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The Silurian of the External Nappes (southeastern Sardinia)

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ABSTRACT - The most complete and best known Silurian succession of southeastern Sardinia is exposed in the Gerrei tectonic Unit. The Silurian sequence starts with Rhuddanian-lowermost Gorstian black graptolitic shales (Lower Graptolitic Shales), followed by a lower Gorstian-end Pridoli nodular calcareous unit (Ockerkalk). Graptolitic shales (Upper Graptolitic Shales) document the Lower Devonian. An integrated scheme of graptolite and conodont biozonation, compiled from Sardinic data, is provided.

KEY WORDS - Silurian, southeastern Sardinia, biostratigraphy, Gerrei tectonic Unit, Lower Graptolitic Shales, Ockerkalk.

INTRODUCTION

Silurian rocks are quite widespread in southeastern Sardinia, where they crop out widely in the Gerrei tectonic Unit and more rarely in the other tectonic units of the area (Sarrabus and Meana Sardo tectonic units). In the first approximation, the sequence is constituted by black graptolitic shales in the lower part, followed by nodular limestones of late Silurian age.

THE GERREI TECTONIC UNIT

The Gerrei tectonic Unit spans from middle Cambrian to Lower Carboniferous and includes the most complete middle Palaeozoic sequence of Sardinia (Fig. 1), which was only weakly affected by metamorphic effects. Most of its components are not yet officially defined and informal names are still in use in literature.

The Gerrei tectonic Unit starts with more than 500 m of terrigenous sediments (San Vito Sandstones) deposited in different environments, varying from inter-tidal to a wide fan-delta system swept by turbidity currents. Monotonous alternances of grey micaceous sandstones, quartzites, siltites and pelites grade to levels of violet, greenish or blackish pelites and thick layers of coarse light-grey quartzites and conglomerates. The age of the San Vito Sandstones spans from the middle Cambrian to the Early Ordovician (Naud & Pittau Demelia, 1987).

The sequence continues, after an important disconformity (Sarrabese Phase) with up to 500 m of volcanics, volcanoclastics and epiclastics, representing the "Ordovician Volcanic Complex". The origin of these volcanic products is a magmatic arc related to subduction

of oceanic crust under the North Gondwanan continental margin (Carmignani et al., 1992). The subduction ceased in the Late Ordovician before reaching the continental collision. The consequent gravitative collapse of the magmatic arc produced extensional stresses associated with basaltic intercalations in terrigenous continental to littoral sediments. Quartzites, sandstones and rarely conglomerates, greyish siltites and argillites with variable

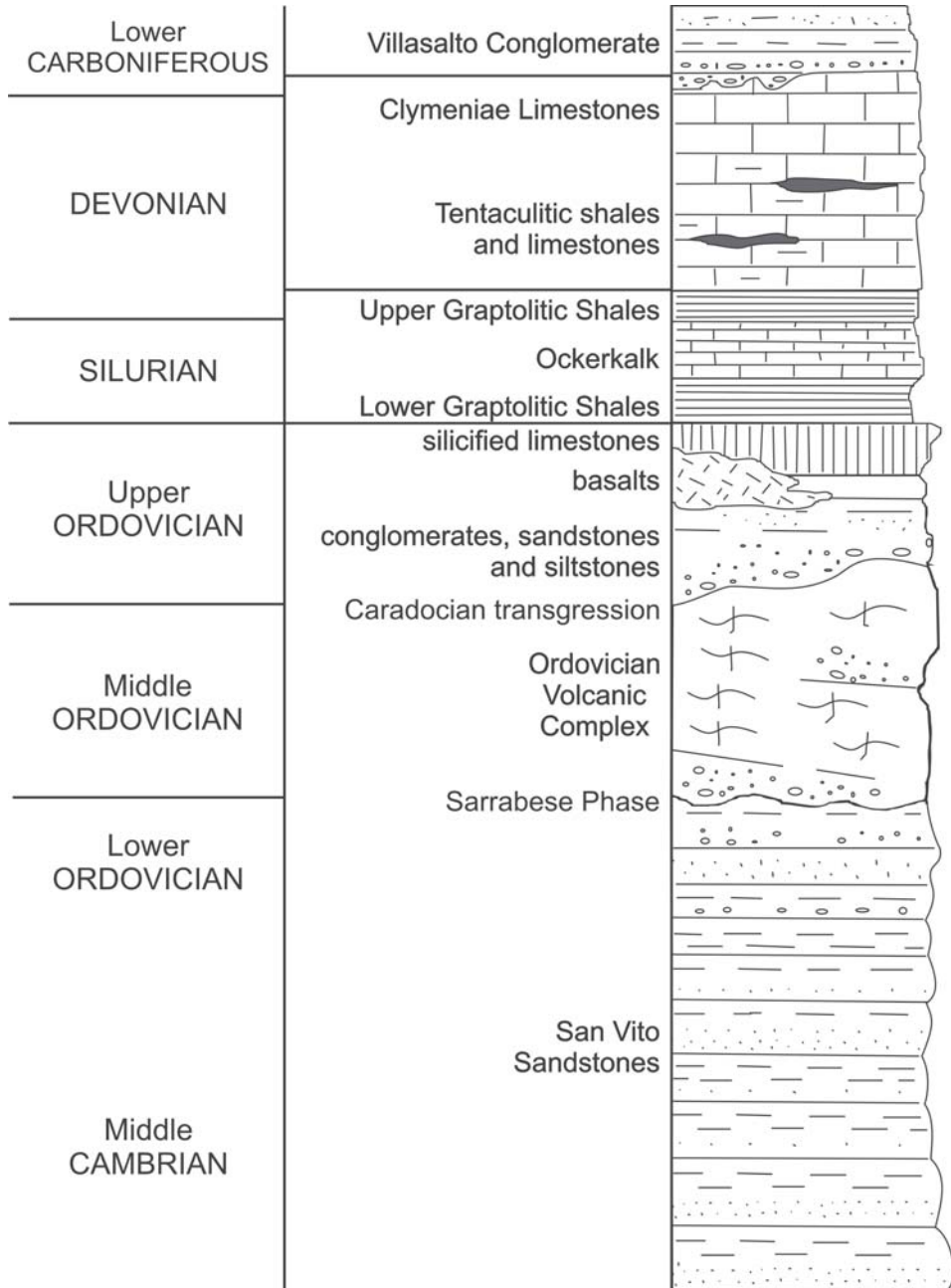


Fig. 1 - Stratigraphical column not to scale of the Gerrei tectonic Unit (modified after Corradini et al., 2002).

carbonatic content were deposited (“Caradocian transgression”). The topmost calcareous beds, locally silicified, are constituted by echinoderm-or bryozoan packstones intercalated in fossiliferous mudstones. These limestones have been dated on the basis of conodonts as Late Ordovician (*Amorphognathus ordovicicus* Zone; Ferretti *et al.*, 1998a, b; Ferretti & Serpagli, 1999).

The Silurian and Lower Devonian are represented by the classical Thuringian facies triad (Jaeger, 1976): “Lower Graptolitic Shales”, “Ockerkalk” and “Upper Graptolitic Shales” respectively.

The Lower Graptolitic Shales (30-40 m) are silica-argillaceous and siltitic shales rich in carbon and pyrite (“alum slates”; Jaeger, 1977). Lydites (cherts) are interbedded in the

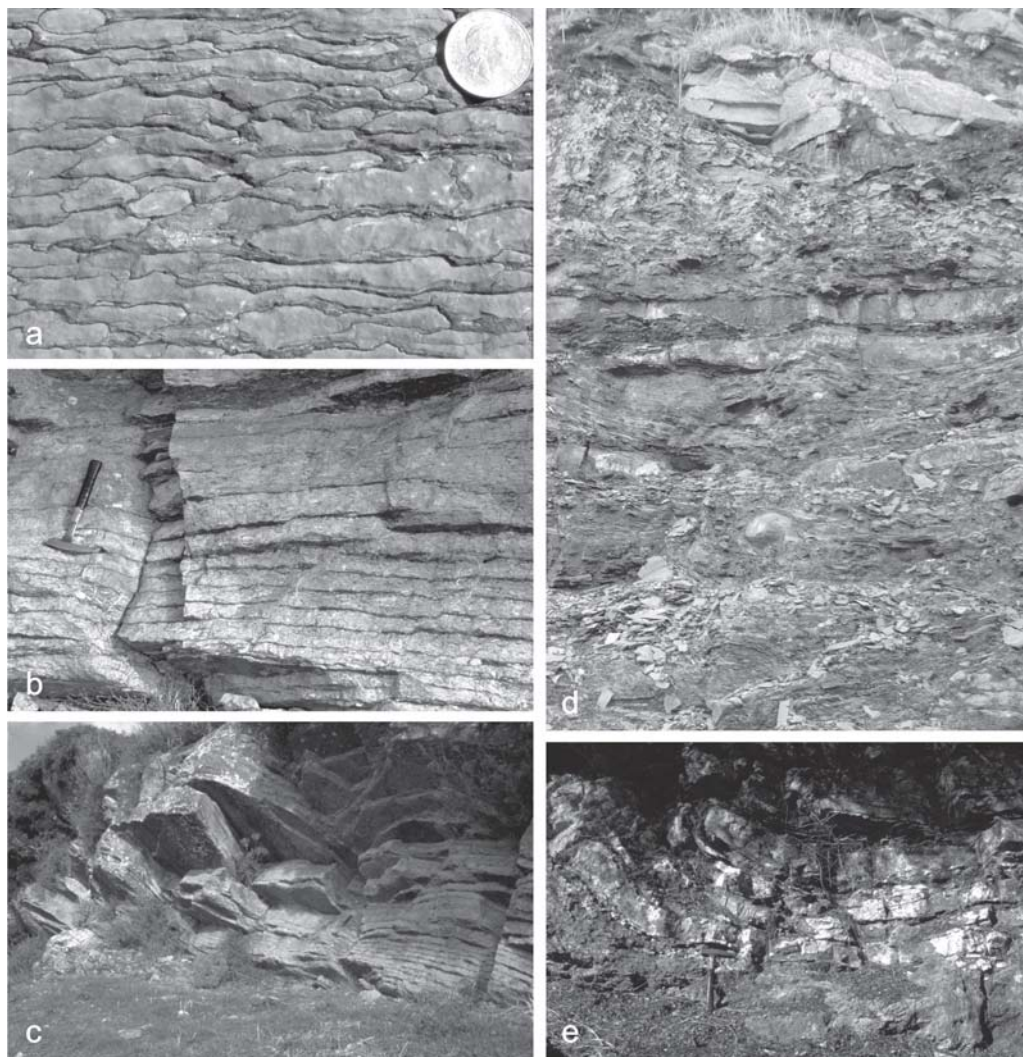


Fig. 2 - a) Typical flaser structure of the Ockerkalk limestone in the Silius section; b) Ockerkalk limestone near Silius; c) View of the Silius Cimitero section; d) The Lower Graptolitic Shales-Ockerkalk transition at Lantini Tunnel section; e) The Lower Graptolitic Shales-Ockerkalk boundary at the base of the Riu Murru de Callus section.

lower part as well as phosphorites occur in the middle-upper part of the unit. The age of the unit spans from Llandovery to earliest Ludlow, and a detailed biostratigraphy has been provided thanks to the abundant graptolite fauna (Meneghini, 1857; Gortani 1923a, b; Jaeger, 1977; Barca & Jaeger, 1990; Storch & Piras, 2009; Storch et al., 2009). The fossil association includes also chitinozoans, microplankton and sponge spiculae (Pittau & Del Rio, 2000; Pittau et al., 2002, 2006).

The Lower Graptolitic Shales grade to the overlying Ockerkalk within a few meters of interbedding shales and nodular limestones (Fig. 2d-e).

The Ockerkalk is an argillaceous limestone with a blue-grey colour, weathering into ochre (wherfrom the name), and a typical irregular flaser texture. It is about 25 m thick. The only macrofossils visible in the outcrops are crinoidal stems, rare cephalopods and loboliths. The lobolith level with bulbous holdfasts of giant pelagic scyphocrinoids, well-known from the Silurian-Devonian boundary beds of northern Gondwana, is found in the upper part of the Ockerkalk, at the base of the *detortus* conodont Zone. On a microscopic scale, ostracods, thin-shelled bivalves, brachiopods, gastropods, trilobite fragments, crinoids, small cephalopods and sponge spicules scattered in the matrix and only locally concentrated in millimetric shell-lags of disarticulated debris were also reported (Barca et al., 1995; Ferretti & Serpagli, 1996, Ferretti et al., 2009). Phyllocarids (mainly mandibles) were recovered from the conodont heavy-fraction. Trace fossils and very small solitary corals were reported by Jaeger (1977). The precise age location of the unit has been possible on the basis of a rich conodont fauna of Ludlow-Pridoli age (Fig. 3) spanning from the *hamata* to the *detortus* zones (Barca et al., 1995; Corradini & Olivieri, 1997; Corradini et al., 1998, 2000; Serpagli et al., 1998). The biostratigraphy of the unit has been recently updated by means of graphic correlations by Gouwy & Corradini (2006).




The boundary with the Upper Graptolitic Shales is never exposed, due to the strong tectonics; however biostratigraphical data from the two units allow to stress that the formation boundary is more or less coincident with the Silurian-Devonian boundary.

The Upper Graptolitic Shales (about 30 m) are exclusively composed by alum slates (Barca & Jaeger, 1990). Pelagic graptolites are the only abundant fossils found throughout the unit (Jaeger, 1976, 1977; Piras et al., 2009). Crinoidal stems, calyces and possible loboliths occur at the base of the unit. Rare *Ceratiocaris* (Jaeger, 1977) and bivalves (Barca & Jaeger, 1990) have been so far recorded. The lowermost Devonian graptolite biozones *uniformis*, *praehercynicus* and *hercynicus* were documented.

A few meters of poorly fossiliferous, thin nodular grey limestone may locally cover the shales, which otherwise grade to an alternation of dark and black phyllites and nodular limestones (Tentaculitic shales and limestones). On the basis of tentaculites (Alberti, 1963; Gessa, 1993) and rare conodonts (Bagnoli, 1980; Corradini et al., 2001; Gouwy & Corradini, 2007) the age of this strongly tectonised complex may be referred to the Early-Middle Devonian.

The succession continues with a thick sequence of massive limestone (Clymeniae Limestones) of Late Devonian-earliest Carboniferous age (Corradini et al., 2003; Corradini, 2007). Several dozen meters of sandstones and conglomerates (Conglomerato di Villasalto,

Fig. 3 - Stratigraphical distribution of the Silurian-lowermost Devonian units in southeastern Sardinia. Documented biozones are shaded (data from Sarrabus and Gerrei tectonic units are merged). Lower Graptolitic Shales, Sedda de S'Ortu, *turriculatus* Zone; Ockerkalk, Ponte Monte Lora, Pridoli; Upper Graptolitic Shales, Sa Ruinosa, *uniformis* Zone (modified after Corradini et al., 2002).

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

Upper Graptolitic Shales

Ockerkalk

Lower Graptolitic Shales

Auct.) are present above the Clymeniae Limestones. They represent the transition to the terrigenous sedimentation which terminates the pelagic succession of the Palaeozoic in southeastern Sardinia. Redeposited clasts and blocks of various Silurian and Devonian ages are recorded within this unit.

THE SILURIAN IN THE SARRABUS AND MEANA SARDO TECTONIC UNITS

The sequence described above for the Gerrei tectonic Unit is well comparable to those of the other units of the External Nappes. However, the following differences for the Silurian should be highlighted:

- The *Meana Sardo tectonic Unit* is the more internal of the External Nappes, and therefore the metamorphic degree is slightly higher. Black shales and nodular limestones, equivalent to the Lower Graptolitic Shales and to the Ockerkalk, are relatively abundant in some areas. However, fossils are quite rare, apart some crinoidal stems visible in some levels of the limestones. Unfortunately, up to now all attempts for a clear biostratigraphical definition of the unit were unsuccessful.

- In the *Sarrabus tectonic Unit* the sequence ends with the Lower Graptolitic Shales, which are here quite widespread. Lydites are more abundant than in the Gerrei. Graptolites fauna is quite rich and several biozones from Rhuddanian to Gorstian are documented in the Rio Ollastu area (Jaeger, 1977; Barca & Jaeger, 1990; Storch & Piras, 2009; Storch et al., 2009).

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