The Mt Perda Liana section (Middle Jurassic, central-eastern Sardinia): revised stratigraphy and brachiopod faunas

Iginio DIENTI, Francesco MASSARI & Vladan RADULOVIĆ

INTRODUCTION

The lower part of the Jurassic succession of eastern Sardinia is generally made up of dolostones which failed generally to give information useful for a biostratigraphic attribution, due to the scarcity or absence of fossils. However, in places the succession includes calcareous lenses to layer bundles of limited lateral persistence, containing rich fossil assemblages, mostly bivalves and less abundant brachiopods, allowing to establish some firm chronostratigraphic points. One of the richest section, useful to this purpose, is that of Mt Perda Liana in the “Tacchi” area of central-eastern Sardinia, which is taken into account in this paper, by illustrating stratigraphic and palaeontologic data.

The first unit of the local Jurassic cover is represented by continental to marginal-marine siliciclastic deposits of the Genna Selole Formation (defined by Dieni et al., 1983), transgressive on the Palaeozoic and locally Triassic substrate and bearing palynomorphs and plant macrorests indicating a Bajocian-Bathonian age (Dieni et al., 1983; Del Rio, 1984). The basal, coarse-grained conglomerates record alluvial fan sedimentation accounting for denudation of a rugged relief, with deep erosion of the substrate. This episode is conceivably related to the rifting which affected the south-European margin in the Middle Jurassic, generating a swell-and-basin topography, concomitantly with the initial Tethys opening (Lemoine et al., 1978). The continental to marginal-marine sedimentation gave way to marine carbonate ramp sedimentation, more completely preserved in the Ogliastra, Supramonte and Barone areas of eastern Sardinia - as exemplified by the Dorgali Formation, Mt Tului Limestone, locally grading basinswards into S’Adde Limestone, and Mt Bardia Limestone (Amadesi et al., 1961; Casellato et al., 2012, and references therein). The deposits share several characteristics of the Jurassic carbonate platforms of the south-European margin (Stampfli et al., 2002; Costamagna & Barca, 2004), for instance in Provence (Fourcade et al., 1977) and in the Corsica autochthonous succession (Peybernès et al., 2001). Similar record of Middle Jurassic transgressive carbonates bounded at the base by a marked unconformity is known in the Briançonnais (Bourbon et al., 1973), and part of the Swiss and French “Préalpes médianes” (“Domain intermédiaire”; Septfontaine, 1983).

GEOLOGIC AND STRATIGRAPHIC SETTING

(I. Dieni & F. Massari)

Geologic setting

The Monte Perda Liana (sometimes written as Perdaliana or Perda 'e Liana; hereafter simply called Perda Liana) is an isolated, tower-shaped mount (1293 m a.s.l.), located in central-eastern Sardinia, in the territory of Gairo (boundary area between the Barbagia of Seulo...
and Ogliastra). It is one of the so called “Tacchi” (Fig. 1) of central-eastern Sardinia, hills generally rising from the Palaeozoic basement (Fig. 2) and consisting of carbonate mesas. They are true natural monuments of characteristic aspect, resembling castles, towers and ruins (Barrocu & Gentileschi, 1966; Fig. 3a), and represent isolated remains of a much wider carbonate platform covering most part of Sardinia. Their morphology somewhat recalls that of the mesas of the Monument Valley (U.S.A.). As outlined above, the Perda Liana section, like most part of the “Tacchi”, is the record of the lower part of the Jurassic succession of eastern Sardinia, more completely developed in the Ogliastra, Supramonte and Baronie areas.

An appreciable synthesis on the Middle Jurassic succession of the “Tacchi” area, highlighting the state of the art on these deposits, especially from the viewpoints of the palaeogeography and regional geology, was presented by Costamagna & Barca (2004). They distinguished three units within the Genna Selole Formation on lithostratigraphic grounds: the conglomeratic “Laconi-Gadoni Lithofacies”, the sandy-clayey “Nurri-Escalaplano Lithofacies” and the mixed siliciclastic-carbonate “Ussassai-Perdasdefogu Lithofacies”, grading upwards into the Dorgali Formation. They argued that the Genna Selole type-section, located in the Ogliastra region, is poorly representative and inadequate to illustrate the full range of lithotypes in the Tacchi area. For this reason they proposed a formal redefinition of the formation, which would include the three above mentioned lithofacies, introducing two parastratotypes in the areas of Escalaplano and Perdasdefogu, characterised by good exposures and continuity. The threefold subdivision proposed by Costamagna & Barca (2004) was accepted by Scanu et al. (2012) in a preliminary study of the Jurassic plant fossils based on the revision of the Lovisato Collection.

Fig. 1 - Distribution of Jurassic formations in central-eastern Sardinia (from Dieni et al., 1985, modified).

Fig. 2 - Geologic sketch-map of the Mt Perda Liana area (from Atzeni, 1967). 1: limestone and dolostone (Dorgali Formation, Middle Jurassic); 2: quartz-conglomerate, arenite and carbonaceous claystone (Genna Selole Formation, lower Middle Jurassic); 3: quartz-porphyry in dykes and subvolcanic bodies (Variscan cycle); 4: Variscan granite; 5: graptolite-bearing slate (Wenlock, Silurian); 6: phyllite (Llandovery, Silurian); 7: Orthis-bearing slate and quartz-phyllite (Ordovician); 8: fault.
The stratigraphic succession of Perda Liana

The stratigraphic succession of Perda Liana is palaeontologically well known as it yielded abundant and varied macrofaunas, formerly studied by La Marmora (1857; Fig. 3b), Meneghini (1857), Fucini (1894, 1899), Pampaloni (1900) and Dainelli (1903). A preliminary study of the section was performed by De Biasi (1985).

The lower siliciclastic part of the succession (of which only the uppermost portion is represented in the log of Fig. 4) may be attributed to the Genna Selole Formation (sensu Dieni et al., 1983), and may be correlated to the lithofacies recognized in the “Tacchi” area by Costamagna & Barca (2004) respectively as “Laconi-Gadoni Lithofacies” and “Nurri-Escalaplano Lithofacies”. Conversely, we do not share the opinion of these authors concerning the inclusion of their “Ussassai-Perdasdefogu Lithofacies”, mostly consisting of limestone, in the Genna Selole Formation. Considering its palaeontological content and environmental setting we believe that this unit can be formally distinguished as a member of the Dorgali Formation (Perda Liana Member, see below), due to its essentially carbonate lithology.

Six units may be distinguished in the sedimentary succession:

1. Unit I (not illustrated in the log) is represented by about 15 m of poorly outcropping, scarcely cemented whitish, clast-supported quartz conglomerate, with clasts of pluricentimetric dimensions, clearly derived from veins of the underlying crystalline schists.

2. Unit II, a few metres thick, consists of an association of massive fine quartzarenite and mudstone, with common plant remains and lignite seams. The top layer is a tightly cemented arenite with sub-spherical ferruginous concretions (formerly iron sulphides) commonly bearing plant remains in their core.

3. Unit III consists of grey-beige, very fine-grained, heavily bioturbated, limestone (wackestone and mudstone), commonly marly, with conchoidal fracture, in places containing a small fine-grained quartz fraction. A lower plane-parallel-bedded interval 19 m thick shows muddy interbeds, plant remains, molluscs (among which very abundant infaunal bivalves, usually in life position), common brachiopods and characteristic bioclastic infilling of burrows. It grades into an interval 20.5 m thick, where compaction on thorough bioturbation resulted in a predominantly flaser to nodular bedding (Fig. 4).

4. Unit IV, 8.5 m thick, is a succession of three, normally graded layers, individually comprising a lower grainstone interval with hummocky cross bedding and ripples in the upper part, and an upper bioturbated, flaser-bedded wackestone/packstone interval similar to the lithology of the underlying unit. The macrobenthos is represented by molluscs and rare brachiopods.

5. Unit V, about 5 m thick, consists of thin- to medium-bedded grainstone layers, generally graded and rippled/bioturbated in the upper part. The nerineid Cossmannrea cf. eudesii (Morris & Lyckett, 1851) locally occurs in this interval together with other sparse molluscs and plant remains. The interval is bounded at the base by an erosional surface draped by a coarse layer of quartz pebbles.

6. Unit VI corresponds to the typical, thick-bedded dolostone facies of the Dorgali Formation, of which only the initial part has been measured. This facies forms the vertical walls of the Perda Liana tower, with an estimated height of about 70 m (Fig. 3).

The interval including units III to V has been chosen as type-section of the Perda Liana Member of the Dorgali Formation.

MATERIAL AND METHODS

After the necessary field survey, the Perda Liana section has been logged and about 50 samples of the
Fig. 4 - Stratigraphic log of the type-section of the Perda Liana Member.
RESULTS

Microfacies description

Unit III mostly consists of a wackestone, rarely packstone, with sparse angular quartz grains of variable size, sometimes sorted out and concentrated into the burrows. Bioturbation is diffuse and framboidal clusters of iron sulphide are quite common. Remains of bivalves and gastropods, sometimes micritized, are present with variable abundance and commonly show marginal micro-borings. They are preserved as calcite moulds after aragonite, with lacking evidence of shell collapse indicating that calcite precipitation into dissolution voids occurred after lithification of the sediment. Other minor constituents observable in thin sections are foraminifers (such as nodosariids, textulariids, miliolids, “siphovalvulinas” and encrusting forms), echinoderm fragments, ostracods, sparse ooids and peloids. The thin sections 3 and especially 4 (Fig. 4) show a peculiar composition, with abundant sponge spicles and radiolarians. Brachiopod remains are particularly abundant in the upper part of the third unit.

The three layers of unit IV consist of a grainstone in the lower part grading into a packstone and wackestone upwards. Worth noting is the presence in this unit, among the foraminifers, of *Bosniella croatica* (Gušić, 1969) and *Amijiella amiji* (Henson, 1948). Unit V mostly consists of an ooidal grainstone.

Environmental interpretation

Units I and II were deposited in a continental setting (alluvial fan to braided stream), grading into brackish, and finally marine-marginal (marshy coastal plain) environment. Unit III may be attributed to a low-energy open lagoon (shelf lagoon) environment. The local abundance of siliceous organisms suggests blooms related to episodes of high productivity. Unit IV contains a high-energy, storm-related back-barrier setting, alternating with a low-energy lagoonal setting. The erosional surface at the base of unit V is thought to represent a “ravinement” surface marking the transition to storm-dominated, inner-ramp, marine deposits. The interval comprising units III to V corresponds to the calcareous variety (b) of the “Ussassai-Perdasdefogu lithofacies” of Costamagna & Barca (2004), typical of the north-eastern “Tacchi” area.

In a study of salinity-controlled Bathonian benthic faunas of the Causses (southern France) Fürsich et al. (1995) attribute the *Pholadomya lirata* and *Ceratomya striata* associations to a normal marine environment. In the Perda Liana unit III bivalves of the above associations are well represented and, together with the evidence of low-energy environment, suggest that the assumed shelf-lagoon environment was in a wide connection with the open sea. Only the lowermost part of the third unit contains some species adapted to a lower-salinity environment associated with plant remains, such as *Viviparus scoticus*, probably transported from nearby areas.

FAUNAL CONTENT

The Perda Liana fossil content is certainly the richest and taxonomically most various assemblage within the Middle Jurassic successions of Sardinia. Most fossils studied by former authors (Meneghini, 1857, who determined the macrofaunas collected by La Marmora; Pampaloni, 1900, who presented a brief list of fossils, most of them subsequently studied in detail by Dainelli, 1903) were mostly obtained from the scree deposits at the foot of the tower-like hill, given their abundance in the limestone debris fallen from the cliffs. Here we present a preliminary list of most characteristic taxa, while a more complete palaeontologic and biostratigraphic study of the Middle Jurassic macrofaunas of eastern Sardinia will be the subject of another paper in progress. Of the fossils here reported, several specimens come from the detritus; however those presented alongside the stratigraphic log of Fig. 4 were collected in situ.

In addition to the following list, the presence of rare specimens of large discoidal solitary corals and teeth of hybodontid sharks (Fig. 5) is worth mentioning.

**Brachiopods**

- *Kallirhynchia oranensis* (Flamand, 1911)
- *Holothyrhis angulata* Buckman, 1918

**Bivalves**

- *Grammatodon (Cosmetodon)* sp.
- *Modiolus (M.) imbricus* J. Sowerby, 1818
- *Inoperna plicata* (J. Sowerby, 1819)
- *Pinna subcancellata* (Lissajous, 1923)
- *Trichites cf. thurmanni* Choffat, 1888
- *Pteria plana* (Morris & Lycett, 1854)
- *Pteroperna costatula* (Deslongchamps, 1824 (=*Pteroperna funicui* Dainelli, 1903)
- *Costigervilla crassicosta* (Morris & Lycett, 1853)
- *Eligmus perdalianae* (Meneghini, 1857)

![Fig. 5 - Tooth of hybodontid shark (a: upper view; b: lateral view) (MGP 31180).](image-url)
Entoliolum (E.) corneolum (Young & Bird, 1828)
Camptonecetes (C.) laminatus (J. Sowerby, 1818)
Plicatula sp.
Placunopsis socialis Morris & Lycett, 1853 (= Placunopsis pampalonii Dainelli, 1903)
Plagiomastoma hellicum (d’Orbigny, 1850)
Trigonia (T.) cf. hemisphaerica Lycett, 1850
Mesomitha bellona (d’Orbigny, 1850)
Protoacardia (P.) lycetti Rollier, 1912
Pachymyna (Arcymyna) meneghinii (Dainelli, 1903)
Pholadomya (Bucardiomya) lirata (J. de C. Sowerby, 1850)
Homomya gibbosa (J. Sowerby, 1812)
Gresslyla peregrina (Phillips, 1829)
Ceratomya striata (J. de C. Sowerby, 1812)
Actinostreon gregareum (J. Sowerby, 1815)

Gastropods
Viviparus scoticus (Tate, 1873) ("Viviparus aurelianus" Benn. reported by Dorn, 1940, p. 326, in the "Tacchi" area)
Globularia ranvillensis (d’Orbigny, 1850) (= Natica parthenica Meneghini, 1857)
Harpagodes wrightii (Morris & Lycett, 1851)

Echinoids
Acrosalenia hemicidaroides Wright, 1851

**BIO- AND CHRONOSTRATIGRAPHY**

Among the fossils occurring in the studied section, some forms are long ranging, either from the Bajocian to the Kimmeridgian (Modiolus imbricatus, Inoperna plicata, Entoliolum corneolum, Actinostreon gregareum, Gresslyla peregrina, etc.), or from the Bajocian to the Bathonian or the Callovian (Bosniella croatica, Amijiella amii, Pieropena costatula, Camptonecetes laminatus, Pholadomya lirata, Homomya gibbosa, Ceratomya striata, etc.). Other taxa, such as Pincta subesculenta, Placunopsis socialis, Plagiomastoma hellicum, Pachymyna meneghinii, Viviparus scoticus, Globularia ranvillensis, Harpagodes wrightii, Acrosalenia hemicidaroides, etc., have a more restricted stratigraphic distribution, being exclusive of the Bathonian. The Bathonian age of the assemblage is thus confirmed, as formerly established by Pampaloni (1900) and Dainelli (1903). A further age precision is provided by the two species of brachiopods Kallirhynchia oranensis and Holcothyris angulata. K. oranensis occurs in one level (6; Fig. 4) while H. angulata was collected from two levels (7 and 9; Fig. 4). They document the Oranensis Zone of the brachiopod biostratigraphic zonation, which in turn can be correlated to the Lower Bathonian Zigzag Zone of the ammonite chronostратigraphic zonation (Alméras et al., 1997). Therefore, the Perda Liana calcareous interval, here erected as lower member of the Dorgali Formation, can be dated, at least in its type-section, to the Early Bathonian.

**FORMAL INSTITUTION OF THE PERDA LIANA MEMBER**

The Dorgali Formation, which is widespread and typical of the lower part of the Jurassic carbonate succession of eastern and central Sardinia, has in general quite uniform dolomitic lithology and is usually barren of fossils, so that its age is poorly constrained. However, important biostratigraphic data are yielded by some locally occurring lenses of even thin packages of limestone beds, in places partly dolomitized, generally containing abundant fossils. These fossil-bearing limestones occur at the base, as in the case of Perda Liana, or at various levels within the Dorgali Formation, such as the lenses of limestone to silty limestone identified in the Monte Albo area (Janna Portellitos and Punta Casteddu sections) containing brachiopods indicating the Bremeri and Retrcostatum zones, such as Burmirhynchia turigida Buckman and Arceythysis diptyca (Oppel), which testify the Upper Bathonian (Alméras et al., 1997).

Here we reserve however the name of Perda Liana Member only to the lower calcareous package of the Dorgali Formation, which should correspond to the variety “b” of the “Usassai-Perdasdefoug lithofacies” of Costamagna & Barca (2004), characterised by predominantly calcareous limestone and confined in the north-eastern part of the “Tacchi” area. In our opinion, even their mostly dolomitic variety “a” should not be distinguished as a separated unit from the essentially dolomitic facies of the Dorgali Formation. There is no doubt that the first two lithofacies distinguished by Costamagna & Barca (2004), i.e. the “Laconi-Gadoni and Nurri-Escalaplano lithofacies”, characterised by terrigenous lithology, are to be included in the Genna Selole Formation. On the other hand, considering the lithostratigraphic and environmental relationships of the limestone package with the dolostones of the Dorgali Formation, in our opinion this carbonate unit should be regarded as a member of this formation, instead of part of the Selole Formation as claimed by Costamagna & Barca (2004).

The fossil content of the Perda Liana Member, dominated by bivalves, is generally quite uniform and generally indicates an Early Bathonian age (see above). As type-section of the Perda Liana Member of the Dorgali Formation, we selected the Perda Liana section, whose characteristic features (lithology, thickness, sedimentary structures, fossils, etc.) are presented in the stratigraphic log of Fig. 4. The lower boundary of the member is with the siliciclastic facies of the Genna Selole Formation, the upper boundary is marked by the first dolostone beds of the Dorgali Formation. As supplementary section we may mention the one exposed NW to the village of Ullassai (Fig. 1) (locality Gedili, near Bruncu Pranedda) for the lower part of the member, already studied by Dorn (1940), and the one located SW of the same village (locality Matta Prana, western slope of Bruncu Matzeu), for the upper part.

**SYSTEMATIC PALAEONTOLOGY**

(I. Dieni & V. Radulović)

Repositories - The studied specimens are housed in the following institutions:
- Museo di Geologia e Paleontologia, Università di Padova, Dieni Collection (MGP);
- Museo di Storia Naturale e del Territorio, Università di Pisa, Meneghini Collection (MUP);
- Museo di Storia Naturale, Sezione di Geologia e Paleontologia, Università di Firenze, Dainelli Collection (IGF).

Phylum BRACHIOPODA Duménil, 1806
Order RHYNCHONELLIDA Kuhn, 1949
Family TETRARHYNCHIIDAE Ager, 1965

Genus KALLIRHYNCHIA Buckman, 1918

Kallirhynchia oranensis (Flamand, 1911)
Figs 6, 7a-e, 10a-d

<table>
<thead>
<tr>
<th>Specimen</th>
<th>L</th>
<th>W</th>
<th>T</th>
<th>W/L</th>
<th>T/L</th>
<th>T/W</th>
<th>NRDV</th>
<th>Commissure</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>MGP 31346</td>
<td>16.0</td>
<td>16.5</td>
<td>7.6</td>
<td>1.03</td>
<td>0.47</td>
<td>0.46</td>
<td>18</td>
<td>asymmetric</td>
<td></td>
</tr>
<tr>
<td>MGP 31368</td>
<td>16.1</td>
<td>16.4</td>
<td>10.9</td>
<td>1.02</td>
<td>0.68</td>
<td>0.66</td>
<td>18</td>
<td>symmetric</td>
<td></td>
</tr>
<tr>
<td>MGP 31347</td>
<td>18.6</td>
<td>21.0</td>
<td>13.4</td>
<td>1.13</td>
<td>0.72</td>
<td>0.64</td>
<td>21</td>
<td>symmetric</td>
<td>Fig. 7a</td>
</tr>
<tr>
<td>MGP 31348</td>
<td>19.4</td>
<td>25.3</td>
<td>16.1</td>
<td>1.30</td>
<td>0.83</td>
<td>0.64</td>
<td>18</td>
<td>symmetric</td>
<td>Fig. 7b</td>
</tr>
<tr>
<td>MGP 31349</td>
<td>19.7</td>
<td>21.0</td>
<td>13.0</td>
<td>1.07</td>
<td>0.66</td>
<td>0.62</td>
<td>18</td>
<td>?asymmetric</td>
<td>Fig. 7c</td>
</tr>
<tr>
<td>MGP 31350</td>
<td>21.2</td>
<td>23.7</td>
<td>17.3</td>
<td>1.12</td>
<td>0.82</td>
<td>0.73</td>
<td>20</td>
<td>symmetric</td>
<td>sectioned, Fig. 7d</td>
</tr>
<tr>
<td>MGP 31369</td>
<td>21.3</td>
<td>21.3</td>
<td>13.7</td>
<td>1.00</td>
<td>0.64</td>
<td>0.64</td>
<td>18</td>
<td>symmetric</td>
<td></td>
</tr>
<tr>
<td>MGP 31370</td>
<td>23.8</td>
<td>26.1</td>
<td>16.6</td>
<td>1.10</td>
<td>0.70</td>
<td>0.64</td>
<td>19</td>
<td>symmetric</td>
<td></td>
</tr>
<tr>
<td>MGP 31351</td>
<td>26.6</td>
<td>26.5</td>
<td>20.3</td>
<td>0.99</td>
<td>0.76</td>
<td>0.77</td>
<td>18</td>
<td>asymmetric</td>
<td>Fig. 7e</td>
</tr>
<tr>
<td>IGF 3488E</td>
<td>15.8</td>
<td>16.7</td>
<td>9.0</td>
<td>1.06</td>
<td>0.57</td>
<td>0.54</td>
<td>18</td>
<td>symmetric</td>
<td></td>
</tr>
<tr>
<td>MUP 13899</td>
<td>17.5</td>
<td>17.7</td>
<td>11.2</td>
<td>1.01</td>
<td>0.64</td>
<td>0.63</td>
<td>21</td>
<td>symmetric</td>
<td>Fig. 10a</td>
</tr>
<tr>
<td>MUP 13892</td>
<td>19.7</td>
<td>20.0</td>
<td>12.4</td>
<td>1.01</td>
<td>0.63</td>
<td>0.62</td>
<td>16</td>
<td>symmetric</td>
<td>Fig. 10b</td>
</tr>
<tr>
<td>MUP 13882a</td>
<td>21.6</td>
<td>20.8</td>
<td>14.2</td>
<td>0.96</td>
<td>0.66</td>
<td>0.68</td>
<td>21</td>
<td>asymmetric</td>
<td>Fig. 10c</td>
</tr>
<tr>
<td>MUP 13882b</td>
<td>23.5</td>
<td>22.2</td>
<td>14.4</td>
<td>0.94</td>
<td>0.61</td>
<td>0.65</td>
<td>21</td>
<td>symmetric</td>
<td>Fig. 10d</td>
</tr>
</tbody>
</table>

Tab. 1 - Biometric parameters of the Kallirhynchia oranensis (Flamand, 1911) studied specimens. L = length; W = width; T = thickness; NRDV = number of ribs on the dorsal valve.
Fig. 6 - Transverse serial sections of *Kallirhynchia oranensis* (Flamand, 1911) through the specimen MGP 31350 (the same as Fig. 7d), Lower Bathonian of Perda Liana. Numbers indicate the distance in mm from the tip of the ventral umbo.
Internal characters (Fig. 6): Dental plates slender and straight, ventrally divergent, totally disappearing at the level of full teeth development. Delthyrial cavity trapezoidal; lateral umbonal cavities triangularly rounded. Deltidial plates inwardly curved. Hinge teeth globular and crenulated, inserted in deep dental sockets with lateral denticula. Outer hinge plates initially ventrally deflected, anteriorly becoming horizontal, relatively wide, and straight. Septalium not present. Septalial plates short, pendant. Euseptoideum reduced to a short and low ridge. Crural bases crescent-like, concave laterally, slightly projected ventrally and dorsally from the hinge plates. Crura curving ventrally, with widened and thickened distal ends (similar in appearance to a diabolo in transverse sections), calcariform, terminating at a distance of 0.26 dorsal valve length from the dorsal umbo.

Remarks - Meneghini (1857) described and figured from the Jurassic of Perda Liana (the same locality of the studied specimens) as *Rhynchonella subobsoleta*.
Davidson some specimens (MUP I 13899, 13892, 13882a, 13882b) which have the same external morphology as the specimens collected by us. He distinguished three morphotypes, which, according to him, are very close to each other. Their external morphology fits well with our specimens in general shape, dimensions, in tendency to asymmetry, type and number of ribs on the slopes and on the fold and in the sulcus. Dainelli (1903) described one external mould from the Bathonian of the same locality and one small coeval specimen from the Tacco di Seui (central Sardinia). Due to their poor state of preservation, following Meneghini he identified both forms as Rhynochella cfr. subobsoleta. Having carefully examined this material, we arrived to the conclusion that both specimens are to be referred to K. oranensis.

The internal morphology of the sectioned specimen (Fig. 6) entirely coincides with that observed in Rousselle & Demarez (1965, serial sections of six specimens in text-plate of p. 37), Alméras & Fauré (2008, figs 1-5), and especially with the reconstructions of crura by Rousselle (1965, fig. 24), which are calciriform with widened and thickened distal ends (similar in appearance to a diabolo). This supports the inclusion of this species within the genus Kallirhynchia Buckman, 1918.

Kallirhynchia oranensis differs externally from the Upper Aalenian (Ludwigia murchisonae-Graphoceras concavum zones) Globirhynchia subbosoleta (Davidson, 1852, p. 91, pl. 17, fig. 14) of England and France by its larger size and by the fewer number of ribs. In addition, the two taxa can be clearly distinguished by their internal morphology, especially by the development of two different types of crura: with widened distal ends, calciriform (a variant of raduliform) in Kallirhynchia and canaliform in Globirhynchia (Savage et al., 2002, fig. 901, 3e-3m, reproduced from Shi & Grant, 1993, fig. 69), which places them in two different families. Interior of the Sardinian specimens and especially distal ends of the crura (a diabolo in transverse sections), are identical with those in the type species of the genus, Kallirhynchia yaxleyensis (Davidson, 1878), from the Upper Bathonian of Lorraine, France (Savage et al., 2002, fig. 921, 2d-2j), reproduced from Laurin, 1984, fig. 182). However, it differs externally from oranensis in having a globose shape, larger number of ribs (25-31), and always symmetrical uniplication with high rectangular linguiform extension.

Stratigraphic and geographic range - According to Alméras & Fauré (2008) K. oranensis occurs in the uppermost Bajocian (Parkinsonia parkinsoni Zone), Lower Bathonian - Zigzagiceras zigzag-Procreries (Semiordadzia) aurigerus zones - and Middle Bathonian (Cadomites bremeri Zone) of Morocco, western Algeria, and Nepal. Our finding in Sardinia represents therefore the first record of this taxon on the northern margin of the Tethys.

Nomenclatural note - In 1857 Meneghini established the new species Terebratula lamarmorae from the “Great Oolite” (Bathonian; Dainelli, 1903) of Perda Liana, central Sardinia. The name lamarmorae was given in honour of Albert de La Marmora, ending with an “ae”, though, etymologically, it should have been written with an “ai” (I.C.Z.N., Art. 31.1.2, 2000). Nevertheless, the correction of the name would be an unjustified emendation, and the original name (although it has an incorrect genitive ending) should be retained (I.C.Z.N., Art. 31.1.3.).

In 1918 Buckman, apparently unaware of the paper by Meneghini (1857), erected Holcothyris angulata, the type species of his genus Holcothyris Buckman, 1918, from the Namyau Beds (Bathonian) of Burma. H. angulata has been generally accepted and is in widespread use in
Fig. 8 - Transverse serial sections of *Holcothyris angulata* Buckman, 1918, through the specimen MUP I 13880a, syntype of *Terebratula lanarmorae* Meneghini, 1857 (figured by its author in pl. E, fig. 19b and refigured here in Fig. 10e), Lower Bathonian of Perda Liana. Numbers indicate the distance in mm from the tip of the ventral umbo.
Fig. 9 - Transverse serial sections of *Holcothyris angulata* Buckman, 1918, through the specimen MGP 31356 (the same as Fig. 7i), Lower Bathonian of Perda Liana. Numbers indicate the distance in mm from the tip of the ventral umbo.
the palaeontologic and stratigraphic literature, although it is a junior synonym of *Terebratula lamarmorae* Meneghini, 1857. The senior name *T. lamarmorae* has not been used as a valid name since 1899, when it was quoted for the last time by Fucini (1899) (I.C.Z.N., Art. 23.9.1.1.). Conversely, the name *H. angulata* Buckman has been used in more than 25 papers by more than 10 authors in the period from 1918 to 2009 (see synonymy list) (I.C.Z.N., Art. 23.9.1.2.). Therefore, both conditions necessary for reversal of precedence under I.C.Z.N., Art. 23.9 are met, and following Art. 23.9.2 we cite the two names together and explicitly state that the younger name *angulata* Buckman is valid and must be maintained as nomen protectum, while the senior name *lamarmorae* Meneghini is invalid, being nomen oblitum.

**Material** - Six specimens from the Dieni Collection (MGP 31352 - 31356, 31360, collected in situ) and two specimens from the Meneghini Collection (MUP I 13880a, 13880b), all from Perda Liana, central Sardinia, for a total sum of eight specimens available. The exact stratigraphic position of the specimens coming from the Meneghini Collection is unknown.

**Description**

**External characters** (Figs 7f-i, 10e-f): Medium size (Tab. 2), rounded sub-pentagonal outline, lateral margins slightly rounded, always longer than wide, moderately ventri-biconvex. Maximum width and thickness at mid-length. Beak massive, wide, erect, in close contact with the dorsal umbo totally obscuring symphymity, with large circular mesothyrid to permesothyrid foramen. Beak ridges short and rounded. Lateral commissure gently ventrally arched in the posterior two-thirds or nearly straight, and sharply curved ventrally at the anterior; anterior commissure slightly bisulcate. A shallow sulcus developed on the anterior one-third of the dorsal valve, deepens anteriorly, bordered by rounded and parallel folds. Ventral valve with median rounded fold originating on anterior one-third, separated by shorter and narrower sulci. Fine growth lines, much more numerous and crowded anteriorly, and ornament of fine radiating capilli (about two-three capilli per mm near the anterior margin) where exfoliated.

**Internal characters** (Figs 8-9): Two specimens, the smaller (Fig. 8, L = 22.3 mm) from Meneghini’s Collection and the larger (Fig. 9, L >27.8 mm) from the Dieni Collection, have been serially sectioned for studying the internal morphology.

Cardinal process well developed, nearly flat with distinct myophore. Dorsal umbal cavity present. Crural bases high and slender, ventrally tapering, project above hinge plates. Hinge plates narrow, sub-horizontal. Euseptoideum short and low, bordered laterally by two small ridges. Crural processes high, ventrally convergent and tapering. Transverse band relatively wide, high and flat. Loop thin, as long as 0.42-0.45 of dorsal valve length, with very long terminal points.

**Remarks** - Referring to the external characters, such as rounded sub-pentagonal outline, the shape of the anterior commissure, and the finely capillate ornamentation, where exfoliated, the studied specimens fit very well the Lower Bathonian (*Zigzagiceras zigzag* Zone) *Holcothyris angulata* Buckman, 1918, of the Tethyan Realm. The only difference is the sporadical presence of the umbal dorsal sulcus in the latter, which is variable in character (see below). By their internal characteristics, the sectioned specimens from Perda Liana are very close to the specimens of *angulata* described by Alméras (1971), Ovčarenko (1983), Alméras & Gupta (1986), and Alméras et al. (1991). Mainly, the aspects of the hinge plates, the size of the crural bases, the shape and the size of transverse band and especially long terminal points are very similar.

Ovčarenko (1983, p. 112), based on a very large number of specimens (more than 3000), of *H. angulata* from many Bathonian localities of Pamir, stated that “in the dorsal umbonal part a small furrow is usually developed, which sometimes reaches the anterior end” whereas “in adults in the relief of the posterior part it may be absent”. Moreover, Alméras & Gupta (1986) and Alméras et al. (1991) figured specimens of this species of Buckman from the Lower Bathonian of India and Algeria devoid of sulcus in the dorsal umbo. Yang & Shi (1987, p. 47), studying external and internal characters on material from the Lower Bathonian of China belonging to the genus *Holcothyris*, stated in the emended diagnosis of the genus that dorsal valve is “variably furrowed”. As in all the specimens of *H. angulata* from Burma figured by Buckman (1918) and Sahni (1940) and those from China studied by Sun (1990), the sulcus of the dorsal umbo is present. From the above facts it can be concluded that the dorsal umbal sulcus is not always present. It is absent both in all newly collected specimens from Perda Liana and in the two specimens figured by Meneghini (1857).

The two specimens figured by Meneghini (1857, as *Terebratula lamarmorae*) have a slightly higher anterior commissure when compared with the specimens collected

<table>
<thead>
<tr>
<th>Specimen</th>
<th>L</th>
<th>W</th>
<th>T</th>
<th>W/L</th>
<th>T/L</th>
<th>T/W</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>MGP 31352</td>
<td>16.5</td>
<td>14.5</td>
<td>8.0</td>
<td>0.88</td>
<td>0.48</td>
<td>0.55</td>
<td>Fig. 7f</td>
</tr>
<tr>
<td>MGP 31353</td>
<td>20.8</td>
<td>18.8</td>
<td>12.2</td>
<td>0.90</td>
<td>0.59</td>
<td>0.65</td>
<td>Fig. 7g</td>
</tr>
<tr>
<td>MGP 31354</td>
<td>21.8</td>
<td>17.0</td>
<td>&gt;9.3</td>
<td>0.78</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MGP 31355</td>
<td>26.8</td>
<td>22.5</td>
<td>14.8</td>
<td>0.84</td>
<td>0.55</td>
<td>0.66</td>
<td>Fig. 7h</td>
</tr>
<tr>
<td>MGP 31356</td>
<td>&gt;27.8</td>
<td>23.6</td>
<td>18.0</td>
<td></td>
<td>0.76</td>
<td></td>
<td>sectioned, Fig. 7i</td>
</tr>
<tr>
<td>MUP I 13880a</td>
<td>22.3</td>
<td>20.4</td>
<td>14.4</td>
<td>0.91</td>
<td>0.65</td>
<td>0.70</td>
<td>sectioned, Fig. 10e</td>
</tr>
<tr>
<td>MUP I 13880b</td>
<td>29.2</td>
<td>23.5</td>
<td>15.7</td>
<td>0.80</td>
<td>0.54</td>
<td>0.67</td>
<td>Fig. 10f</td>
</tr>
</tbody>
</table>

Tab. 2 - Biometric parameters of the studied specimens of *Holcothyris angulata* Buckman, 1918. L = length; W = width; T = thickness.
by us at Perda Liana, the same locality from which the Meneghini types come. The serial transverse sections of one type of Meneghini Collection (MUP I 13880a; Fig. 8) and of a specimen collected by us (MGP 31356; Fig. 9) have revealed the same internal morphology.

**Holcothyris rotundata** Sahni (1940), co-occurring in Burma with *H. angulata* and *Kallirhynchia oranensis* (Flamand, 1911), differs from the Sardinian specimens of *angulata* by almost spherical shell, and in having a shorter biostratigraphic range (lower part of the *Zigzagiceras zigzag* Zone; Alméras, 2008).

**Stratigraphic and geographic range** - The species is widespread in the Lower Bathonian (*Zigzagiceras zigzag* Zone, sometimes post *zigzag*) of the Tethyan realm: China, Burma, Pamir, Turkmenia, Crimea, Northern Caucasus, Romania, France, Sardinia, and ?England on the northern margin of Tethys; India, Saudi Arabia, Sinai, eastern Africa, northern Africa, and Maghreb on the southern margin of Tethys.

ACKNOWLEDGEMENTS

We are indebted to L. Chiappini (Museo di Storia Naturale e del Territorio of the Università di Pisa) and E. Cioppi (Museo di Storia Naturale, Sezione di Geologia e Paleontologia, Università di Firenze) for the kind loan of the specimens of Meneghini and respectively Dainelli collections in their care. Svetlana Nikolaeva (Natural History Museum, London) and Alessandro Minelli (Dipartimento di Biologia, Università di Padova) helped with nomenclatural questions. We are grateful to M. Murino (Tortolì) for his generous present of fossils from Perda Liana. The reviewers F. Jadoul and A. Vörös are thanked for their constructive and very helpful comments. F.M. Dalla Vecchia is acknowledged for his suggestion concerning the fish teeth. N. Michelon and S. Castelli (Università di Padova) are thanked for their technical contribution. The research was partially supported by the Ministry of Education.
and Science of the Republic of Serbia, Project No. 176015 (grant to VR).

REFERENCES


Atzeni A. (1967). Carta geologica del Massiccio del Gennargentu e dell’Alto e Medio Flumendosa alla scala 1:50.000. Regione autonoma della Sardegna, Assessorato all’Industria e Commercio, Cagliari.


Shi Xiao-ying & Grant R.E. (1993). Jurassic rhynchonellids, internal structures and taxonomic revisions. Smithsonian Contributions to Paleobiology, 73. 190 pp.