**Discussion:** *Cerithium haimei* Vredenburg 1928 from the Oligocene of Pakistan might be related but differs considerably in its much weaker axial ribs, the narrower interspaces and the high number of spiral threads separating the weaker primary spiral threads. *C. markusreuteri* has no counterpart in the Western Tethys faunas. Only *C. acuticosta* Michelotti 1861 from the Oligocene of Dego in Italy is reminiscent but differs by the median angulation and the lack of a second row of nodes below that angulation. Its whorls are strongly
constricted and low compared to that of *C. markusreuteri*. The characteristic sculptural type is partly paralleled by the smaller Recent *C. scabridum* **Philippi 1848**.

*Cebrithium lukenederi* n.sp.

Plate 3, fig. 4

**Material:** 2 shells from Gebel Madrakah (Warak Fm.).

**Holotype:** Plate 3, fig.4, NHMW 2006z0231/0062, h.: 31 mm (fragment), w.: 13 mm.

**Paratype:** NHMW 2006z0231/0058, h.: 11 mm.

**Stratum typicum:** Acropora bearing bioclastic limestones of the Warak Fm.

**Type locality:** Gebel Madrakah, Oman.

**Age:** Oligocene (Chattian).

**Name:** In honour of Alexander Lukeneder, Paleontologist at the Natural History Museum Vienna.

**Diagnosis:** Medium-sized, slender turretted shell with convex whors and wavy sutures. Slightly sigmoidal axial ribs dissected by 10 spiral ribs, forming a regular pattern of delicate nodes at the intersections.

**Description:** Medium-sized, elongate cerithiid. The whors display the maximum convexity in the lower third, passing into an almost flat adapical constriction. The sutures are shallow and partially covered by axial ribs and varices. Sculpture consists of axial ribs which start as almost straight to opisthocyrt ribs on early teleoconch whors and grade into slightly sigmoidal ribs on the later whors. Interspaces are narrow attaining about half of the width of the ribs. These axial ribs fade out on the bodywhorl, where only a broad, rounded varix is developed. The axial ribs are dissected by 10 spiral ribs. An amalgamated pair of secondary threads appears at the upper suture. A very narrow concavity with a single weak spiral appears below, followed by 3 raised primary ribs with two intercalated secondary threads. Below follows an additional weak secondary spiral thread at the lower suture. Spirally elongated granules or nodes form at the intersections of the axial and spiral ribs. These granules are restricted to the upper third on the bodywhorl, where the spiral threads raise to sharp ribs. Aperture largely destroyed; inner lip well demarcated, moderately narrow.

**Discussion:** *Cebrithium pseudocorragatum* d’Orbigny 1852 (based on the description of **Vredenburg** 1928) develops about 13 axial ribs which are crossed by 15 spiral ribs and tends to develop a slightly angular teleoconch whorl profile. These features differ markedly from the Omanian species and confirm the specific separation.

The Oligocene *C. ighinai* **Michelotti 1861** differs by its coarser axial ribbing and the pronounced convexity of the teleoconch whors. Its axial ribs are straight and separated by interspaces of equal width. Within the Oligocene to Aquitanian *C. calcadosum* **Basterot 1825** morphs with very reduced and uniform sculpture occur which are reminiscent of the Omanian species (see **Menegati** 1978, **Fuchs** 1870). Even these morphs, however, are clearly distinguishable from *C. lukenederi* by the higher apical angle, the lower teleoconch whors and the broad bodywhorl. The Late Miocene *C. sucaradjanum* **Martin 1899** from Java is also a morphologically similar species. It differs by the few spiral ribs, the lack of secondary spiral threads and the lower number of axial ribs. *Cebrithium lukenederi* is only known from the Oligocene of Oman. A probably closely related Early Miocene species is *C. bardiei* **Coßmann & Peyrot 1922** from France, which has a well-developed parietal denticle which is lacking in the Omanian species. Furthermore, it bears a lower number of curved axial ribs. *Cebrithium bardiei* might be a western descendant of the Oligocene species.

*Cebrithium rude* **Sowerby 1840**

Plate 3, figs. 10–12

1840 *Cebrithium rude* Sowerby, explanation of plates, (no page number), pl. 26, fig. 10.

1853 *Cebrithium pseudocorragatum* var a – d’Archiac & Haime, p. 299 (partim), pl. 28, fig. 6 (non *Cebrithium pseudocorragatum* d’Orbigny 1852).

1853 *Cebrithium rude* – d’Archiac & Haime, p. 299, pl. 28, figs. 9, 12.

1928 *Cebrithium (Psychocerithium) rude* – Vredenburg, p. 358.

1936 *Cebrithium (Psychocerithium) rude* – Pannekoek, p. 54, pl. 3, fig. 35.

1961 *Cebrithium (Psychocerithium) rude* – Dey, p. 61, pl. 5, figs. 11, 19.

1992 *Cebrithium pseudocorragatum* – PlateL, et al., p. 65 (non *Cebrithium pseudocorragatum* d’Orbigny 1852).
Material: 2 shells from Karmah Pass at Duqm (Warak Fm.), 8 shells from Gebel Madrakah (Warak Fm.), 5 silicone moulds from Gebel Madrakah (Ghubbarah Fm.), 1 silicone mould from Madrakah cliff (Shuwayer Fm.).

Discussion: *Cerithium rude* was intensively discussed by Vredenburg (1928) who described several morphotypes. The species displays a marked change of ornamentation during ontogeny, starting with densely spaced straight to slightly opisthoclinal axial ribs. After about 7 teleoconch whorls this sculpture is replaced by broad, rounded and sometimes angulated axial ribs crossed by 8-10 thin spiral threads. Some very large-sized specimens from the Ghubbarah Formation at Gebel Madrakah develop a sutural band along the upper suture. The bodywhorl lacks the strict axial ornamentation but contains partly granulated spiral threads. This spiral ornamentation usually grades into broad, flat ribs with sharp upper edge on the base. A prominent varix on the broad bodywhorl is characteristic for this large-sized slender species. A broad, flat and well-demarcated inner lip, separated by a deep and narrow groove from the base, is also typical.

*Cerithium rude* is ubiquitous in the Shuwayer, Warak, and Ghubbarah Formations. It is likely, that *Cerithium pseudocorrugatum* of PlateL et al. (1992) from Oman should be attributed to *C. rude* which is a widespread species known from the Lower to Upper Miocene of Pakistan, Java and Borneo (Vredenburg 1928, Pannekoek 1936, Beets 1986) and from the Miocene of southern India (Dey 1961).

*Cerithium cf. progoensis* (Martin 1916)

Plate 3, fig. 13

? 1916 *Potamides (Cerithidea) progoensis* Martin, p. 253, pl. 3, fig. 67–68.

Material: 1 shell from Karmah Pass at Duqm (Warak Fm.), NHMW 2006x0230/0018, h.: 17.5 mm.

Description: A single fragment consisting of 6 rapidly expanding whorls is available. Three weak spiral ribs accentuate the strongly convex whorls. Three weak secondary threads cover the narrow subsutural ramp above the upper rib; three secondary threads are intercalated between the first pair of primaries; four secondary threads follow between the median and lower primary thread and two additional secondaries appear close to the lower suture. Densely spaced but indistinct axial swellings cause a somewhat granulated sculpture on early teleoconch whorls. The axial ribs are more pronounced and form nodes at the intersections with the primary spiral threads. Varices appear in 240° distances. The transition from the flank to the base is marked by a sharp keel-like spiral rib; the moderately convex and low base bears at least two further sharp spiral threads. The aperture is destroyed.

Discussion: The Early Miocene *Cerithium progoensis* Martin 1916 from Java is very similar. Especially subadult specimens, as illustrated in fig. 68 in Martin (1916), correspond in outline and sculpture to the fragment discussed herein. The apparent weaker axial sculpture of the Omani specimen is just a matter of lightning during photography which focused on the spiral sculpture. The Late Miocene shells from Borneo, described by Beets (1941) are a bit more slender than the Early Miocene representatives of *C. progoensis* and therefore differ from the broad Oligocene shell. Despite the similarities, a clear identification is impossible because the distinctive parts of the adult shell are missing.

Genus *Rhinoclavis* Swainson 1840

Type species: *Murex vertagus* Linnaeus 1758. Recent, Indo-Pacific.

*Rhinoclavis submelanoides* (Michelotti 1861)

Plate 3 fig. 5

1861 *Cerithium submelanoides* Michelotti, p. 122, pl. 12, figs. 14–15.
1899a *Semiculverus submelanoides* – Sacco, p. 37, pl. 2, figs. 99–100.
1984 *Semiculverus submelanoides* – Ferrero Mortara et al., p. 34, pl. 34, fig. 15.

Material: 2 shells from Karmah Pass at Duqm, NHMW 2006x0230/0009 and 2 shells from Gebel Madrakah NHMW 2006x0230/0006 (both Warak Fm.).

Description: Small-sized, slender cerithiid with shallow sutures and a flat whorl profile. Pronounced spiral sculpture of 5 granulated spiral ribs. The upper two spiral ribs tend to be composed of 2 amalgamating
secondary ribs. These are separated from the 3 lower spirals by a slightly deeper interspace. Aperture strongly oblique with a characteristic slit-like cavity between the base and the inner lip.

**Discussion:** This rather unique form is known so far only from the Western Tethys, being recorded from the Oligocene of France (LOZOUET 1986a) and the Late Rupelian and Chattian of Italy (SACCO 1895a). The Late Miocene *Rhinocladus saccaradjanus* (MARTIN 1899) from Java is the only comparable species within the Indo-Pacific fauna, differing mainly by a spirally arranged row of low nodes.

*Rhinocladus voglinoi* (MICHIELOTTI 1861)

1861  *Cerithium Voglinoi* MICHIELOTTI, p. 122, pl. 12, fig. 17.
1870  *Cerithium Voglinoi* FUCHS, p. 154, pl. 5, fig. 6.
1895a  *Cerithium (Vertagus) Voglinoi* – SACCO, p. 35, pl. 2, fig. 95.
1895a  *Cerithium (Vertagus) Voglinoi var. conicoscalaris* SACCO, p. 36, pl. 2, fig. 96.
1978  *Clava voglinoi* – MENGATTI, p. 10, pl. 2, fig. 17.

**Material:** 2 shells from Gebel Madrakah (Warak Fm.), NHMW 2006/0231/0011, w: 17 mm, h: 43 mm.

**Discussion:** The preservation of the elongated cyrtoconoid shells with an apical angle of 25-28° is poor. The weathered sculpture consists of a dense pattern of straight axial ribs which are only slightly dissected by weak spiral furrows. On the base of the bodywhorl, the axial sculpture becomes replaced by weak spiral ribs. The fragmentary aperture reveals a broad, well-demarcated inner lip and a narrow angulation corresponding exactly to the shells illustrated by SACCO (1895a) as *K. voglinoi* var. *conicoscalaris*.

*Rhinocladus voglinoi* (MICHIELOTTI) is known so far only from the Oligocene of northern Italy (COLETTI et al. 1973).

**Genus Gourmya FISCHER 1884**

**Type species:** *Cerithium guornyi* COSS 1886. Recent, Indo-Pacific.

**Gourmya baluchistanensis** (VREDENBURG 1928)

Plate 2, fig 11

1928  *Cerithium (Gourmya) baluchistanensis* VREDENBURG, p. 352, pl. 14, figs. 1–2.

**Material:** 2 shells from Karmah Pass at Duqm (Warak Fm.), NHMW 2006/0230/0007, h: 62 mm (fragment), w: 29 mm, NHMW 2006/0230/0008: w: 34 mm (fragment).

**Description:** Stout shell with elongate cyrtoconoid spire of 7 moderately flat teleoconch whorls. A weak shoulder occurs along the upper suture; late teleoconch whorls develop a bulge close to the lower suture. Bodywhorl slightly contracted with insignificant broad varix-like swelling. Sculpture of teleoconch whorls consisting of 9–11 spiral ridges separated by somewhat broader interspaces; secondary spiral threads occur between the ribs on the median of the whorls.

**Discussion:** The illustrated specimen is rather slender; a second fragment suggests a broader outline and a more convex bulge at the lower suture of the penultimate whorl. The coeval *Gourmya delbosi* (MICHIELOTTI 1861), widespread along the northern coast of the Western Tethys, differs considerably in its stocky outline, the low whorls, the distinct suture and the axial nodes or swellings of the spire. This species was known so far only from the Upper Oligocene Nari Formation of Pakistan and is now also documented from the southern Tethys coast. It is unknown from the Western Tethys faunas.

**Gourmya delbosi** (MICHIELOTTI 1861)

Plate 2, figs. 4a–4b

1861  *Cerithium Delbosi* MICHIELOTTI, p. 129, pl. 13, figs. 1–2.
1870  *Cerithium Romeo Bayan* p. 37, pl. 9, fig. 5.
1870  *Cerithium Delbosi* – FUCHS, p. 157, pl. 6, figs. 5–8.
1906  *Cerithium (Gourmya) Romeo* – COSSMANN, p. 68, pl. 1, figs. 8–9.
1922  *Cerithium (Gourmya) Romeo* – GRIFF, p. 58, pl. 11, figs. 9–10.
1978 Cerithium romeo Bayan – Ménegatti, p. 8, pl. 1, fig. 24.
2004 Gourmya delboii – Hazenauer, p. 117, pl. 8, fig. 8.

Material: 1 specimen (NHMW 2006z0231/0043) and 1 silicone mould (NHMW 2006z0231/0033) from Gebel Madrakah (Ghubbarah Fm).

Discussion: A stocky, medium-sized shell with characteristic drop-like axial swellings in the lower part of the whorls. This axial sculpture, the squat outline and the constricted bodywhorl distinguish this species clearly from the larger and more elongate G. baluchistanensis. Gourmya delboii is widespread in Oligocene deposits, occurring in Northern Italy (Ménegatti 1978), Macedonia (Gripp 1922), Greece (Harzhauser 2004) and Oman. In the Turkish Sivas Basin it is also found in Aquitanian deposits (pers. observation).

Family Batillariidae Thiele 1929

Genus Pyrazisinus Heilprin 1887

Type species: Pyrazisinus companions L. Heilprin 1887, Lower Miocene, Florida, USA.

Pyrazisinus monstrosus (Grateloup 1847)

Plate 2, figs. 8–9

1847 Cerithium nodulosum (Lamarck) var. monstrosa Grateloup, suppl., (no page number), pl. 46, fig. 13.
1852 Cerithium subnodulosum d’Orbigny, p. 81, pl. 11, fig. 1492.
1870 Cerithium cochlear Fuchs, p. 177, pl. 6, figs. 1–4.
1895a Pyrazus monstrosus var. trochlearis Sacco, p. 56.
1895a Pyrazus monstrosus var. pedemontana Sacco, p. 56, pl. 3, fig. 37.
1973 Cerithium daemon Coletti et al., p. 9.
1978 Pyrazus daemen – Ménegatti, p. 11, pl. 1, fig. 27.
2002 Pyrazisinus monstrosus – Lesport & Cahuzac, p. 4, figs. 2–9, 10.2, 10.5.
2004 Pyrazus? monstrosus – Harzhauser, p. 122, pl. 8, fig. 1.

Material: 1 silicone mould from Madrakah cliff (Shuwa’yr Fm.), NHMW 2006 z0232/0002 and 5 weathered shells from Gebel Madrakah (Warak Fm.), NHMW 2006z0231.

Discussion: The material from Gebel Madrakah is poorly preserved and shows only traces of the original sculpture. Only the silicone mould from Madrakah cliff allows a description of the delicate spiral threads which are crossed by sigmoidal ophistochryt growth lines, forming a granulated surface sculpture. This feature and the upper spiral cord which is adjoined by a distinct, narrow and incised suture correspond fully to the shells from the type-area in France described by Lesport & Cahuzac (2002). Similarly, the coarser sculpture of blunted, axially elongated, oblique nodes, which grade into spiny nodes on late teleoconch whorls agree in all details with the sculpture of the Burgidial shells from France. Therefore, a separation of the Oligocene populations as (sub)species Pyrazisinus cochlear Fuchs 1870 as discussed by Lesport & Cahuzac (2002) is not supported.

Pyrazisinus monstrosus occurred in Northern Italy (Fuchs 1870, Sacco 1895a) and Greece (Harzhauser 2004) during the Oligocene and displays its southwestern-most distribution in Oman. Its youngest occurrence is reported by Lesport & Cahuzac (2002) from the Burgidial of the Aquitaine. The poorly known P. protebeninus (Vredenburg 1928) from the Early Miocene of Pakistan is a closely related species or might even just represent a subspecies of P. monstrosus because it differs only in its strongly oblique axial sculpture. No relatives are known from the Miocene further to the east. This disjunct Tethyan distribution of that genus during the Early Miocene – with a relic area in the eastern Atlantic and a second one in the early Arabian Sea – might be a hint to a vicariating species (or subspecies) pair resulting from the beginning separation of the Proto-Mediterranean Atlantic Region and the Proto-Indo-West Pacific Region (cf. Harzhauser et al. 2002).

Genus Granulolabium Cossmann 1889

Type species: Cerithium plicatum Bruguière 1792. Lower Miocene, France.
Granulolabium plicatum (Bruguière 1792)
Plate 2, fig. 10

1792 Cerithium plicatum Bruguière, p. 488.
1823 Cerithium plicatum Bronn, p. 71, pl. 6, fig. 12.
1896b Granulolabium plicatum — Lozouet, p. 8, figs. 2 a–d, 4 f.
2001 Granulolabium plicatum — Lozouet et al., p. 27, pl. 8, figs. 1a–3c.
2004 Granulolabium plicatum — Harzhauser, p. 120, pl. 4, fig. 13–14, pl. 5, fig. 1–4 (and references).

Material: 1 shell from Karmah Pass at Duqm (Warak Fm.), NHMW 2006/2231/0041, w.: 7.4 mm.

Discussion: The sculpture of the fragmentary shell differs from typical representatives of Granulolabium plicatum by its strongly elongate nodes. Such morphologies have been also reported from the Oligocene of the Esfahan-Sirjan Basin in Iran (Harzhauser 2004, pl. 4, fig. 13).

Granulolabium plicatum is widespread in the Eurasian Oligocene and Early Miocene, being documented from the North Sea Basin, the eastern Atlantic coast, the entire northern Tethys coast and the Central and Eastern Paratethys (Harzhauser 2004). It was unknown from the eastern Tethys region and in the Oligocene and Miocene of Pakistan.

Family Potamididae Adams & Adams 1854

Genus Terebra Swainson 1840

Type species: Strombus palespis Linnaeus 1758. Recent, Indo-Pacific.

Terebralia bidentata (Defrance in Grateloup 1832)
Plate 2, fig. 3

1832 Cerithium bidentatum Defrance in Grateloup, p. 271.
1847 Cerithium bidentatum — Grateloup, (no page number), pl. 17, fig. 15.
1922 Terebralia bidentata — Costamini & Peyrot, p. 262, pl. 6, figs. 4–5.
1928 Terebralia bidentata — Vredenburg, p. 367, pl. 16, figs. 9–10, pl. 18, fig. 1.
2001 Terebralia bidentata — Harzhauser & Kowalke, p. 278, pl. 5, figs. 7–9.
2001 Terebralia bidentata — Lozouet et al., p. 26, pl. 9, fig. 11.
2004 Terebralia bidentata — Harzhauser, p. 118, pl. 6, fig. 7.

Material: 1 shell from Gebel Madrakah (Warak Fm.), NHMW 2006/2231/0041, h.: 49 mm (fragment).

Discussion: Terebralia bidentata appears during the Oligocene along the entire northern Western Tethys coast from France (Lozouet 1986a) to Turkey (Harzhauser 2004) as well as the Paratethys (Baldi & Steininger 1975). The occurrence of this species in the Oligocene of Oman, documents, that it was part of the southern Tethyan fauna as well. Terebralia bidentata persists into the Miocene, being a ubiquitous species of the mud flats and mangroves up to the Late Miocene. Its easternmost extension is described by Vredenburg (1928) from Lower Miocene deposits of Pakistan. Harzhauser (2004) provides an extensive synonymy.

Family Thiaridae Gill 1871

Genus Bayania Munier-Chalmas in Fischer 1885


Bayania omanispinosa n.sp.
Plate 3, figs. 1–2

Material: 2 specimens from Shuwayr (Warak Fm.).
Holotype: Plate 3, fig. 1, NHMW 2006/2236/0006, h.: 18.5 mm, w.: 8.2 mm.
Paratype: Plate 3, fig. 2, NHMW 2006/2236/0007, h.: 19.3 mm, w.: 7.5 mm.
Type locality: Shuwayr, Oman.
**Stratum typicum:** *Acropora* bearing bioclastic limestones of the Warak Fm.

**Age:** Oligocene (late Rupelian or Chattian).

**Name:** After the Sultanate of Oman and after the spiny sculpture.

**Diagnosis:** Elongate conical, shouldered, heavily sculptured *Bayania*; cancellate pattern of granules resulting from intersections of prominent spiral ribs with strongly dissected axial ribs; spines may form along the shoulder.

**Description:** Small to medium-sized, stout fusiform shell with weakly convex teleoconch whorls, incised sutures and large bodywhorl. A shoulder, covered with irregular nodes, may form on the last two whorls. Early teleoconch whorls bear densely spaced axial ribs which are dissected by 4-5 spiral ribs forming tiny nodes at the intersections. The penultimate whorl bears 5 spiral ribs which dissect the axial ribs into an upper row of granules followed below by a narrow concave ramp. The following row consists of spiny nodes and forms the shoulder. It is composed of the abapical row of spiny nodes (19 on the bodywhorl) and a directly adjoining row of weaker nodes, being united with the upper spine with a ledge. Below follow two spiral rows of granules, increasing to 8 on the bodywhorl. The resulting cancellate sculpture covers the entire slowly narrowing, convex base of the bodywhorl. Aperture elongated ovoid with thick but narrow inner lip and narrow angulation in the upper tip; inner side of the outer lip bears iraca. The lower channel is indistinct, very short and shallow.

**Discussion:** Kowalke (2001) assigns *Bayania* to the family Thiariidae based on protoconch characters. The variability of the sculpure is characteristic for *Bayania*. Typical examples are the Eocene *B. boussi* Szöts (1953) and B. *melaniiformis* (Schlotheim 1820) in Szöts (1953) and *Bayania semidecussata* (Lamarck 1804) ssp. from the Oligocene of Iran (Harzhauser 2004). That latter, extremely spinose morph or subspecies of *B. semidecussata*, differs clearly from the Omani species in its higher number of spiral threads on early teleoconch whorls (about 7–9). Furthermore, it lacks the cancellate sculpture of the bodywhorl and develops much more wide spaced nodes. Both strongly ornamented Oligocene *Bayania* species differ from the western Tethyan representatives, which are usually smooth and lack the axial sculpture on the bodywhorl [e.g. *Bayania stygis* (Brongniart 1823) and *Bayania inaequalis* (Fuchs 1870) from the Oligocene of Italy]. The iraca in the outer lip are also present in *Bayania semidecussata*, supporting the generic affiliation.

**Family Turritellidae Lovén 1847**

**Subfamily Turritellinae Lovén 1847**

**Genus Turritella Lamarck 1799**

**Type species:** *Turbo terebra* Linnaeus 1758. Recent, Indo-Pacific.

**Turritella steiningeri** n.sp.

**Plate 4, figs. 1–2**

**Material:** 3 shells from Gebel Madrakah (Warak Fm.).

**Holotype:** Plate 4, fig. 2, NHMW 2006/0231/0054 h.: 26.5 mm (fragment), w.: 6.5 mm.

**Paratype:** Plate 4, fig. 1, NHMW 2006/0231/0072, h.: 22 mm (fragment), w.: 6 mm.

**Paratype:** NHMW 2006/0231/0055, h.: 23 mm (fragment), w.: 6.8 mm.

**Stratum typicum:** *Acropora* bearing bioclastic limestones of the Warak Fm.

**Type locality:** Gebel Madrakah, Oman.

**Age:** Oligocene (Chattian).

**Name:** In honour of Fritz Steingerer, my mentor who encouraged my paleontological studies.

**Diagnosis:** Very slender *Turritella* with flat whorls, sub-parallel flanks and incised sutures. The spiral sculpture consists of 3 primary ribs separated by broader interspaces with weak secondary threads on early teleoconch whorls, increasing to 5 spiral ribs on later whorls.

**Description:** The fragments represent a very slender species with flat whorls and an apical angle of c. 12°. Early teleoconch whorls contain a median primary rib and two weaker ribs close to the sutures. The latter strengthen and may become even more robust than the first rib, the lower rib being the most prominent. This lower rib bears weak and elongated granules. During growth, the median primary rib shifts into the lower part of the whorl. A secondary rib appears in the thus slightly broader interspace between the first and second primary
rib; later another additional secondary spiral thread appears between the second and third primary rib. These, now five dominant ribs are intercalated by delicate third order spiral threads. Finally, the first primary rib starts to be divided by a faint spiral furrow, without being fully divided. Late teleoconch whorls develop a slight constriction between the first primary rib and the suture.

Discussion: *Haustator postica* Sacco 1895b and *H. subaequinicincta* Sacco 1895b, both very slender species with flat whorls from the Oligocene of northern Italy, differ from *T. steiningeri* by their high number of spiral ribs and the lack of any predominating triplet. The Pliocene Javanese *Turritella subulata* Martin 1884 is distinguished by its broader apical angle (20°) and the lack of a prominent median spiral rib. *Turritella boettgeri* Martin 1884 and *Turritella martini* Wanner & Hahn 1935 from the same area, develop 4 primary spiral ribs of equal strength. The Early Miocene Pakistani *Turritella beberti* d’Archiac & Haime 1853 is superficially similar to *T. steiningeri* in its size and the narrow apical angle. It is distinguished by the keel-like spiral ribs at the sutures, the slightly imbricated whorl profile and the high number of secondary threads. The (Eocene?) *Cerithium stracheyi* d’Archiac & Haime (1853) from Pakistan develops a very similar sculpture but is much smaller and even more slender.

*Turritella* sp. 1

Plate 4, fig. 5

Material: 1 silicone mould from Madrakah cliff (Shusayr Fm.), NHMW 2006/2032/0006, w.: 7 mm.

Description: Slender, small-sized shell with an apical angle of 14°. High teleoconch whorls with moderately convex profile and 5 thin and sharp spiral ribs. The lower 4 ribs are evenly spaced, tending to be slightly more prominent along the maximum convexity of the whorls. A narrow ramp separates the uppermost, being sculptured by a weak secondary spiral thread. Another secondary rib appears between the second and third primary rib. The preservation, however, obscures any further sculpture.

Discussion: The Late Oligocene *Turritella stephanensis* Cossmann & Peyrot 1921, from France, is superficially similar but differs by distinctly lower early teleoconch whorls which display a more pronounced convexity. *Turritella assimilis* Sowerby 1840 from the Miocene of Pakistan differs in its more convex whorl profile and deeper sutures. It lacks the primary spiral rib close to the lower suture but bears the primary ribs in the middle part of the whorls instead.

Subgenus *Haustator* Montfort 1810


*Turritella* (Haustator) conofaciata (Sacco 1895)

Plate 4, fig. 4

1853 *Turritella affinis* d’Archiac & Haime, p. 295 (pars), pl. 27, fig. 17.
1895b *Haustator conofaciatus* Sacco, p. 18, pl. 1, fig. 67.
1900 *Turritella conofaciata* – Rovereto, p. 143, pl. 8, fig. 12.
1928 *Turritella conofaciata* – Vredenburg, p. 382.
1956 *Haustator conofaciatus* – Brunn, p. 176, pl. 14, fig. 9.
2004 *Turritella* (Haustator) conofaciata – Harzhauser, p. 125, pl. 4, figs. 2, 4–5.

Material: 4 shells from Gebel Madrakah (Warak Fm.), NHMW 2006/2031/0056–0057.

Description: Medium-sized shell with an apical angle of 17°. Early whorls develop a prominent primary rib in their lower quarter, forming a marked angulation. The adapical part of the whorl displays a strong concavity which is bordered close to the suture by a weak spiral thread and a moderately convex sutureal bulge. Soon, this indistinct bulge and the spiral thread merge into a spiral rib which remains separated by a delicate, shallow spiral groove. On adult whorls, this structure finally grades into a spiral rib pair united in an adstural bulge. The lower, angulated spiral rib remains dominant but is adjoined by a secondary spiral rib at the suture. The median concavity is sculptured by 2–4 weak and thin secondary ribs. Several very delicate, somewhat wavy spiral threads appear on late teleoconch whorls covering the angulation down to the lower suture.
Discussion: This species displays a considerably degree in variability concerning the spiral sculpture. Especially the spiral ribs close to the upper suture are sometimes partly reduced (e.g. holotype in SACC 1895b and own observations on material from the Mesohellenic Trough, Greece). *Turritella conofasciata* is a widespread Oligocene species, which is known from Italy, Greece, Turkey and Pakistan (Vredenburg 1928).

*Turritella* (*Haustator*) cf. *sedanensis* (Martin 1905)
Plate 4, fig. 3

1905 *Turritella sedanensis* Martin, 234, pl. 35, fig. 554.
1941 *Turritella sabulata sedanensis* – Beets, p. 28, pl. 9, fig. 347.
1974 *Haustator (Karosoma) sedanensis* – Shutto, p. 150, pl. 21, figs. 8–9.

Material: 1 shell from Gebel Madrakah (Warak Fm.), NHMW 2006x0231/0063, w.: 6.5 mm.

Description: A single small fragment of 4 teleoconch whorls is preserved. It displays weakly imbricated whorls and a narrow shell angle of c. 12°. The sculpture consists of 3 prominent spiral ribs in the lower two thirds of the whorl and additional 2 slightly weaker spiral ribs in the upper part. The upper part is slightly constricted, giving rise to an imbricated outline. Delicate secondary spiral riblets are intercalated between the primary ribs.

Discussion: Beets (1941) and Wanner & Hahn (1935) emphasise the great variability of the spiral sculpture of *Turritella sedanensis*. The sculpture of the Omanian shell corresponds fully to those of *T. sedanensis* as described by Martin (1905) and Shutto (1974). A difference is the smaller shell angle, whereas the Javanese shell displays an angle of 15°. The fragmentary preservation of the single Omanian specimen prevent from a clear identification. *Turritella sedanensis* Martin is recorded from the Lower Miocene West Progo- and Rembang beds of Java and persisted into the Late Miocene in Borneo and Sumatra (Shutto 1974).

Suborder Hypsogastropoda Ponder & Lindberg 1997
Infraord Littorinimorpha Golikov & Starobogatov 1975

Superfamily Littorinioidea CHILENS 1834

Family Littorinidae CHILENS 1834

Genus Tectarius Valenciennes 1832

Type species: *Tectarius coronatus* Valenciennes 1832. Recent, Indo-Pacific.

*Tectarius elegans* (Faujas 1817)
Plate 4, fig. 11

1817 *Monodontia elegans* Faujas, p. 197, pl. 10, fig. 4.
1825 *Monodontia elegans* – Basterot, p. 31, pl. 1, fig. 22.
1840 *Monodontia elegans* – Gratefou, p. 14, fig. 1.
1917 *Astralium (Calcar) degrangeri* Cossmann & Peyrot, 69, p. 331, pl. 5, figs. 35–38.
1986a *Tectarius elegans* – Lozouet, p. 230, pl. 14, figs. 1–2.

Material: 2 shells from Shuwayr (Warak Fm.), NHMW 2006x0236/0001.

Description: A small-sized, depressed cyrtocoenid shell with straight whorls and a conspicuous spiral sculpture, consisting of 9 rugose spiral ribs. The ribs are irregular, slightly wavy and densely spaced. There are three primary ribs with indistinct nodes or beads. Three granulated secondary ribs are intercalated between the middle one and the lower one, which coincides with a keel. A single secondary thread appears between the middle and upper primary rib and two almost amalgamated secondary ribs are located just below the upper suture. Early teleoconch whorls are hardly separated by sutures, whereas the late teleoconch whorls develop a prominent keel directly above the now deeply incised suture. The following whorl is slightly constricted below
the upper suture. The base passes from a concave band, directly below the angulation, via a moderately convex periphery into the finally almost flat circum-umbilical part. A sculpture of coarse spiral threads occurs on the base.

**Discussion:** *Tectarius elegans* appears during the Oligocene and persist into the Aquitanian. Oligocene records are documented from the Adour Basin (Lozouet 1986a) and probably also from northern Italy (Sacco 1896). During the Aquitanian, the species is still widespread and occurred in the Adour Basin (Cossmann & Peyrot 1917), southern Italy (Lamberti-Bocconi 1999) and Turkey (Sivas Basin, own observation).

**Superfamily Cypraeoida Rafinesque 1815**

**Family Pediculariidae Adams & Adams 1854**

**Subfamily Jennerinæ Thiele 1929**

**Genus Projenneria Dolin 1997**

**Type species:** *Cypraea ludoviciana* Johnson 1899. Moody's Branch Formation (Upper Eocene), Louisiana (U.S.A.).

**Projenneria sabaca** Feihse n. sp.

Plate 6, figs. 7a–c

**Material:** 1 specimen from Gebel Madrakah (Ghubbarah Fm.).

**Holotype:** NHMW 2006z0231/0070, h.: 22.5 mm, w.: 12 mm.

**Stratum typicum:** Bioclastic limestones of the Ghubbarah Fm.

**Type locality:** Gebel Madrakah, Oman.

**Age:** Early Miocene (Aquitanian).

**Name:** In honour of the famous Queen of Sabah who came to listen the wisdom of the legendary King Solomon of Israel.

The description of *Projenneria sabaca* is provided by Dirk Feihse (Bavarian State Collection of Zoology: Diagnosís: Large-sized, robust, sub-cylindrical, with spaced, weak apertural dentition; denticles continued as short, strong ventral folds; 18 columellar teeth, 21 labral teeth, the latter exceeding the former; maximum globosity in the lower third; apex covered by callus.

**Description:** Large sized for genus; robust, sub-cylindrical; length exceeds width and height; narrowed and slightly extended anteriorly and posteriorly; dorsum evenly elevated; ventrum weakly convex with posterior terminal somewhat recurved; protoconch and apex covered by callus; aperture almost straight and of nearly same width over entire length; anal and siphonal canal deeply indented, bordered by strong projecting callus, latter curved; denticles weak to moderately strong, spaced, continued as strong, short folds onto ventrum, irregular on columellar side; columellar teeth 18, not extended on columella and fossula; labral teeth 21, exceeding columellar teeth; inner labral margin slightly, evenly curved, not sinuous, anteriorly declivous; outer labral margin slightly callused, more towards terminal collars; internal structures (fossula and inner columella) not examinable. Sculpture moulded by fine, close-set spiral threads, faint, only barely visible, covered by callus in matured specimens.

**Discussion:** Dolin (1997) introduced *Projenneria* as subgenus of *Jenneria* Jousseaume 1884 (type species: *Cypraea pustulata* Solander, 1786. Holocene, Plata Island, W Mexico). *Projenneria* consists of species that have a smooth dorsum, the ventral folds are rarely continued to the lateral margins and the dorsal sulcus is mostly obscured. All species are so far as known extinct and they were distributed in all tropical and subtropical seas. In contrast, species in the genus *Jenneria* possess a strongly pustulated dorsum, the ventral folds are strong and always extended to the lateral margins and the dorsal sulcus is mostly well developed. At least one species of *Jenneria – J. pustulata* – has survived. Their distribution is restricted to Western Europe, the Caribbean region and the Eastern Pacific. Juvenile shells of both genera – *Jenneria* and *Projenneria* – show a structural pattern of spiral threads that is covered in adult shells by a callus. Than the spiral threads are obscured and rarely visible.

The new species belongs to a group within the genus *Projenneria* that possess sub-cylindrical shells and relatively short ventral folds. This group contains the species *Projenneria laeviapennimina* (Sacco 1894) from the Oligocene of Italy and France, *P. neumayri* from the Badenian of the Paratethys and *P. sabaca* from the Early Miocene of Oman. All other known species of *Projenneria – Projenneria pregnans* (de Gregorio 1880) comb.
nov. from the Eocene of Italy, *P. ludoviciana*, *Projenmeria lapogyensis* (Sacco 1894) comb. nov. from the Badenian of the Paratethys, *Projenmeria borzatti* (Bini 1982) comb. nov. from the Late Miocene of the Philippines and *Projenmeria eniwetokensis* Dolin 1997 (this species might a junior synonym of *P. borzatti*) from the Miocene of Eniwetok Atoll – possess an ovate shell with ventral folds posteriorly and anteriorly extended almost to the lateral margins. (Note that *P. lapogyensis* has been often misidentified as *P. neumayri* by several authors; e.g. Schilder 1925, Dolin 1997).

*Projenmeria laeviappenninica* is similar to *P. sabaica* n. sp. in first sight but the new species differs immediately from the Oligocene species by the less numerous and irregularly spaced ventral folds on the columellar side, by the in general stronger ventral folds, by the more cylindrical shape, by the deeper indented canals and by the more projected terminals. *Projenmeria sabaica* n. sp. is distinguished from *P. neumayri* by its larger size. The ventral folds are stronger, the posterior terminal collar is more projected, the inner labral margin is evenly curved whereas it is sinusous in *P. neumayri* and the anal canal is deeper indented. The new species might close a gap of a lineage that would relate the Oligocene *P. laeviappenninica* with the mid-Miocene *P. neumayri*. This group of sub-cylindrical shelled species have been restricted to the Paratethys, early Mediterranean Sea and adjacent Atlantic. Unfortunately, very little information is known about these rarely found species.

**Superfamily Stromboidea Rafinesque 1815**

**Family Strombidae Rafinesque 1815**

**Subfamily Strombinae Rafinesque 1815**

**Genus Varicospira Eames 1952**

*Type species:* *Strombus cancellatus* Lamarck 1822. Recent, Indo-Pacific.

**Varicospira zuschini** n. sp.

*Plate 4, figs. 6a-b*

**Material:** 2 shells from Karmah Pass at Duqm (Warak Fm.).

**Holotype:** NHMW 20060230/0001, w.: 18 mm, h.: 36 mm.

**Stratum typicum:** Acropora bearing bioclastic limestones of the Warak Fm.

**Type locality:** Karmah Pass at Duqm, Oman.

**Age:** Oligocene (Chattian).

**Name:** In honour of Martin Zuschin, Paleontologist at the University of Vienna.

**Diagnosis:** High spired, moderately slender *Varicospira* with short bodywhorl, convex teleoconch whorls and deep sutures. Regular, straight axial ribs crossed by delicate, regular spiral threads, being most prominent in the axial interspaces. Short siphonal canal, smooth outer lip with one stout spine. Very long, straight adapical canal crossing 2.3 teleoconch whorls.

**Description:** Medium-sized, moderately slender, high spired shell of 8 teleoconch whorls; protoconch unknown. Teleococon whorls convex, sculptured by straight to feebly opisthocyrt, rounded axial ribs (18 on the last teleococh whorl), separated by a deep, slightly wavy suture. Early teleococon whorls develop two varices in more or less opposite position; later the varices are indistinct. The axial ribs become very prominent and angulated on the dorsal part of the bodywhorl but are indistinct on the ventral part close to the aperture and also insignificant but crowded close to the wing. A regular spiral pattern of spiral threads, separated by interspaces of equal width, appears between the axial ribs (13 spirals on the last teleococon whorl). These ribs cross also the axial elements but are hardly visible there. On the bodywhorl, the spiral sculpture becomes dominating resulting in a cancellate sculpture close to the aperture and on the base. Base contracting rapidly terminating in a short, slightly twisted siphonal canal. Inner lip smooth, well demarcated from the base by a narrow furrow; outer lip thickened, flaring with shallow siphombd notch accompanied by a single stout spine. Adapical canal long, almost straight, crossing 2 teleococon whorls and touching the lower third of the adjacent one.

**Discussion:** The Oligocene *Varicospira narica* (Vredenburg 1925) and the Early Miocene *Varicospira subrimosa* (d’Orbigny 1852) from Pakistan and Assam (Mukerjee 1939) both differ by their spiral sculpture which crosses the axial ribs. *Varicospira apenninensis* (Sacco 1893) from the Oligocene of Italy is clearly
distinguished by its slender outline, the less angulated but higher body-whorl and the shorter adapical canal which crosses only the last teleonch whorl. The Miocene *Varicospira decussata* (Basterot 1825) has a curved canal. Despite the high number of taxa described by Martin (1899), Pannekoek (1936), Beets (1941) and Hoek Ostende et al. (2002) from the Miocene Indo-Pacific no species is conspecific with the Omanian taxon. *Varicospira gertbi* (Pannekoek 1936) and *V. rembangensis* (Pannekoek 1936) differ in their smaller size and the strong axial sculpture; *V. martini* (Pannekoek 1936) is more elongate and bears denticles along the outer lip; *V. longirostra* (Pannekoek 1936) is much more elongate; *V. semicancellata* (Martin 1899) has sharper axial ribs and a strongly curved adapical canal; *V. spinfera* (Martin 1899) is very elongate, has a cancellate sculpture and a dentated outer lip and *V. javana* (Martin 1879) differs in its strongly deflected adapical canal. The Omanian shell shares several features with the Early Oligocene *Varicospira integra* (Koenen 1889) from the North Sea Basin, but differs in its shorter bodywhorl, wider aperture and broader axial ribs.

*Varicospira mordax* (Martin 1916)

Plate 4, figs. 7-8

1916 *Rimella mordax* Martin, p. 246, pl. 2, figs. 49a-c.

Material: 6 specimens from Karmah Pass at Duqm (Warak Fm.), NHMW 2006x0230/0003-0004, 2 silicone moulds from Madrakah cliff (Shuwayr Fm.) and 1 silicone mould from Gebel Madrakah (Ghubbahar Fm.).

Description: A variable species concerning outline and sculpture. Stout fusiform shell with strongly convex and slightly angulated teleonch whorls. Dense pattern of sharp to weakly rounded axial ribs which are crossed by numerous spiral threads. The generally straight ribs tend to become sigmoidal along the angulation towards the incised sutures. Two indistinct varices appear per whorl, forming two near-continuous lines along the spire. Bodywhorl rapidly contracting. Aperture very narrow; inner lip very thick and well demarcated; outer lip flaring thickened and structured by blunt teeth. Adapical canal narrow, dorsally deflected and crossing at least the last teleonch whorl. The axial sculpture on the bodywhorl is sometimes reduced, being than of the same strength as the spiral threads, thus resulting in a cancellate ornamentation. A deep concavity is formed between bodywhorl and outer lip, being ornamented by prominent spiral threads. (Note that the broad outline of the specimen on plate 4 fig. 7 is overemphasised due to the position of the varix on the left side. The axial sculpture is partly eroded in both illustrated specimens but excellently preserved on the silicone moulds).

Discussion: According to Hoek Ostende et al. (2002) *Varicospira mordax* and *Varicospira sokkohensis* (Martin 1916) are synonymous. Following this concept, the Omanian specimens range well within the variability of that species concerning outline and small size (e.g. specimen fig. 7 is closer to *V. mordax* sensu Martin 1916 whereas fig. 8 approaches the type of *Varicospira sokkohensis*). A constant difference, however, is the higher number of axial ribs on the bodywhorl of the Omanian specimens. Therefore, the described shells might represent an Oligocene chrono-subspecies of the Miocene Javanese species.

The shells are reminiscent of the Miocene *Varicospira decussata* (Basterot 1825). Especially angulated morphotypes with broad lips, such as *V. decussata amplexiabiata* (Sacco 1893), are similar. A constant difference is the absence of denticles in *Varicospira decussata* and its generally larger size. The Late Miocene *Varicospira javana* (Martin 1879) differs in its even stronger deflected adapical canal and the stout bodywhorl. *Varicospira mordax* was known so far only from the Early Miocene of Java (Hoek Ostende et al. 2002).

Genus *Dilatilabrum* Cossmann 1904

Type species: *Strombus fortissii* Bronn-Iart 1823. Eocene, Italy.

*Dilatilabrum sublatissimus* (d’Orbigny 1852)

Plate 4, figs. 12a-b

1847 *Strombus latissimus* Grateloup, suppl. pl. 1, fig. 3 (non *Strombus latissimus* Linnaeus 1758).
1852 *Strombus sublatissimus* d’Orbigny, p. 11, nr. 177.
1958 *Strombus coronatus* – Azzaroli, p. 123, pl. 34, fig. 11 (non *Strombus coronatus* Defrance 1824).
2004 *Strombus* (Tri carnus) *sublatissimus* – Harzauser, p. 129, pl. 11, figs. 3–4, pl. 12, figs. 1–2 (and references).

Material: 2 specimens from Gebel Madrakah, (Ghubbahar Fm.), NHMW 2006x0231/0026, w.: 114 mm.
Discussion: Despite the poor preservation, the internal moulds can be clearly identified based on their size and on the extremely expanded wing. In addition, the characteristic bulge at the angulation of the dorsal part of the bodywhorl allows the identification. This giant conch is the largest strombid in the Tethyan Oligocene. It is documented from the Adour Basin in France, the Mesohellenic Trough in Greece and the central Iranian Basins (Harzhauser 2004). From the southern Tethys Oligocene, it is known from the Maltese Islands in the west (own observation; Natural History Museum Gozo) and from Somalia in the east (Azzaroli 1958; erroneously identified as *Strombus coronatus* DeFrance). In the Iranian Esfahan-Sirjan Basin it persists into the Aquitanian (Harzhauser 2004).

*Dictatibrus sublatissimus* was only found as steinkerns in the Ghubbarah Formation at Gebel Madrakah where it co-occurs with *Strombus gijskronenbergi*. A further perfect Omani specimen with the typical giant wing is presented at the Natural History Museum in Muskat (Sultanate of Oman).

Genus *Strombus* Linnaeus 1758

*Strombus gijskronenbergi* n.sp.

Plate 5, figs. 6–8

1958 *Strombus* cf. *nodus* – Azzaroli, p. 123, pl. 34, fig. 10 (*non* *Mitra nodosa* Borson 1820 = *Strombus bonelli* Bronn & Hart 1823).

Material: 10 steinkern specimens and 5 silicone moulds from Gebel Madrakah (Ghubbarah Fm.).

Holotype: Plate 5, fig. 6: NHMW 2006/231/0030, w.: 64 mm, h.: 116 mm.

Paratype: Plate 5, fig. 7: NHMW 2006/231/0027, w.: 67 mm.

Paratype: Plate 5, fig. 8: NHMW 2006/231/0031, h.: 96 mm.

Remainder: NHMW 2006/231/0032 (silicone specimens); 2006/231/0029 (steinkern specimens).

Stratotype: bioclastic limestones of the Ghubbarah Fm.

Type locality: Gebel Madrakah, Oman.

Age: Early Miocene (Aquitanian).

Name: In honour of the malacologist and strombid-specialist Gijs Kronenberg.

Diagnosis: A moderately large-sized, thick-shelled, slender strombid with high spire. Teleconch whorls sculptured by a single row of very large and long spines; bodywhorl with 3 rows of spines and weaker spiral ribs. Wide wing with deep posterior notch and prominent posterior tip.

Description: Biconical, slender shell with high spire with an apical angle of 47° and a bodywhorl of about 33°; protoconch unknown. Teleconch consisting of 9 strongly angulated teleconch whors with up to 9 prominent spines of subtrigonal cross-section. Earliest teleconch whors bear characteristic varices separated by 4–5 angulated axial ribs. Suture regular, straight, thread-like. The interspaces, where the bases of the spines merge, form a sharp angulation, separating a flat to feebly concave ramp from the contracting abapical part of the whors. Bodywhorl sculptured with a row of 7–9 very large and long spines along the shoulder and two additional but slightly weaker rows of spines. The entire shell surface bears a sculpture of spiral ribs, separated by broader interspaces. Those ribs covering also the spines, are slightly more prominent, being best developed on the lower side of the spines. In juvenile specimens the spiral ornament consists of dense spiral threads. The wide wing contrasts with the slender shape; it expands quite abruptly and forms a concavity between wing and bodywhorl. The sculpture of the last whorl persists to the lip. On the inner surface, the position of the rows of spines is reflected as shallow furrows. Stromboid notch very deep and well developed, forming a narrow up to 2 cm deep canal. Siphonal canal similarly deep and narrow, terminating in a strongly deflected canal. An additional deep posterior notch separates the bodywhorl from the protruding tip of the wing.

Discussion: *Strombus gijskronenbergi* differs from the probably related *Strombus bernielaudanti* n.sp. in its larger size, the longer bodywhorl and the long spines on the lower part of the bodywhorl. This species is the most frequent mollusc in the Ghubbarah Formation at Gebel Madrakah, but was undetected in the underlying Warak Formation. All shells are dissolved in the limestone of the Ghubbarah Formation. Therefore, only casts and silicone moulds are available.

Steinkern specimens from the Oligo/Miocene of Somalia, reported as *Strombus cf. nodus* Borson by Azzaroli (1958), might also represent *Strombus gijskronenbergi*. Poorly preserved steinkerns from the Miocene
of Kenya discussed by Cox (1930) might be a further but doubtful hint to an Arabian–East-African distribution of this species. Its absence in the well-known Western Tethys faunas of Italy and France suggests that *Strombus gijskroenberghi* is a southern Tethys element which never migrated into the north-west. It is unknown from the eastern faunas of Borneo or Java as well. Only the much younger strombid from the Late Miocene of Guam, determined as *Strombus cf. preoccupatus* Finlay 1921 by Ladd (1972), is similar in size and sculpture. It differs mainly in the higher teleoconch whorls and the prominent spiral grooves in the adapical part of the whorls.

*Strombus bernielandai* n.sp.

Plate 5, figs. 1–5

**Material:** 35 specimens from Gebel Madrakah (Warak Fm).

**Holotype:** Plate 5, fig. 4, NHMW 2006×0231/0035, w.: 39 mm, h.: 52.5 mm.

**Paratype:** Plate 5, fig. 1, NHMW 2006×0231/0039, w.: 36 mm, h.: 47.5 mm.

**Paratype:** Plate 5, fig. 2a–2b, NHMW 2006×0231/0038, w.: 30.4 mm, h.: 43.5 mm.

**Paratype:** Plate 5, fig. 3a, NHMW 2006×0231/0037, w.: 34 mm, h.: 42.5 mm.

**Paratype:** Plate 5, fig. 3b, NHMW 2006×0231/0036, w.: 35.5 mm.

**Paratype:** Plate 5, fig. 5, NHMW 2006×0231/0034, w.: 38.5 mm, h.: 53 mm.

**Stratum typicum:** Acropora bearing bioclastic limestones of the Warak Fm.

**Type locality:** Gebel Madrakah, Oman.

**Age:** Oligocene (Chattian).

**Name:** In honour of the great malacologist Bernard Landau.

**Diagnosis:** Small-sized, thick-shelled, stout strombid with a row of knobby to spiny nodes on the teleoconch whorls and a row of 6–8 spines on the bodywhorl. Spiral threads cover the ramp of the angulated whorls; coarse spiral ribs appear on the bodywhorl which bears two irregular spirals of nodes or knobs. Thick, triangular pointed wing, demarcated from the bodywhorl by a deep concavity.

**Description:** Squat, robust, small-sized shell with high spire of 7 teleoconch whorls and broad conical bodywhorl; protoconch unknown. Teleoconch whorls weakly angulated in the lower third, resulting from a row of 7–9 knobs or nodes, which rarely develop spiny tips. Upper ramp covered by spiral threads, being best developed close to the irregular, wavy suture. On the bodywhorl, this delicate spiral sculpture is accompanied by much coarser, irregular spiral ribs. One of these ribs, in the middle of the bodywhorl, and a second one in the lower part, close to the stromboid notch, may develop knobs or spirally elongated nodes. The marked angulation of the bodywhorl coincides with a row of nodes or spines of variable number (6–8). Thus, the sculpture of the bodywhorl is very variable. The angulation persists into the wing, forming the tip of the pointed triangular wing. A deep concavity, below the last spine of the bodywhorl, separates the wing, which develops only the secondary spiral elements. The upper margin of the wing is straight; stromboid notch narrow and deep.

**Discussion:** The widespread *Strombus preoccupatus* Finlay 1927 from the Indo-Pacific and western Pacific Miocene is highly reminiscent of *Strombus bernielandai* and might represent a closely related species. *Strombus preoccupatus* has been described by Martin (1881, 1899, 1921) from the Miocene of Java and Borneo, as *Strombus spinosus*, a name which was already preoccupied as pointed out by Finlay (1927). *Strombus bernielandai* differs from *Strombus preoccupatus* by a shorter and more conical bodywhorl due to the absence of the broad, flat and subparallel area between the shoulder and the first row of spines on the bodywhorl typical of *S. preoccupatus*. Strongly pointed spines on the bodywhorl of *S. preoccupatus* are missing in the new species which develops 2 rows of low and axially elongated knobs. The strongly thickened outer lip is distinctly separated as varix-like swelling from the wing but is developing continuously from the bodywhorl in *S. preoccupatus*. Finally, *Strombus preoccupatus* develops lirae in the outer lip (see Beets 1941, pl. 3, fig. 13) whilst the Omanian shells display smooth inner lips. *Strombus guilonensis* Dey 1961 from the (late?) Miocene of Kerala in southern India is also similar but lacks the typical axially elongated knobs on the longer bodywhorl and differs in the strong lirae along the inner lip. It might simply be a less ornamented subspecies of *Strombus preoccupatus*.

This small-sized *Strombus* is extremely frequent in the Warak Formation at Gebel Madrakah, where it co-occurs with *Acropora* branches and various cerithiids. In the overlying Ghubbarah Formation it is fully replaced by *Strombus gijskroenberghi*. *Strombus bernielandai* is unknown from the northern coast of the Oligocene Tethys and seems to be a typical southern Tethys species. Its virtually close relation with *Strombus preoccupatus* suggests that it is a Proto-Indo-Pacific element. The morphologic characters suggest that the Oligocene *Strombus*
berrielandtau might have been the ancestor of the Aquitanian Strombus gijskroenberghi and the Early to Late Miocene Strombus preoccupatus (see Beets 1986 for stratigraphic range). The latter seems to be followed by Strombus quilonensis. This purely Indo-Pacific lineage might be rooted in the Oligocene to Miocene Strombus radix-bonelli group of the Western Tethys (pers. comm. Gijs Kronenberg). Therefore, this Tethyan strombid-lineage was not only invading the western Atlantic bioprovince, as documented by Lozouet & Maestrati (1986) and Jung & Heintz (2001), but has also infiltrated the eastern faunas.

**Family Seraphsidae Gray 1853**

Genus Seraphs Montfort 1810

*Seraphs cf. subconvolatus* (d’Orbigny 1852)

Plate 4, fig. 9

? 1852 Terebellum subconvolatum d’Orbigny, p. 9.
? 1972 Terebellum (Terebellum) fusiforme – Moisescu, p. 101, pl. 37, fig. 1 (non Terebellum fusiforme Lamarck 1802).
1974 Seraphs cf. subconvolatus – Jüng, p. 27, pl. 8, figs. 11–12.

Material: 1 specimen from Gebel Madrakah (Warak Fm.), NHMW 2006a/02301/0071, w.: 7.5 mm.

Discussion: The slender steinkern specimen agrees well in shape and angle of the suture with the specimens from the Oligocene of Liguria identified by Jung (1974) as *Seraphs cf. subconvolatus*. This type differs from *Seraphs subconvolatus* in its even more slender outline – a feature that allows also to distinguish the Omani, Italian (Sacco 1895b) and Romanian (Moisescu 1972) species from the Oligocene *Seraphs naricus* (vredenburg 1925) from Pakistan. The identification remains provisional, due to the very poor state of preservation. This species was also documented during the fieldtrip in the Ghubbarah Formation at Gebel Madrakah.

**Family Xenophoridae Troschel 1852**

Genus Xenophora Fischer von Waldheim 1807

*Xenophora laevigata* Fischer von Waldheim 1827. Recent, Caribbean Sea.

*Xenophora cf. desbayesi* (Michelotti 1847)

1847 *Phorus desbayesi* Michelotti, p. 173.

Material: 5 specimens from Karmah Pass at Duqm (Warak Fm.), NHMW 2006a/0230/0220, w.: 33 mm.

Discussion: The preservation of the steinkernels does not allow a clear identification. Nevertheless, the high-spired shells differ clearly from the comparably flat species with cytroconoid spire such as *Xenophora cumulans* (Brongniart 1823) from the European Oligocene or *Xenophora dunkeri* Martin 1879, from the Indonesian Miocene. Its general outline agrees well with the Miocene *Xenophora desbayesi*. Comparable specimens, which are also identified as X. cf. desbayesi have been found in the latest Oligocene to Aquitanian deposits of Qom, Chaleghareh and Zefreh in Iran (Esfahan-Sirjan Basin, Qom Basin). These shells might thus represent the earliest representatives of the otherwise Miocene species or might be a hint to an undescribed “eastern” species.

The systematic treatment of the Xenophoridae as a family within the Stromboidea follows the paper of Kiel & Perrilliat (2001).
Superfamily Capuloidea Fleming 1822

Family Capuliidae Fleming 1822

Genus Capulus Montfort 1810

Type species: Patella hungarica Linnaeus 1758. Recent, Mediterranean Sea.

Capulus aniceps (Michelotti 1861)
Plate 4, fig. 10

1861 Pileopus aniceps Michelotti, p. 134.
1896 Capulus barrandi aniceps – sacco, p. 38, pl. 5, figs. 9a–c.

Material: 1 specimen from Gebel Madrakah (Warak Fm.), NHMW 2006/0230/0017, w.: 11 mm, h.: 7.5 mm.

Discussion: The Omani shell corresponds fully to the Oligocene type from Italy which is characterised by a thick shell, an irregular, elongated ovoid aperture, weak wavy growth lines, a moderately protruding apex, and moderately expanding “Exogyra-like” teleoconch. Sacco (1896) treated this species as subspecies of “Capulus barrandi” HöRNES 1856” from the Middle Miocene of the Paratethys Sea. This strongly sculptured species, however, has nothing in common with Capulus aniceps from the Oligocene of Dego. The comparison with eastern faunas is difficult. No Capulus species are reported from the Oligocene and Early Miocene of Pakistan and only few species are described from the Miocene of Java and eastern India: Capulus junghuhnii Martin 1905 differs only in its smaller size and the shorter apical tip which does not protrude as much as that of Capulus aniceps. Capulus javanus WANNER & HAHN 1935 attains about half of the size, displays a very slowly expanding early teleoconch and bears two axial ridges in the posterior concavity. Capulus lissus SMITH 1894 (not seen) sensu MUKERJEE (1939) from the Early Miocene of Assam is smaller and its apex is extremely recurved. The rarely documented Capulus aniceps is thus an Oligocene species, which occupied the northern and southern coast of the Tethys Ocean.

Superfamily Tonnaidea Suter 1913

Family Personidae Gray 1854

Genus Distorsio RöDING 1798

Type species: Murex anus Linnaeus 1758. Recent, Indo-Pacific.

Distorsio aff. cancellina (Lamarck 1803) n.sp.
Plate 6, fig. 8

? 1870 Triton subclathratus – Fuchs, p. 39, pl. 1, figs. 7–8.
? 1925 Person a reticulata var. subclathrata – Vredenburg, p. 234 (pars).
? 2004 Distorsio sp. – Landau et al., p. 74, pl. 6, fig. 4.

Material: 1 fragment from Gebel Madrakah (Warak Fm.), NHMW 2006/0231/0042, w.: 36 mm.

Discussion: The fragment consists only of the last teleoconch whorl and parts of the bodywhorl. Its sculpture and outline corresponds fully to that of the still unnamed Oligocene Distorsio species from France and Italy (illustrated in Fuchs 1870, MacNeil & Dockery 1984 and Landau et al. 2004). This species was usually described as Distorsio subclathratus (o’Orbigny 1852). According to Landau et al. (2004), this name however, is a junior synonym of Distorsio cancellina (Lamarck 1803) and was applied to a Neogene species. The Oligocene Western Tethyan species would therefore require a new name. The large size of the Omani species (about 60 mm calculated from the fragment) however, would not justify a separation from the Miocene species, which is documented with shells of up to 70 mm in height in the collection of the NHMW.
Infraorder Neogastropoda Wenz 1938  
Superfamily Buccinoidea Rafinesque 1815  
Family Melongenidae Gill 1871  
Genus Melongena Schumacher 1817  

Type species: *Murex melongena* Linnaeus 1758. Recent, Caribbean Sea.  

*Melongena lainei* (Basterot 1825)  
Plate 6, fig. 3

1825 *Pyrula Lainei* Basterot, p. 67, pl. 7, fig. 8.  
1904 *Melongena Lainei* – Sacco, p. 32, pl. 9, figs. 23, 24.  
1928 *Melongena Lainei* – Peyrot, p. 35, pl. 5, fig. 33–36.  
1939 *Melongena Lainei* – Stchepinsky, p. 37, pl. 10, figs. 31–32.  
1939 *Melongena (Pyrula) Lainei biconigata* nov. var. Stchepinsky, p. 38, pl. 10, figs. 33–34.  
2001 *Melongena lainei* – Lozouet et al., p. 62, pl. 28, figs. 1–3.

**Material:** 1 specimen from Gebel Madrakah (Warak Fm.), NMHW 2006e0231/0076, h.: 39 mm, w.: 25 mm.

**Discussion:** A subadult shell is available showing the characteristic deeply furrowed ramp with five coarse spiral ribs. The spire is stepped and the whorls bear a marked angulation. This ramped morphology agrees fully with the Aquitanian to Burdigalian types of *Melongena lainei* as described by Lozouet et al. (2001) and thus differs from the Chattian (chrono)subspecies *Melongena lainei sensetiana* (Erdős 1900), which develops a flat shell (see Baldi 1973).

Vredenburg (1925) reports *Melongena lainei* from the Lower Miocene Gáj Formation in Pakistan. As emphasised by Lozouet et al. (2001), it might be even represented in the Miocene of the Indo-Pacific, referring to the specimens described by Beets (1941) from Borneo as *Melongena gigas*.

Superfamily Muricoidea Rafinesque 1815  
Family Volutidae Rafinesque 1815  
Subfamily Volutininae Rafinesque 1815  
Genus *Lyria* Gray 1847  

Type species: *Voluta pattersenia* Perry 1811. Recent, Pacific.

*Lyria madrakabensis* n.sp.  
Plate 6, fig. 1

**Material:** 2 specimens from Gebel Madrakah (Warak Fm.).  
**Holotype:** Plate 6, fig. 5, NMHW 2006e0231/0053, w.: 23 mm.  
**Paratype:** NMHW 2006e0231/0059, w.: 25 mm.  
**Stratum typicum:** *Acerora* bearing bioclastic limestones of the Warak Fm.  
**Type locality:** Gebel Madrakah, Oman.  
**Age:** Oligocene (Chattian).  
**Name:** After Ras Madrakah, a small village close to the section.

**Diagnosis:** Medium-sized, slender, angulated *Lyria* with high teleoconch whorl, moderately convex bodywhorl and large varix close to the aperture. Dense, rounded-trigonal, sigmoidal axial ribs with narrow, spiral-thrads-bearing, interspaces.

**Description:** Moderately elongated shell with gradate spire, angulated whorls and prominent, densely spaced axial ribs. The flanks of the middle part of the bodywhorl and of the lower part of the last teleoconch whorl are sub-parallel and almost straight. About 15 sigmoidal axial ribs of rounded triangular cross section cover
the bodywhorl. The opisthocyt upper part of the ribs coincides with the convex ramp of the bodywhorl, whilst
the prosocyt lower part covers the base. Indistinct, spiny nodes are developed on the axial ribs along the
angulation. Numerous spiral threads cover the interspaces between the ribs without crossing the axial ribs.

Elongated narrow aperture demarcated by a thick swollen varix which is terminated by a thin, sharp axial
ridge. This ridge reaches into the siphonal canal and ends at the beginning of the colurnellar lip. Siphonal canal
deep, broad and slightly twisted. Columnellar structure largely destroyed; a series of columnellar folds reaching up
to the adapical angulation of the aperture is preserved, starting with two strongly oblique and prominent lower
folds, whereas the following folds are much weaker. A 4 mm broad, poorly demarcated fascioconal swelling in the
neck bears at least 8 thin spiral grooves.

Discussion: None of the Italian Oligocene and French Miocene Lyria species (described by Bellardi
1890, Sacco 1904 and Peyrot 1928) develops a similar angulation and ramp. All these species are distinguished by
the convex outline of the body and the teleoconch whorls. None of these species produces tiny spines on the
shoulder. Only a single but widespread Lyria species is described from the Proto-Indo-Pacific faunas, being
comparable with the Omanian fossil: Lyria jugosa (Sowerby 1840) (= Lyria edwardsii (Archiac 1850)]. This
species is well known from the Early to Late Miocene of Pakistan, India, Madagascar, Java, Borneo,
(Vredenburg 1925, Beets 1941, Cox 1948, DeY 1961) and was documented by Beets (1941) to develop even
slightly spineose and weakly shouldered morphs. These specimens, described as Lyria jugosa spinulosa Beets 1941
are slightly reminiscent of the Omanian species but differ significantly in their convex bodywhorl, the wide
spaced axial ribs and the wider aperture. Typical Lyria jugosa are distinguished by the lack of the shoulder, the
convex bodywhorl, less sigmoidal to straight axial ribs and the protruding adapical tips of the ribs.

Genus Athleta Conrad 1853

Type species: Voluta varisima Lamarck 1811. Lower Miocene, Aquitaine Basin, France.

Athleta cf. ficulina (Lamarck 1811)

1811 Voluta ficulina Lamarck, p. 79.

Material: 2 specimens from Karmah Pass at Duqm (NMW 2006/0230/0019) and Gebel Madrakah (NMW 2006/0231/0064).

Discussion: A single fragment of the angulation of the last whorl with the characteristic spines is
available. Of course, the identification of such poorly preserved material is always doubtful. Nevertheless,
the fragments correspond fully to typical Athleta ficulina specimens from the Miocene of Europe in the collection of
the NHM. Oligocene occurrences of the chiefly Miocene Athleta ficulina have been documented by Baldei
(1973) from the Central Paratethys Sea.

Athleta pygmaea (Bellardi 1890) from the Oligocene of Italy differs in its smaller size and the convex,
though angulated ramp above the spines.

Family Turbinellidae Swainson 1835

Subfamily Vasiiae Adams & Adams 1853

Genus Vassum Röding 1798

Type species: Murex tubinellus Linnaeus 1758. Recent, Indo-Pacific.

Vassum omanicum n.sp.

Plate 6, figs. 4a–b

Material: 1 specimen from Gebel Madrakah (Warak Fm.).

Holotype: NMW 2006/0231/0060, w: 24.5 mm.

Stratum typicum: Acropora bearing bioclastic limestones of the Warak Fm.

Type locality: Gebel Madrakah, Oman.

Age: Oligocene ( Chattian).

Name: After the Sultanate of Oman.
Diagnosis: Small-sized *Vasum* with stout biconical shell, fig-like bodywhorl, stepped spire, angulated whorls and narrow sutural ramp. Blunt, swollen axial ribs below angulation crossed by coarse spiral threads. Narrow aperture with four columellar folds.

Description: Depressed, stout, biconical shell with short base and short siphonal canal. Teleoconch whorls display a median angulation which bears indistinct knobs caused by blunt axial swellings. The ramp is sculptured by 3 prominent spiral ribs, intercalated by secondary threads. Two coarse, irregular spiral ribs – one coinciding with the angulation – decorate the lower half of the teleoconch whorls, with a weaker secondary rib in the interspace. Suture wavy and deep. Fig-like bodywhorl with rapidly contracting base; sculptured by 7 blunt axial ribs which terminate in indistinct nodes at the angulation. Ramp decoration equal to that of the teleoconch whorls. 11 primary spiral ribs cover the lower part of the bodywhorl and the base, each separated by an intervening secondary rib. Inner lip expanding as thin cover on the base without clear demarcation. Slightly curved columella with 4 oblique columellar folds in the convex middle part of the columella; the lower two folds are weaker and densely spaced.

Discussion: This Oligocene species is morphologically closely related to *Vasum intermedium* (Grateloup 1847) from the Burdigalian of France. Differences are the even shorter bodywhorl, the stronger spiral ornamentation, and the steeper ramp. The third columellar fold of *Vasum intermedium* is very weak and the teleoconch whorls lack the coarse spiral cords but develop knobby nodes along the lower suture.

The coeval Western Tethys Oligocene to Early Miocene *Vasum* complex with *Vasum duchassangei* (Micheletti 1861) (syn.: *Volutella creata bellaardi* Rovereto 1900), *Vasum excrenatum* Sacco 1904 and *Vasum stephanense* Peyret 1928 differs clearly by its slender outline and gradate spire. The stout Aquitanian *Vasum aquitanicum* Peyret 1928 and its Oligocene ancestor *Vasum subpugillare* d’Orbigny 1852 develop spines, a much stronger concavity of the bodywhorl and coalescing teleoconch whorls [see Grateloup (1847), Sacco (1904), Peyret (1928)]. *Vasum ceramicum* var. from the Miocene of Java in Martin (1921) is larger, has a concave ramp, a more inflated, convex bodywhorl and short spines.

The occurrence of *Vasum* in the Oligocene of Oman is an important contribution for the biogeographic history of that genus. There are only five Vasiniae described from the Oligocene and Miocene of Europe. The genus first appears in the Upper Eocene of Louisiana (Vokes 1966) and arrives in the European Atlantic and the western Tethys as late as the Oligocene when it is recorded from France with *Vasum subpugillaris* d’Orbigny 1852 (syn.: *Turbinella pugillaris* Grateloup 1847) and from Northern Italy with *Vasum excrenatum* Sacco 1904 and *Vasum duchassangei* Micheleletti 1861. In the western Tethys, the genus passes the Paleogene/Neogene boundary but is recorded mainly from the French Atlantic coast where it is represented by *Vasum aquitanicum* Peyret 1928 and *Vasum stephanense* Peyret 1928. From that Aquitanian stock, *Vasum intermedium* Grateloup 1847 develops as sole species in the Burdigalian and seems to be the last representative of the genus in the European Miocene. In contrast, the record of *Vasum* in the Ind–Pacific sets in during the Early Miocene with a species described by Martin (1921) as *Vasum ceramicum* var. from Java. The Omani Oligocene species would thus act as “missing link between the western Tethys and the Proto-Indo-Pacific faunas”.

Family Mitridae Swainson 1829

Genus Mitra Lamarck 1799

Type species: *Voluta mitra* Linnaeus 1758. Recent, Pacific.

*Mitra* cf. dufresnei Bastert 1825
Plate 6, fig. 2

1825 *Mitra Dufresnei* Bastert, p. 44, pl. 2, fig. 8.
1904 *Mitra Dufresnei* – Sacco, p. 80, pl. 18, fig. 1.
1928 *Mitra Dufresnei* – Peyrot, p. 94, pl. 9, figs. 34–36.
2001 *Mitra dufresnei* – Lozouet et al., p. 65, pl. 29, fig. 10.

Material: 1 specimen from Gebel Madrakah (Ghubrah Fm.), NHMW 2006z0231/0265, h.: 64 mm, w.: 22 mm.
Discussion: The steinkern is poorly preserved and complicates the identification. It agrees well with the Aquitanian to Burdigalian *Mitra dufresnei* from France and Italy in outline, size and apertural features. The cylindrical bodywhorl allows a separation from the Italian Oligocene *Mitra apposta* Bellardi 1887, which develops a convex bodywhorl with shallow, concave neck. The Omanian specimen exhibits a straight columella with five strong folds as typical for *Mitra dufresnei*, whereas *Mitra apposta* develops a columellar concavity above the folds.

Genus *Cancilla* Swainson 1840

Type species: *Tara isabella* Swainson 1831. Recent, Indo-Pacific.

*Cancilla* n. sp.
Plate 6, fig. 11

Material: 1 specimen from Gebel Madrakah (Warak Fm.), NHMW 2006x0231/0066, h.: 7 mm.

Description: Medium-sized elongate shell of moderately convex and high teleoconch whorls. Elongate bodywhorl with shallow, concave neck. Teleoconch whorls bear 6 rounded spiral ribs separated by narrower interspaces. There, a dense succession of weaker axial threads causes a cancellate ornamentation. The spirals increase in width towards the bodywhorl and rise to 16 in number on bodywhorl and base. Elongate aperture with thin and well-demarcated inner lip. Three oblique columellar folds are preserved; of these the upper two are most prominent.

Discussion: The Western Tethyan faunas bear only few comparable species. Most of them are described by Bellardi (1887) from the Early Miocene of the Turin Mountains: *Cancilla exarata* (Bellardi 1887) is highly reminiscent but lacks the concave neck. *Cancilla effosa* (Bellardi 1887) differs mainly in its longer bodywhorl and the narrow interspaces between the spiral ribs. *Cancilla adita* (Bellardi 1887), which is the most similar Italian species, differs from the Omani shell in its more delicate spiral sculpture of the base and the lower number of spirals on the teleoconch whorl (5 instead of 6). In the French Miocene described by Peyrot (1928), *Cancilla salomacensis* (Meyer 1891) develops a shorter spire and an evenly convex bodywhorl. *Cancilla vasconiensis* (Peyrot 1928) is smaller, has a flat-sided bodywhorl and incised sutures. The Proto-Indo-Pacific faunas, too, lack a fully corresponding species: *Cancilla vandervelkii* (Beets 1941) from the Miocene of Mangkalihat (Borneo) is quite similar in shape and sculpture but develops only 5 spiral ribs on the late teleoconch whorls. *Cancilla rembangensis* (Martin 1906) from the Early Miocene of Java, too, is reminiscent but develops 8 spiral ribs on the last teleoconch whorl. *Mitra aruzzeni* Martin 1916 from the Lower Miocene Progo Group in Java displays flat sided whorls. *Mitra somerbyi* d’Orbigny 1852 from the Miocene of Pakistan differs in its ovoid outline and the short teleoconch whorls. Unfortunately, the specimen is too fragmentary to serve as holotype.

Superfamily Conoidea Fleming 1822
Family Turridae Adams & Adams 1853
Subfamily Crassispirinae McLean 1971

Genus *Crassispira* Swainson 1840

Type species: *Pleurotomella bottae* Kiener 1839. Recent, Panama.

*Crassispira* n. sp.
Plate 6, fig. 12

Material: 1 specimen from Gebel Madrakah (Warak Fm.), NHMW 2006x0231/0073, h.: 17 mm, w.: 6 mm.

Description: Small-sized fusiform shell with high spire and flat-sided teleoconch whorls. A deep, rounded groove separates a knobby sutural band. The axial sculpture consists of blunt ribs which are also interrupted by the spiral groove; their adapical terminations form the knobs of the sutural band. About 10 axial
ribs appear on the slender bodywhorl forming a slight angulation below the spiral groove. The axial ribs fade out before the weakly concave neck. Ten spiral ribs cover the base, partly crossing also the abapical terminations of the axial ribs.

**Discussion**: The surface is strongly eroded obscuring the strength of the spiral sculpture. One side of the shell is even completely dissolved. Therefore, the description of that probably new species remains incomplete. Despite the poor preservation, a separation from other Western Tethyan and Proto-Indo-Pacific *Crassispira* species is evident: The Early Miocene *Crassispira kochensis* (VREDENBURG 1925) develops angulated whorls and a stepped spire. The Miocene *Crassispira obeliscus* (DESMOULINS 1842) is larger and develops convex teleoconch whorls. Its base is separated from the bodywhorl by a concave neck. Miocene representatives of *Crassispira postulata* (BROCCHI 1814) (sensu BALUK 2003) are very reminiscent of the Omanian species concerning sculpture but are stout and develop a lower spire. Other Early Miocene species from the Turin Mountains, such as *Crassispira fraterrula* (BELLARDI 1877) and *C. seminucula* (BELLARDI 1877), are distinguished by the median angulation of the late teleoconch whorls. *Crassispira semijuncta* (BELLARDI 1877), also from that Italian locality, develops a broad and angulated bodywhorl with concave sutural.

**Family Terebridae MÖRCH 1852**

**Genus Terebra BRUGUIÈRE 1789**

Type species: *Buccinum subulatum* LINNAEUS 1767. Recent, Indo-Pacific.

*Terebra perturrita* Sacco 1891

Plate 6, fig. 5

1891  *Terebra subteessellata* var. *perturrita* Sacco, p. 25.
1900  *Terebra subteessellata* (var. *perturrita*) – ROVERETO, p. 183, pl. 9, fig. 8.
1925  *Terebra subteessellata oligocenica* nov. ssp. – VREDENBURG, p. 14, pl. 1, figs. 3–4.
1980  *Terebra subteessellata oligocenica* – IQBAL, p. 53, pl. 36, fig. 11.
2004  *Terebra subteessellata perturrita* – HARZHAUSER, p. 142, pl. 16, figs. 10–11.

Material: 1 specimen from Karmah Pass at Duqm (Warak Fm.), NHMW 2006/0230/0015, h.: 28 mm.

**Discussion**: When establishing *Terebra subteessellata oligocenica* VREDENBURG (1925) clearly referred to the Italian specimen described as *Terebra subteessellata* var. *perturrita* Sacco in ROVERETO (1900) which is a valid name. *Terebra perturrita* is thus known during the Oligocene from the northern coast of the Western Tethys from Italy via Iran to Pakistan (HARZHAUSER 2004) and is now documented also for the southern Tethys coast.

**Family Conidae FLEMING 1822**

**Subfamily Coninacea FLEMING 1822**

**Genus Conus LINNAEUS 1758**

Type species: *Conus marmoreus* LINNAEUS 1758. Recent, Indo-Pacific.

*Conus* n.sp. 1 (aff. *gratelowi* d’ORBIGNY 1852)

Plate 6, figs. 9a–b

? 1852  *Conus gratelowi* d’ORBIGNY, p. 11.
1925  *Conus ineptus* – VREDENBURG, p. 87 (partim), pl. 1, fig. 12 (non *Conus ineptus* MICHELLOTTI 1861).

Material: 2 specimens from Gebel Madrakah (Warak Fm.), NHMW 2006/0231/0069, h.: 33 mm, w.: 19 mm. 1 silicone mould from Gebel Madrakah, Ghubbarah Formation.

**Description**: Medium-sized biconical shell with broad conical spire composed of 7 teleoconch whorls with narrow but incised suture. Concave ramp sculptured adapically with 4 spiral ribs, separated by narrow furrows. On the bodywhorl these spirals are crossed by growth lines causing a granulated surface of the spirals.
Close to the lower suture a somewhat swollen bulge replaces the spiral ribs and forms the angulation between ramp and suture. This bulge bears indistinct nodes or granules which are best developed on early teleoconch whorls. Due to these bumps the suture becomes slightly wavy. Cyptoconoid base with an angle of 30° sculptured by more than 30 indistinct, low, spiral ribs separated by slightly wider interspaces. Aperture narrow with parallel margins but largely filled by sediment.

Discussion: The species is related to the species group of Conus diversiformis Deshayes 1824 and Conus grateloupd’Orbigny 1852. The whole the grateloupd-ineditus-diversiformis complex seems to consist of several species which lack a modern revision. The Omanian shells correspond well in their size, the slender shape and the spire sculpture to the Oligocene Conus grateloupd (also referred to as C. ineditus Michelotti 1861) of Italy but differ in their higher spire. Similar shells are also recorded from the Oligocene of Pakistan (Vredenburg 1928) and Iran (Harzauser 2004).

Conus n.sp. 2 (aff. antiquus Lamarck 1810)

Plate 6, figs. 10a-b

Material: 1 specimen from Gebel Madrakah (Warak Fm.), NHMW 2006t0231/0067, h.: 44 mm, w.: 35 mm.

Description: Medium-sized, broad conical shell with depressed spire and coalescing early whorls with stepped profile between penultimate and last whorl. Seven teleoconch whorls with broad, flat shell sculptured by delicate and indistinct spiral grooves. Bodywhorl strongly angulated, passing via an almost flat, cylinder-shaped part into the cyptoconoid base with an angle of 35°. More than 25 hardly visible, very shallow spiral grooves suggest a spiral ornamentation of the bodywhorl. Aperture and lower part of the base are destroyed. Some Oligocene shells of the Conus diversiformis-grateloupd complex, such as those from Sangonini in Italy (e.g. Ferrero & Piccoli 1970, pl. 2, fig. 2), display a low and sharply angulated spire which does not differ in shape from the Omanian shell. These broad-conical and low-spired shells bear little in common with the rather slender Conus grateloupd’Orbigny 1852 and represent a separate species. The relationship of the Omanian specimen to that unnamed Western Tethys species is unclear, because of the fragmentary state of the base. This distinctive part of the shell forms a somewhat stem-like termination in the Italian shells. In the Miocene faunas, only the European Conus antiquus Lamarck 1810 develops a corresponding spire-morphology. The Early to Middle Miocene Conus antiquus differs mainly in its larger size and the slightly more convex shell close below the angulation of the bodywhorl. The Omanian species might be an ancestral form which gave rise to the larger Early Miocene Conus antiquus. The Early to Late Miocene Conus odengensis Martin 1895 from Indonesia is superficially similar but differs in its less angulated but rounded shoulder.

Subfamily Conorbinae de Gregorio 1880

Genus Conorbis Swainson 1840

Type species: Conus dormitor Solander in Brander 1766. Eocene, London Basin.

Conorbis protensus (Michelotti 1861)

Plate 6, fig. 13

1861 Pleurotomis protensus Michelotti, p. 129, pl. 12, figs. 1–2.
1893 Conorbis protensus – Sacco, p. 125, pl. 11, fig. 41.
1900 Conorbis protensus – Rovereto, p. 180, pl. 9, fig. 13.

Material: 1 specimen from Gebel Madrakah (Warak Fm.), NHMW 2006t0231/0068, h.: 23.5 mm, w.: 7 mm.

Description: The subadult fusiform-biconical shell displays a paucispiral, bulbous protoconch of about 1.5 whorls and 5 teleoconch whorls. The moderately convex teleoconch whorls with incised sutures are separated by a markedly incised furrow in the adapical third, which separates a broad adsutural band. The bodywhorl develops a rounded angulation and bears a series of about 10 spiral ribs on the base. The inner lip is broad but very thin and indistinct.
Discussion: The Oligocene Conorbis bhagothorensis VREDENBURG 1925 and the Early Miocene Conorbis sindiensis VREDENBURG 1925 from Pakistan both differ clearly by their spiral sculpture of delicate threads, which cover the entire teleoconch.

Conorbis protensis is known from the Oligocene (Late Rupelian-Early Chattian) of the Western Tethys (Italy). Further occurrences are documented from the Oligocene of Bulgaria (KARAGIUEVA 1964, pl. 57, fig. 2) but have been erroneously confused with the Eocene Cryptoconus filosus LAMARCK.

Ordo Opisthobranchia MILNE-EDWARDS, 1848
Suborder Cephalaspidea FISCHER 1883
Superfamily Philinoidea GRAY 1850
Family Cylichnidae ADAMS & ADAMS 1854
Genus Cylichnella GABB 1873

Type species: Bulla bidentata d’ORBIGNY 1841. Recent, Caribbean Sea.

Cylichnella duqmensis n.sp.

Plate 6, fig. 14

Material: 1 specimen from Karmah Pass at Duqm (Warak Fm.).
Holotype: NHMW 2006o230/2021, h.: 8 mm, w.: 4.8 mm.
Stratum typicum: Aerogora bearing bioclastic limestones of the Warak Fm.
Type locality: Karmah Pass at Duqm, Sultanate of Oman.
Age: Oligocene (Chattian).
Name: After the village Duqm.

Diagnosis: Large-sized for a Cylichnella of rounded subcylindrical outline. Distinct upper colomellar fold separated by a deep concavity from the dominant basal colomellar fold. Base covered by delicate spiral grooves.

Description: Relatively large-sized shell for the genus, with rounded sub-cylindrical outline, bearing the maximum convexity in the middle of the shell. Apical-umbilicus narrow and deep, covering the spire completely. Aperture narrow in the upper half with incised notch at the apex. Lower part strongly widening due to the abruptly contracting colomellar area. This is structured by a small but well-defined upper colomellar fold and broader, blunt lower fold. Both are separated by a deep and rounded concavity. The colomellar callus forms a broad band projecting from the aperture and proceeding into the thin outer lip. About 8 narrow spiral grooves cover the base.

Discussion: Cylichnella vasatensis (GOSSMANN 1895) from the Aquitanian of France and Cylichnella newielli (PEYROT 1932) from the Burdigalian of France seem to be the closest relatives in the Cenozoic faunas. Cylichnella vasatensis is distinguished from C. duqmensis by its smaller size (~ 4mm), the evenly convex and slightly broader bodywhorl, wider lower part of the aperture, and the weaker basal colomellar fold. The younger Cylichnella newielli attains a comparable size and displays a similar outline and develops even a similar spiral ornamentation of the base. This Burdigalian species is distinguished from C. duqmensis by its weak axial sculpture in the upper part of the bodywhorl and by the weak basal colomellar fold.

Cylichnella durgae (BEETS 1941) from the Miocene of Borneo is smaller and differs clearly in its spiral sculpture on the base and on the apex. The Middle Miocene Cylichnella stibara WOODRING 1970 from the Gatun Formation in the Panama Canal Zone is minute and develops a cylindrical shape with sub-parallel flanks. A synopsis of further Miocene American Cylichnella species is presented by JUNG (1969); all these species are distinctly smaller in size.
Superfamily Bulloidea Gray 1827

Family Bulildae Gray 1827

Genus Bulla Linnaeus 1758

Type species: Bulla ampulla Linnaeus 1758. Recent, Pacific Ocean.

Bulla argosensis n. sp.

Plate 6, figs. 15a–b

Material: 1 specimen from Gebel Madrakah (Warak Fm.).
Holotype: NHMW 2006/0231/0074, h.: 31 mm, w.: 20 mm.
Stratum typicum: Acropora bearing bioclastic limestones of the Warak Fm.
Type locality: Gebel Madrakah, Oman.
Age: Oligocene (Chattian).
Name: After the city of Argos; masses of flies at Gebel Madrakah recollected the drama of Sartre, in which flies haunted the city of Argos.

Diagnosis: Moderately large-sized Bulla of elongated elliptical outline. Moderately convex flanks and rather narrow aperture. Apical-umbilicus perforate but largely covered by the expanded aperture.

Description: A single steinkern is available, reflecting a rather slender subcylindrical shell with evenly convex whorls. Apical umbilicus very narrowly perforate, but largely covered by the wing-like expansion of the aperture, which terminates directly in the apical-umbilicus. Aperture rather narrow in the upper half, due to the almost parallel margins of the penultimate whorl and the outer lip, but wide in the lower part. Aperture margin strongly expanding at the base and at the apex. The thickened part of the outer lip is preserved as narrow furrow that continues towards the columella. Sculpture not preserved.

Discussion: Despite the steinkern preservation, the shell can be clearly assigned to Bulla, which is a poorly known genus during the Oligocene and Early Miocene of the western Tethys and the Proto-Indo-Pacific. In contrast, the genus is already well established during the Early and Middle Miocene in the eastern Pacific and Caribbean faunas (e.g. Addicott 1970, Woodring 1970).

No records are known to the author from the Mediterranean Oligocene. The Early Miocene is similarly poorly documented: Sacco (1897) describes only Bulla subampulla taurinensis from the Burdigalian of the Turin Hills. This small-sized shell is poorly preserved and even the generic affiliation seems to be quite doubtful. Peyrot (1932) emphasizes the absence of Bulla in the Miocene of the Aquitaine. Mediterranean occurrences, mentioned by Sacco (1897) from Italy and by Erünlai–Erentüz (1958) from the Turkish Antakya Basin are of Pliocene age. All these specimens are described as Bulla subampulla d’Orbigny 1852. Similarly, fossil Bulla ampulla Linnaeus 1758 is recorded in the Indo-Pacific faunas by Martin (1895) only from Pliocene sections. Both taxa differ clearly from the Omanian species by their rounded, globular outline.

7. Conclusions

The newly reported Omani fauna of 51 species provides an insight into the composition of the shallow marine gastropod communities of the Late Oligocene and Early Miocene on the Arabian shelf. The described fauna lacks any information on adjacent sublittoral and deep-water faunas because all shells have been found in coral- and/or mangrove-associated environments. Despite that limitation, it is the very first of its kind and, therefore, is crucial for biogeographic reconstructions at the interface between the Western Tethys and Proto-Indo-West Pacific Regions in a time when the centre of diversity shifted from the former to the latter.

The fauna displays a high degree of endemism, comprising 42% of species unknown from other localities. This endemism has to be put into the perspective of the poor state of knowledge about coeval faunas of the eastern and northern African coast. Their absence in the much better studied Mediterranean–Iranian Province (MIP) in the west and the Western Indian Province (WIP) in the north and northeast, however, suggests the existence of a discrete biogeographic entity called herein the Eastern-African–Arabian Province (EAAP). The influence from adjacent bioprovinces is documented by an uneven proportion of shared species. The strongest links are present
with the MIP (40%), whereas the connections with the WIP and Proto-Indo-Polynesian Province (PIPP) faunas are surprisingly low. These data imply that, during the Oligocene and Aquitanian, the exchange between the MIP and PIPP faunas was quite low along the southern coast of the Tethys. In contrast, the WIP faunas, described by Vredenburg (1925, 1928), suggest a much higher influx from the eastern faunas along the northern coast of the Tethys. Hence, during the considered time interval, the gastropod fauna of the Arabian shelf contributed to a discrete biogeographic province, which was still part of the Western Tethys region.

The biostratigraphic relations of the faunas suggest an Oligocene ( Chattian) age for the Warak Formation and a probably Aquitanian age for the overlying Ghubarah Formation. In the Madrakah area, a Burdigalian or Langhian age of the latter formation as indicated by Platelet et al. (1992) is very unlikely based on the occurrence of typically Oligocene to Aquitanian taxa such as Dilatilabrum sublatissimum (O’bigny 1852), Campanile pseudoobiliscus (Grateloup 1832) and Gourmy delaebi (Michelotti 1861). As the Ghubarah Formation covers large parts of the south-eastern Arabic peninsula, this new but local dating calls for a revision of other sections as well.

Acknowledgements

This study was granted by the FWF-Project P-18189-N10: Biogeographic Differentiation and Biotic Gradients in the Western Indo-Pacific during the Late Oligocene to Early Miocene, under the leadership of Werner Piller (University Graz, Austria). I thank him and my colleagues Andreas Kroh (Natural History Museum Vienna) and Markus Reuter (University Graz, Austria) for their cooperation during our Omanian fieldtrip. Many thanks to Gijs Kronenberg (Eindhoven, The Netherlands), Dirk Fehse (Berlin/Munichen), Bernie Landau (International Health Centres, Albufeira, Portugal), Manuel Malaquias (Natural History Museum, London) and Frank Wesselingh (National Museum of Natural History Leiden, The Netherlands) for your great help, pre-reviews, information and stimulating comments.

David Bassi (Dipartimento delle Risorse Naturali e Culturali, Università di Ferrara) provided the identifications of the larger foraminifers and a stratigraphic frame for this study.

The entire "Middle-East" working group is deeply indebted to Director Dr. Salim Al Busaidi of the Ministry of Commerce & Industry of the Sultanate of Oman for his kind support and friendly discussions.

References


(1972): Cenozoic fossil molluscs from Western Pacific islands; Gastropods (Turritellidae through Strombidae). – Geol. Surv. Prof. Pap., 532: 1–79.


(1809): Philosophie Zoologique, ou exposition des considérations relatives à l'histoire naturelle des Animaux; à la diversité de leur organisation et des facultés qu'ils en obtiennent; aux causes physiques qui maintiennent en eux la vie et donnent lieu aux mouvements qu'il exécute; enfin à celles qui produisent les unes le sentiment, et les autres l'intelligence de ceux qui en sont doués. – Paris, 1: 428, 2: 1–475.


(1767): Systema Naturae, seu per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. – 12th Ed. 2: 533–1327, Holmiæ.


Explanations of the Plates

All specimens are stored in the collection of the Natural History Museum Vienna.

Plate 1

*Tectus longyi* (tr'Archiac & Haim 1853) – 1a, 1b, 1c, height: 44 mm, Gebel Madarakh, Warak Fm., NHMW 2006x231/0021.

*Tectus longyi* (tr'Archiac & Haim 1853) – 2, height: 32.5 mm, Gebel Madarakh, Warak Fm., NHMW 2006x231/0022.

*Tectus longyi* (tr'Archiac & Haim 1853) – 3, width: 13 mm, Gebel Madarakh, Warak Fm., NHMW 2006x231/0024.

*Cerithides (Berula) elephas* n.sp. – 5, holotype, height: 14.2 mm, Gebel Madarakh, Warak Fm., NHMW 2006x231/0013.

*Scoloceratella* krohi n.sp. – 6, holotype, height: 8.5 mm, Madarakah cliff, Shuwayr Fm., NHMW 2006x232/0004.

*Scoloceratella* krohi n.sp. – 7, paratype, height: 8 mm, Madarakah cliff, Shuwayr Fm., NHMW 2006x232/0003.

*Warakia pelleri* n. gen., n.sp. – 8a, 8b, 8c, paratype, height: 24.5 mm, Gebel Madarakh, Warak Fm., NHMW 2006x231/0015.

*Warakia pelleri* n. gen., n.sp. – 9a-9b, holotype, height: 27.5 mm, Gebel Madarakh, Warak Fm., NHMW 2006x231/0016.

*Warakia pelleri* n. gen., n.sp. – 10, paratype, silicone mould, diameter: 40 mm, Gebel Madarakh, Warak Fm., NHMW 2006x231/0014.

Plate 2

*Campanile gigas* (Martin 1881) – 1, width: 54 mm, Gebel Madarakh, Warak Fm., NHMW 2006x231/0009.

*Campanile gigas* (Martin 1881) – 2, width: 88 mm, Gebel Madarakh, Warak Fm., NHMW 2006x231/0007.

*Terebratula bidentata* (Defrance in Grateloup 1832) – 3, height: 49 mm, Gebel Madarakh, Warak Fm., NHMW 2006x231/0041.

*Gowryma delbosii* (Michelotti 1861) – 4a, silicone mould, height: 28 mm, Gebel Madarakh, Ghabbarah Fm., NHMW 2006x231/0033.

*Gowryma delbosii* (Michelotti 1861) – 4b, height: 52 mm, Gebel Madarakh, Ghabbarah Fm., NHMW 2006x231/0043.

*Campanile pseudoaeolicus* (Grateloup 1832) – 5 height: 64 mm, Karmah Pass, Warak Fm., NHMW 2006x231/0012.

*Campanile pseudoaeolicus* (Grateloup 1832) – 6 height: 68 mm, Karmah Pass, Warak Fm., NHMW 2006x231/0011.

*Campanile pseudoaeolicus* (Grateloup 1832) – 7, height: 62 mm, Gebel Madarakh, Warak Fm., NHMW 2006x231/0018.

*Pyrazinos monstrosos* (Grateloup 1847) – 8, height: 91 mm, Gebel Madarakh, Warak Fm., NHMW 2006x231/0021.

*Pyrazinos monstrosos* (Grateloup 1847) – 9, height: 68 mm, Gebel Madarakh, Warak Fm., NHMW 2006x231/0004.

*Granulolabium plicatum* (Bruguére 1792) – 10, width: 7.4 mm, Karmah Pass at Duqm, Warak Fm., NHMW 2006x231/0014.

*Gowryma baluchistanensis* (Vredenburg 1928) – 11, width: 29 mm, Karmah Pass at Duqm, Warak Fm., NHMW 2006x230/0007.

Plate 3

*Bayania omanisipina* n.sp. – 1, holotype, height: 18.5 mm, Shuwayr, Warak Fm., NHMW 2006x236/0006.

*Bayania omanisipina* n.sp. – 2, paratype, height: 19.5 mm, Shuwayr, Warak Fm., NHMW 2006x236/0007.

*Tenisceratium manicum* n.sp. – 3, holotype, height: 14.5 mm, Shuwayr, Warak Fm., NHMW 2006x236/0005.

*Certibium lukanerdi* n.sp. – 4, holotype, height: 31 mm, Gebel Madarakh, Warak Fm., NHMW 2006x231/0062.

*Rhinoceras submelanoides* (Michelotti 1861) – 5, height: 18 mm, Karmah Pass at Duqm, Warak Fm., NHMW 2006x230/0009.

*Certibium archiaci* Vredenburg 1928 – 6, height: 53 mm, Gebel Madarakh, Warak Fm., NHMW 2006x231/0050.

*Certibium archiaci* Vredenburg 1928 – 7, height: 39.5 mm, Gebel Madarakh, Warak Fm., NHMW 2006x231/0051.

*Certibium markusreineri* n.sp. – 8, holotype, height: 46 mm, Gebel Madarakh, Warak Fm., NHMW 2006x231/0045.

*Certibium markusreineri* n.sp. – 9, paratype, height: 31 mm, Gebel Madarakh, Warak Fm., NHMW 2006x231/0044.

*Certibium rude sowerry* 1940 – 10, height: 56 mm, Gebel Madarakh, Warak Fm., NHMW 2006x231/0048.

*Certibium rude sowerry* 1940 – 11, height: 43 mm, Karmah Pass, Warak Fm., NHMW 2006x230/0016.

*Certibium rude sowerry* 1940 – 12, height: 50 mm, Gebel Madarakh, Ghabbarah Fm., NHMW 2006x231/0047.


*Certibium archiaci* Vredenburg 1928 – 14, height: 43 mm, Gebel Madarakh, Warak Fm., NHMW 2006x231/0052.

Plate 4

*Turritella steineri* n.sp. – 1, paratype, height: 22 mm, Gebel Madarakh, Warak Fm., NHMW 2006x231/0072.

*Turritella steineri* n.sp. – 2, holotype, height: 26.5 mm, Gebel Madarakh, Warak Fm., NHMW 2006x231/0054.

*Turritella (Haustator) cf. sedanensis* (Martin 1905) – 3, diameter: 6.5 mm, Gebel Madarakh, Warak Fm., NHMW 2006x231/0063.

*Turritella (Haustator) conofoasciata* (Sacco 1895) – 4, height: 48 mm, Gebel Madarakh, Warak Fm., NHMW 2006x231/0056.

*Turritella sp. 1 – 5, silicone mould, width: 7 mm Madarakah cliff, Shuwayr Fm., NHMW 2006x232/0006.

*Varicosporia zschitza* n.sp. – 6a-6b, holotype, height: 36 mm, Karmah Pass at Duqm, NHMW 2006x230/0001.


*Varicosporia morida* (Martin 1916) – 8, height: 16 mm, Karmah Pass at Duqm, Warak Fm., NHMW 2006x230/0004.
Seraphis cf. subconvolutus (d’Orbigny 1852) – 9, diameter: 7.5 mm, GebelMadrahak, Warak Formation, NHMW 2006x02301/0071.

Crepidula acephalosa (Michelotti 1861) – 10, diameter: 11 mm, GebelMadrahak, Warak Fm., NHMW 2006x02301/0017.

Tetraceras elegans (Frutys 1817) – 11, height: 12.5 mm, Shuwayr, Warak Fm., NHMW 2006x02301/0001.

Dilatolabrum sublatum (d’Orbigny 1852) – 12a-12b, width: 144 mm, Gebel Madrahak, Ghubbarah Fm., NHMW 2006x02301/0026.

Plate 5

*Strombus bernieliandai* n.sp. – 1, paratype, height: 47.5 mm, Gebel Madrahak, Warak Fm., NHMW 2006x02301/0039.

*Strombus bernieliandai* n.sp. – 2a-2b, paratype, height: 43.5 mm, Gebel Madrahak, Warak Fm., NHMW 2006x02301/0038.

*Strombus bernieliandai* n.sp. – 3a, paratype, height: 42.5 mm, Gebel Madrahak, Warak Fm., NHMW 2006x02301/0037.

*Strombus bernieliandai* n.sp. – 4, holotype, height: 52.5 mm, Gebel Madrahak, Warak Fm., NHMW 2006x02301/0035.

*Strombus bernieliandai* n.sp. – 5, paratype, height: 53 mm, Gebel Madrahak, Warak Fm., NHMW 2006x02301/0034.

*Strombus gigasrenenbergi* n.sp. – 6, holotype, silicone mould, height: 116 mm, Gebel Madrahak, Ghubbarah Fm., NHMW 2006x02301/0030.

*Strombus gigasrenenbergi* n.sp. – 7, paratype, silicone mould, width: 67 mm, Gebel Madrahak, Ghubbarah Fm., NHMW 2006x02301/0027.

*Strombus gigasrenenbergi* n.sp. – 8, paratype, silicone mould, height: 96 mm, Gebel Madrahak, Ghubbarah Fm., NHMW 2006x02301/0031.

Plate 6

*Lyria madrakahensis* n.sp. – 1, holotype, width: 23 mm, Gebel Madrahak, Warak Fm., NHMW 2006x02301/0053.

*Mitra cf. dufresnii* Basterot 1825 – 2, height: 64 mm, Gebel Madrahak, Ghubbarah Fm., NHMW 2006x02301/0065.

*Melongena laevis* (Basterot 1825) – 3, height: 39 mm, Gebel Madrahak, Warak Fm., NHMW 2006x02301/0076.

*Vasum omanicum* n.sp. – 4a-4b, holotype, width: 24.5 mm, Gebel Madrahak, Warak Fm., NHMW 2006x02301/0060.

*Terebra portesi* Sacco 1891 – 5, height: 28 mm, Karmah Pass at Duqm, Warak Fm., NHMW 2006x02301/0015.

*Pachydermum hartii* (Pannekoek 1936) – 6, silicone mould, height: 46 mm, Gebel Madrahak, Ghubbarah Fm., NHMW 2006x02301/0061.

*Proenneria sabata* n.sp. Feihe – 7a-7c, holotype, silicone mould, height: 22.5 mm, Gebel Madrahak, Ghubbarah Fm., NHMW 2006x02301/0070.

*Distorsio aff. cancella* (Lamarck 1803) n.sp. – 8, width: 36 mm, Gebel Madrahak, Warak Fm., NHMW 2006x02301/0042.

*Conus* n.sp. 1 (aff. grateloupi d’Orbigny 1852) – 9a-9b, height: 33 mm, Gebel Madrahak, Warak Fm., NHMW 2006x02301/0069.

*Conus* n.sp. 2 (aff. antiquus Lamarck 1810) – 10a-10b, height: 44 mm, Gebel Madrahak, Warak Fm., NHMW 2006x02301/0067.

*Cancilla* n.sp. – 11, diameter: 7 mm, Gebel Madrahak, Warak Fm., NHMW 2006x02301/0066.

*Crassispira* n.sp. – 12, height: 17 mm, Gebel Madrahak, Warak Fm., NHMW 2006x02301/0073.

*Conus boletus* (Michelotti 1861) – 13, height: 23.5 mm, Gebel Madrahak, Warak Fm., NHMW 2006x02301/0068.

*Cylindrella duquenii* n.sp. – 14, holotype, height: 8 mm, Karmah Pass at Duqm, Warak Fm., NHMW 2006x02301/0021.

*Bulla argus* n.sp. – 15a-15b, holotype, height: 31 mm; Gebel Madrahak, Warak Fm., NHMW 2006x02301/0074.
M. Harzhauser: Oligocene and Aquitanian Gastropod Faunas from the Sultanate of Oman.
M. Harzhauser: Oligocene and Aquitanian Gastropod Faunas from the Sultanate of Oman.
M. Harzhauser: Oligocene and Aquitanian Gastropod Faunas from the Sultanate of Oman.
M. Harzhauser: Oligocene and Aquitanian Gastropod Faunas from the Sultanate of Oman.
M. Harzhauser: Oligocene and Aquitanian Gastropod Faunas from the Sultanate of Oman.
M. Harzhauser: Oligocene and Aquitanian Gastropod Faunas from the Sultanate of Oman.