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The Silurian of the Foreland Zone (southwestern Sardinia)

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ABSTRACT - The Silurian exposed in southwestern Sardinia is well-known for its precious faunal content. Lower part of the sequence consists of black graptolitic shales (Genna Muxerru Formation) comprising much of the Llandovery. It is suceeded by a calcareous unit (Fluminimaggiore Formation), locally rich in cephalopods, covering the rest of the Silurian. Even the Lower Devonian is represented by limestones. A precise and detailed biostratigraphical assignment of the units has been achieved by graptolites and conodonts.

KEY WORDS - Silurian, southwestern Sardinia, biostratigraphy, Genna Muxerru Fm., Fluminimaggiore Fm., graptolitic limestone.

INTRODUCTION

Silurian rocks of southwestern Sardinia are, from a palaeontological point of view, among the best known sediments of the whole Palaeozoic succession of the island. Several authors, starting from Meneghini (1857), illustrated different aspects of that rich fauna which includes graptolites, cephalopods, bivalves, and conodonts, beside several other less abundant fossil groups.

Despite the richness and the good preservation of the fossil material, outcrops are in general quite disappointing, since only a few meters of rocks, normally strongly tectonized, or a group of scattered blocks are exposed here and there, without any undisturbed section. Two formations (Fig. 1) were formally described by Gnoli et al. (1990) in the Silurian of southwestern Sardinia: the Genna Muxerru Formation (Llandovery) and the Fluminimaggiore Formation (uppermost Llandovery-lowermost Lochkovian).

THE GENNA MUXERRU FORMATION

The Genna Muxerru Fm. consists of about 20-25 metres of graptolitic silica-argillaceous and siltitic shales, interbedded by subordinate lydites in the lower part (Gnoli et al., 1990). Local greywacke bodies crop out at the type locality Genna Muxerru (Storch & Serpagli, 1993). Faulting, cleavage and small scale folding characterized the whole unit.

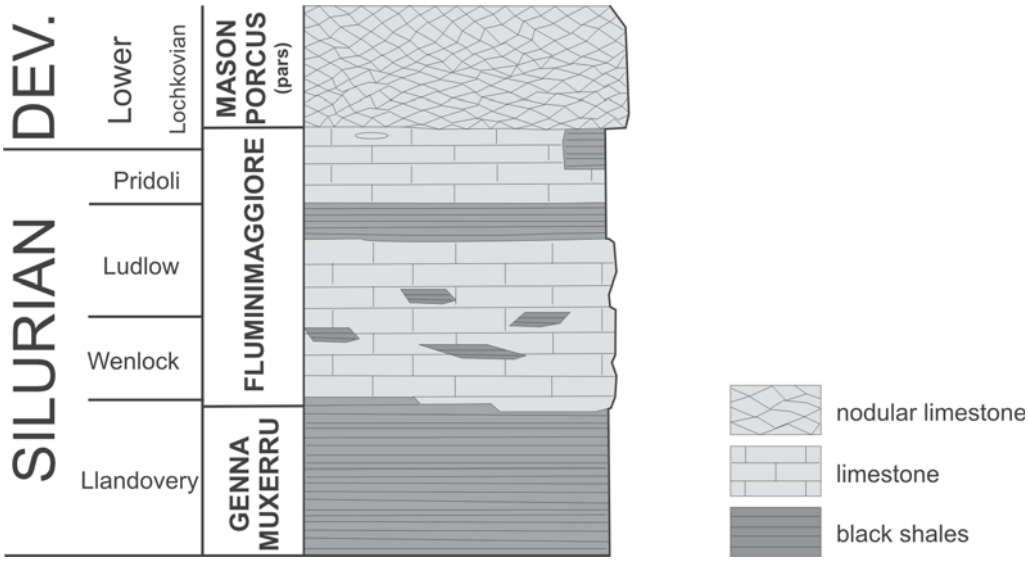


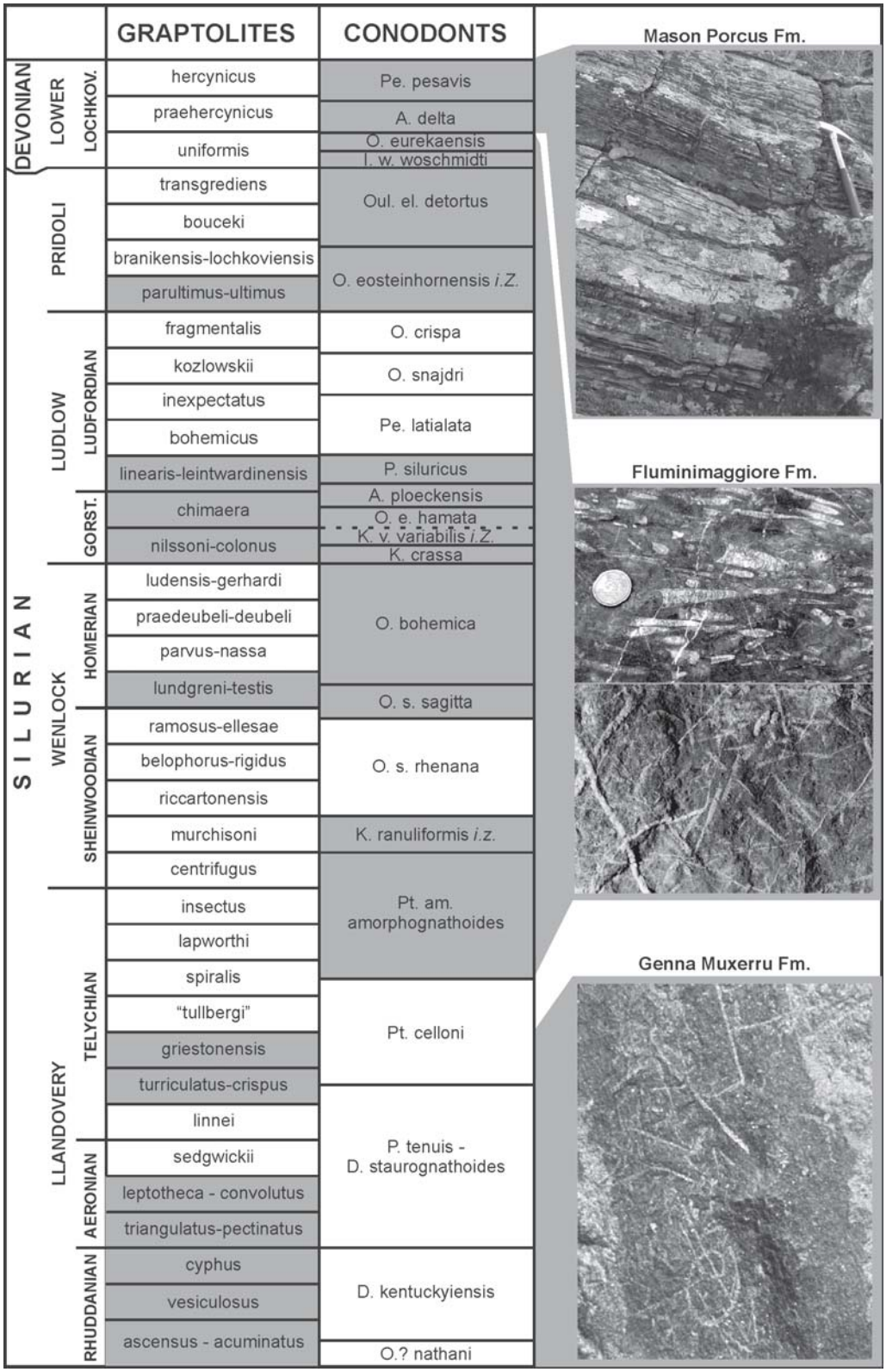
Fig. 1 - Stratigraphical scheme of the Silurian and lowermost Devonian of southwestern Sardinia (modified after Gnoli et al., 1990).

The lower boundary of the formation is never clearly exposed but no evidence of discontinuity in sedimentation between Ordovician and Siluro-Devonian sequences is present. Furthermore, the latest Hirnantian age of the Rio San Marco Fm. (Leone et al., 1991; Storch & Leone, 2003) is in accordance with the occurrence of *A. ascensus* and *P. acuminatus* in the lowermost beds of the Genna Muxerru Fm. (Storch & Piras, 2009).

Graptolites are the only fossils documented from the unit: more than fifty taxa have been described by Storch & Serpagli (1993) and Rickards et al. (1995), documenting several Llandovery biozones, from early Rhuddanian *ascensus-acuminatus* Zone, through to middle Telychian *griestonensis* Zone (Fig. 2).

The Genna Muxerru Fm. seems to grade into the overlying Fluminimaggiore Fm., but the boundary is never exposed (Gnoli et al., 1990). In the Perda S'Altari area, south of Arbus, an unusual situation occurs: a gradual transition between the Genna Muxerru and the Mason Porcus formations has been recently described and illustrated, without apparently any evidence of the Fluminimaggiore Fm. in the area (Corriga & Corradini, 2008). In this case, the thickness of the Genna Muxerru Fm. needs to be increased as the unit could span the whole Silurian (Corriga & Corradini, 2008).

Fig. 2 - Stratigraphical distribution of the Silurian-lowermost Devonian units in southwestern Sardinia. Documented biozones are shaded. Mason Porcus Fm.: view of the Perda S'Altari section; Fluminimaggiore Fm.: *Orthoceras* limestone, Sant'Antonio Donigala [top] and graptolitic limestone, Fluminimaggiore area [below]; Genna Muxerru Fm.: slab from the type locality.


GRAPTOLITES
CONODONTS
SILURIAN
DEVONIAN
LOWER
LOCHKOV.
PRIDOLI
LUDLOW
LUDFORDIAN
GORST.
WENLOCK
HOMERIAN
SHEINWOODIAN
LLANDOVERY
TELYCHIAN
AERONIAN
RHUDDANIAN
hercynicus
praehercynicus
uniformis
transgrediens
bouceki
branikensis-lochkoviensis
parultimus-ultimus
fragmentalis
kozlowskii
inexpectatus
bohemicus
linearis-leintwardinensis
chimaera
nilssoni-colonus
ludensis-gerhardi
praedeubeli-deubeli
parvus-nassa
lundgreni-testis
ramosus-ellesae
belophorus-rigidus
riccartonensis
murchisoni
centrifugus
insectus
lapworthi
spiralis
"tullbergi"
griestonensis
turriculatus-crispus
linnei
sedgwickii
leptotheca - convolutus
triangulatus-pectinatus
cyphus
vesiculosus
ascensus - acuminatus
Pe. pesavis
A. delta
O. eurekaensis
I. w. woschmidti
Oul. el. detortus
O. eosteinhornensis *i.Z.*
O. crispa
O. snajdri
Pe. latialata
P. siluricus
A. ploeckensis
O. e. hamata
K. v. variabilis *i.Z.*
K. crassa
O. bohemica
O. s. sagitta
O. s. rhenana
K. ranuliformis *i.z.*
Pt. am. amorphognathoides
Pt. celloni
P. tenuis - D. staurognathoides
D. kentuckyiensis
O.? nathani
Mason Porcus Fm.
Fluminimaggiore Fm.
Genna Muxerru Fm.

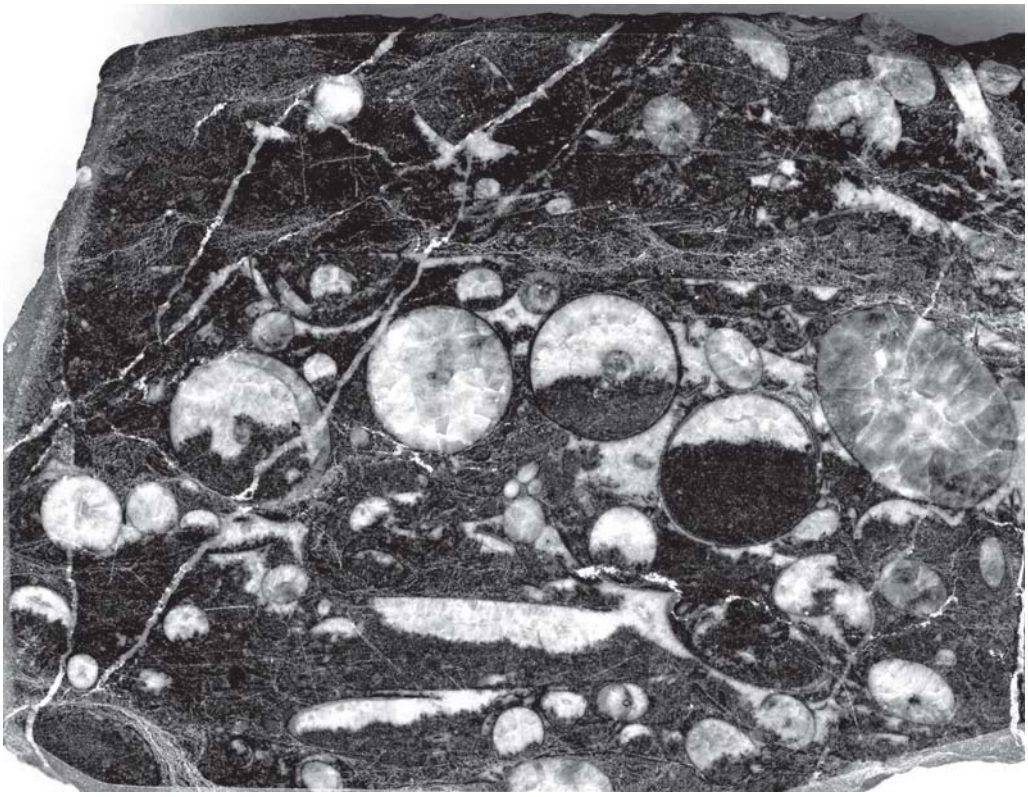


Fig. 3 - Polished slab of the *Orthoceras* limestone of the Fluminimaggiore Fm. (Sant'Antonio Donigala area).

The Fluminimaggiore Formation

The Fluminimaggiore Fm. roughly corresponds to the "calcari a *Orthoceras*, *Cardiola*, *Monograptus*, etc." of the early authors. It is mainly constituted by black limestone lenses and layers alternating with dark non-calcareous pelites and shales. Carbonate deposition is characterized by dominant fossiliferous wackestones-packstones, that grade to fossiliferous mudstones. Microbiofacies were described by Ferretti (1989) and Ferretti et al. (2009). Plastic deformation and cleavage strongly altered the shales, while limestone blocks preserve fossils mostly in full three dimensions (Gnoli et al., 1980). The black colour and the peculiar bituminous smell reveal a high content of organic matter. The thickness of the Fluminimaggiore Fm. should be 40-50 m, but it can be only indirectly estimated, since no sections expose completely the unit due to the strong tectonic deformation. A septariae-bearing horizon occurs in the middle part of the formation, whereas an encrinitic packstone with crinoidal bioclasts is present at the top (Gnoli et al., 1990).

The fauna is dominated by cephalopods (Serpagli & Gnoli, 1977; Gnoli & Serventi, 2009) and bivalves (Kriz & Serpagli, 1993; Kriz, 2009), associated with pelagic ostracodes, graptolites, conodonts, chitinozoans. Gastropods, eurypterid fragments and the problematic *Kolihaia* are rare. Phyllocarids and pelagic crinoids are occasionally present in the upper

part of the unit. Bivalves are the only significant indicators of an epibenthic fauna, while almost no trilobites and brachiopods have been reported, revealing the presence of oxygen-depleted environmental conditions unfavourable to these organisms.

Graptolites are frequently found packed together in peculiar pseudo-lenticular limestone bodies or thin calcareous layers preserving three-dimensional specimens. Five graptolite biozones and co-occurring conodonts document the lower Homerian to lower Pridoli (Ferretti & Serpagli, 1996), allowing a precise tying between the two biozonation schemes (Corradini & Serpagli, 1999).

A precise biostratigraphical assignment of the Fluminimaggiore Fm. was established on the basis of conodonts, that have documented twelve conodont Zones from the *amorphognathoides* Zone (top Llandovery-early Wenlock) to the *woschmidti* Zone (Lochkovian) either from the *Orthoceras* or the graptolitic limestones (Fig. 2). However, some intervals have not been found yet: they are probably represented by shales strongly deformed and displaced by tectonics (Gnoli et al., 1990). The Silurian/Devonian boundary occurs in the uppermost part of the Fluminimaggiore Fm., just below the lobolith horizon with the giant pelagic crinoid *Scyphocrinites* (Gnoli et al., 1988), well known along the northern Gondwana margin across the Silurian/Devonian boundary.

The Fluminimaggiore Fm. is overlaid by the Mason Porcus Formation (Lochkovian-Emsian), which mainly consists of nodular and massive limestones alternating with compact dark siltstones and shales. Stromatactis bearing carbonate mounds, forming lenticular bodies of massive limestone have been documented in the Mt. Padenteddu area (Gnoli et al., 1981). The unit is dominated by dacryoconarida, cephalopods, conodonts, and ostracodes in association with minor crinoids, trilobites, phyllocarids, corals and sponge spiculae (Gnoli et al., 1990). In the mud mound facies, tabulate and colonial corals are also present, together with abundant stromatactis structures (Gnoli et al., 1981). Conodonts have documented seven Lower Devonian biozones, from the *delta* Zone to the *serotinus* Zone (Olivieri & Serpagli, 1990; Ferretti et al., 1998).

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