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THE "GERMANIC" TRIASSIC OF SARDINIA (ITALY): A STRATIGRAPHIC, DEPOSITIONAL AND PALAEOGEOGRAPHIC REVIEW

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Riassunto. La raccolta di nuovi dati stratigrafico-sedimentologici ha portato ad una revisione delle conoscenze sul ciclo di sedimentazione triassico in Sardegna. I più importanti affioramenti triassici sono stati rivisitati, reinterpretati e reinquadrati in un contesto organico. Viene proposto un quadro stratigrafico dettagliato ed omogeneo, composto da unità formali ed informali, viene precisato il significato paleoambientale di tali unità e viene fornito un più preciso inquadramento paleogeografico delle successioni interessate, evidenziando anche le analogie sia con il tipico Trias germanico dell'Europa centrale che con la biofacies sefardica mediotriassica dell'Europa occidentale e dell'Africa settentrionale.

Le unità litostratigrafiche basali, prevalentemente silicoclastiche e discordanti sul basamento Paleozoico, sono assimilabili all'associazione di facies "Buntsandstein". La loro datazione indica un'età generalmente anisica. Il loro ambiente di sedimentazione è compreso fra il continentale-transizionale di elevata energia sino alla piana alluvionale gradualmente trasgredita da un mare epicontinentale.

Al di sopra si passa ai complessi carbonatici dell'associazione di facies "Muschelkalk", da dolomitici alla base a generalmente calcarei alla sommità. La datazione di tali complessi è riferibile al Ladinico. Gli ambienti deposizionali ipotizzati sono riferibili ad una rampa carbonatica suddivisibile in vari subambienti ed inquadrabile nell'ambito di un ciclo trasgressivo-regressivo.

Le rare successioni triassiche superiori dell'isola indicano l'esistenza durante questo periodo di condizioni deposizionali differenziate fra nord e sud. A sud gli ambienti deposizionali sono ancora di piattaforma carbonatica, con subambienti lagunari o marini marginali, mentre a nord sono rappresentati da facies evaporitico-silicoclastico-carbonatiche di ambienti fra paralico-continentali e lagunari ristretti, inferiormente molto simili al "Keuper" germanico. Le evidenze rinvenute rendono plausibile l'ipotesi dell'appartenenza delle successioni triassiche superiori della Sardegna meridionale ad un contesto ambientale di tipo transizionale, in posizione intermedia fra le successioni ad affinità alpino-tetidea ed il Trias germanico propriamente detto.

In ultimo, è stato eseguito un tentativo di correlazione con i cicli eustatici del Trias medio-superiore.

Abstract. The collection of new lithostratigraphical and sedimentological data has allowed to re-examine the Triassic sedimentation cycle in Sardinia. The most important outcrops have been revisited and their general setting reinterpreted. A detailed and homogeneous depositional, palaeoenvironmental and stratigraphic picture is proposed, pointing to the analogies with both the typical Germanic Triassic of Central Europe, and the Middle Triassic Sephardic domain of Western Europe and North Africa.

The lower, essentially siliciclastic, lithostratigraphic units, resting discordantly on the Hercynian Palaeozoic basement, resemble the "Buntsandstein" facies association. They are generally of Anisian age. Their depositional environments range from high-energy continental to transitional environments to the floodplain, where a shallow, epicontinental sea gradually transgressed.

Overlaying these are the carbonate units of the "Muschelkalk" facies association. They are generally dolomitic at the bottom passing to calcareous at the top. These deposits, generally of Ladinian age, formed in the various subenvironments of a carbonate ramp.

The few Upper Triassic successions in Sardinia point to the existence, during this period, of diverse depositional conditions in the North (Nurra) and South (Sulcis) of the island. In southern Sardinia, lagoon to shallow sea carbonate shelf deposition predominates, with minor amounts of evaporites and siliciclastics. By contrast, in Northern Sardinia mixed evaporitic-siliciclastic-carbonate facies of paralic-continental (mudflat), locally restricted lagoonal environments, were deposited. The latter are very similar to the classic Germanic "Keuper" facies. These data suggest that the Upper Triassic successions in Southern Sardinia can be set in a transitional environmental context between the open Alpine-Tethyan domain and the Germanic Triassic proper.

An attempt has been made to correlate these successions with the Middle to Late Triassic eustatic cycles.

Introduction

The Triassic successions in Sardinia have long been recognised (Bornemann 1881; Lovisato 1884, 1896; Oosterban 1936; Vardabasso 1959, 1966; Damiani & Gandin 1973a,b,c; Gandin, 1977, 1978a,b). However, our research group has conducted studies aimed at completing the lithostratigraphic setting of the outcropping depositional sequences.

Over the last few years we have devoted a major effort to the description and sedimentological interpretation of Triassic lithostratigraphic units, so as to gain a better knowledge of the depositional environments and their relationships (Barca et al. 1995b,c; Barca & Costamagna 1997a,b; Barca et al. 1997; Costamagna 1998, 2000; Costamagna et al. 2000).

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Fig. 1 - Location of main Triassic outcrops in Sardinia. Legend - 1: Scivu-Is Arenas; 2: Campumari; 3: Porto Pino; 4: Escalaplano; 5: Orroli; 6: Monte Maiore; 7: Punta del Lavatoio; 8: Ghisciera Mala; 9: Cala Viola; 10: Monte Santa Giusta; 11: Monte Corredda; 12: Erula.

In addition to new stratigraphical and sedimentological data, we have also attempted to apply to the Sardinian Triassic, the "Germanic" Triassic depositional model (Aigner 1984, 1985), based on a Middle Triassic carbonate homoclinal ramp. This sedimentary model has also been applied to the depositional context of the Triassic carbonates of Cataluña (Calvet & Tucker, 1988)

Geographic setting

Triassic outcrops are found throughout Sardinia (Fig. 1), with the exception of the northeastern part of the island.

Usually, the outcrops are limited in extension and thickness. The most complete succession, about 300 m thick, was found in the Cugiareddu borehole (Pomesano Cherchi 1968), in the northwest (Nurra), and begins with "red beds", (probably of Permian age), unconformably overlaying the Hercynian basement (Gasperi & Gelmini 1979; Cassinis et al. 1996b). The "red beds" are in turn overlain by dolostones and limestones ("Muschelkalk") and then by claystones, gypsum and subordinate dolostones ("Keuper", attributed to the Carnian on the basis of the microflora, Pittau & Del Rio 1980).

In other areas of the island, the Triassic outcrops are not so frequent and nowhere they are complete. They consist either of the lower part of the succession, ranging from the "Buntsandstein" facies group to the "Muschelkalk" facies group (Scivu-Is Arenas: Damiani & Gandin 1973c; Barca et al. 1995b; Barca & Costamagna 1997b; Costamagna 1998. Campumari: Cocozza & Gandin, 1976; Barca & Costamagna 1997b; Costamagna 1998. Monte Maiore: Damiani & Gandin 1973a,b; Barca et al. 1997; Costamagna 1998; Costamagna et al. 2000), or, of the upper part, ranging from the "Muschelkalk" to the "Keuper" facies group (Porto Pino: Barca & Costa-

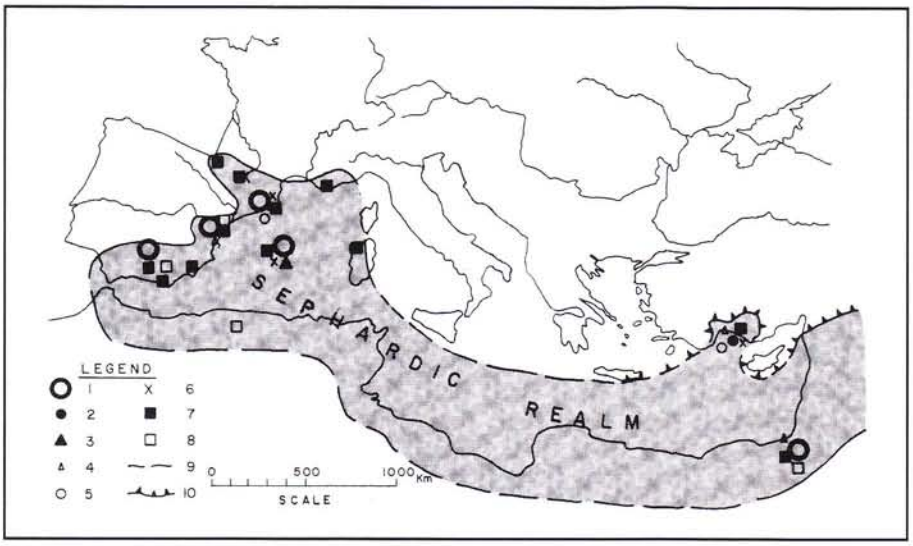


Fig. 2 - Sephardic Realm outcrops and late Ladinian Sepharadic faunal distribution (modified from Parnes et al., 1985); *1) Protrachyceras hispanicum; 2) P. archelaus; 3) P. pseudoarchelaus; 4) P. ladinum; 5) Iberites; 6) Daonella lommeli;* 7) Sepharadic conodont-assemblage; 8) Sepharadic bivalve-assemblage; 9) limits of the Sephardic realm; 10) boundary overthrusted.

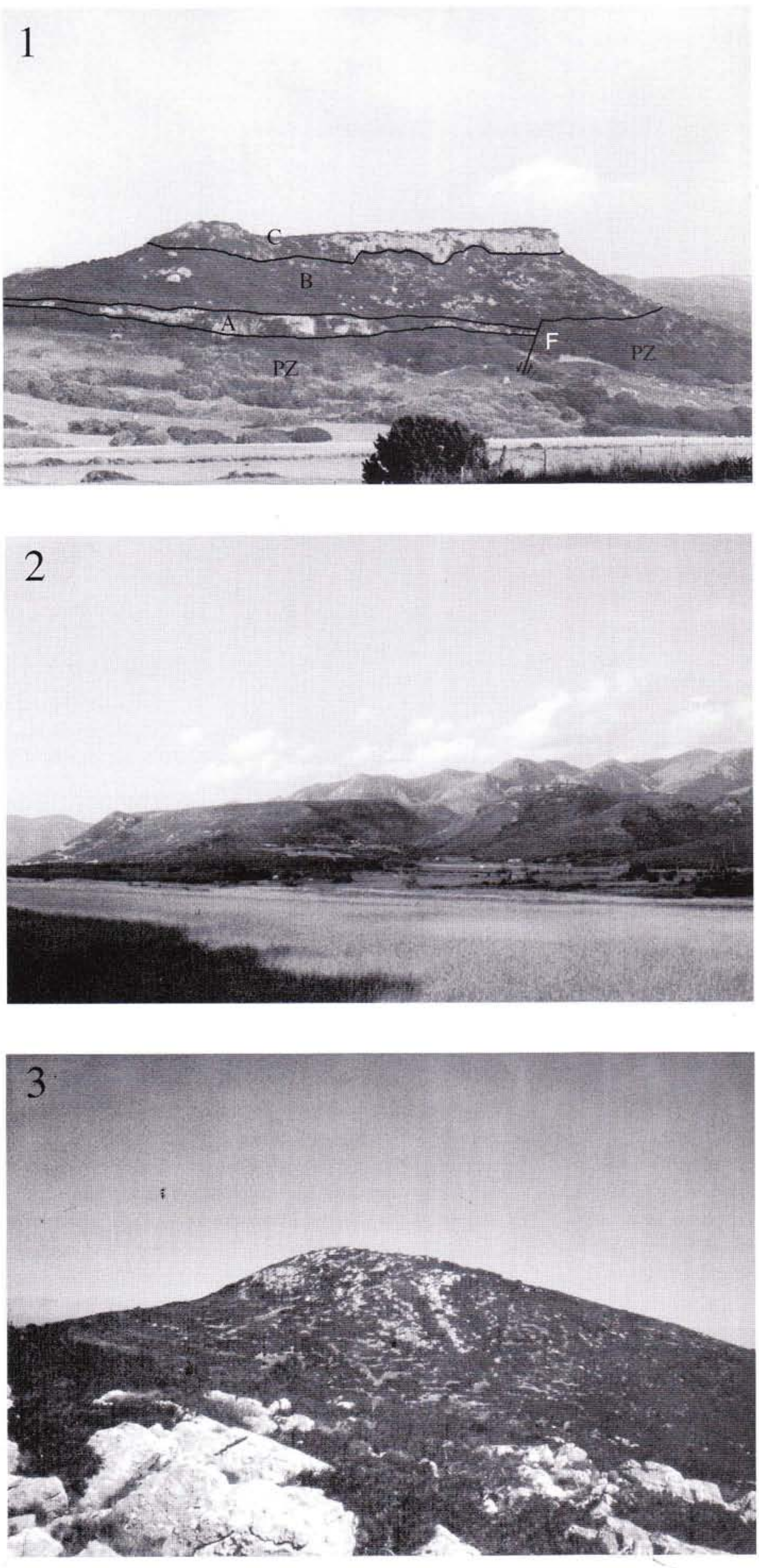


Fig. 3 - 1)- Scivu-Is Arenas, Arburese, Southwestern Sardinia: Punta Su Nuraxi hill. Here is located the Punta Su Nuraxi Fm. type section: at the base, overlying the Palaeozoic basement (PZ) the first ledge (A) consists of the Bruncu Pilloni Mb. of the Punta S'Arridelli Fm.; at the top, the last ledge (C) is composed of the blue limestones of the Bruncu Zippiri Mb. of the Punta Su Nuraxi Fm.. In between (B), the whitish limestones of the Case Pisano Mb. of the Punta Su Nuraxi Fm.. 2) - Campumari, Iglesiente, Southwestern Sardinia: a view of the Campumari highlands. In the background, the Palaeozoic reliefs. 3) - Monte Santa Giusta ridge, Nurra, Northwestern Sardinia: overview.

magna 1997a; Costamagna 1998; 2000). Average thickness is around 40-60 m; only in the southwesternmost area (Porto Pino) is the Triassic succession more than 120 m thick.

"Germanic" nature of the Sardinian Triassic

The affinity of the Triassic succession of Sardinia with those of the "Germanic" basin has long been well-established (Bornemann 1881; Tornquist 1902; Oosterban 1936). The typical tripartition of the sequence ("Buntsandstein", "Muschelkalk" and "Keuper" facies), the resemblance with the classic outcrop zones of the "Germanic" Triassic, together with evidence of a restricted environment and of the presence of evaporites enhance the possibility of correlation.

Nevertheless, the attribution of the Sardinian Triassic to the "Germanic" Sephardic biofacies domain rather than to the German domain claimed by Hirsch (1971; 1972; 1977) warranted further investigation. Based on faunistic features (Fig. 2), Hirsch (1971, 1972, 1977) established a precise distinction between various "Germanic" Triassic domains hypothesizing that the Corsica-Sardinia block belonged to the "Sephardic" biofacies domain, more precisely to the Sardo-Provençal subdomain. This hypothesis was substantiated by palaeontological and palaeogeographical data, such as the close affinities between the conodont assemblages of Provence/Sardinia and Iberian and Israeli assemblages containing *Tardogondolella (Epigondolella) mungoensis* (Hirsch 1972). Hirsch (pers.com.) still maintains that the faunal taxa of the Middle Triassic Sardinian carbonate platform (especially bivalves, ammonoids and, as stated before, conodonts) exhibit at a specific level close affinity with the Sephardic taxa. The separation and drifting of the Corsica-Sardinia block from the European craton took place after the Aquitanian (Orsini et al. 1980). According to Hirsch, the Sardo-Provençal subfacies could be a transitional palaeontological domain between a true "Sephardic" and a possibly "Tethyan" domain.

In this paper new data on the lithological, sedimentological and palaeogeographic evolution have been produced to corroborate the hypothesis of a gradual transition, in the depositional environment of Sardinian between the "Germanic" and "Tethyan" Triassic domains.

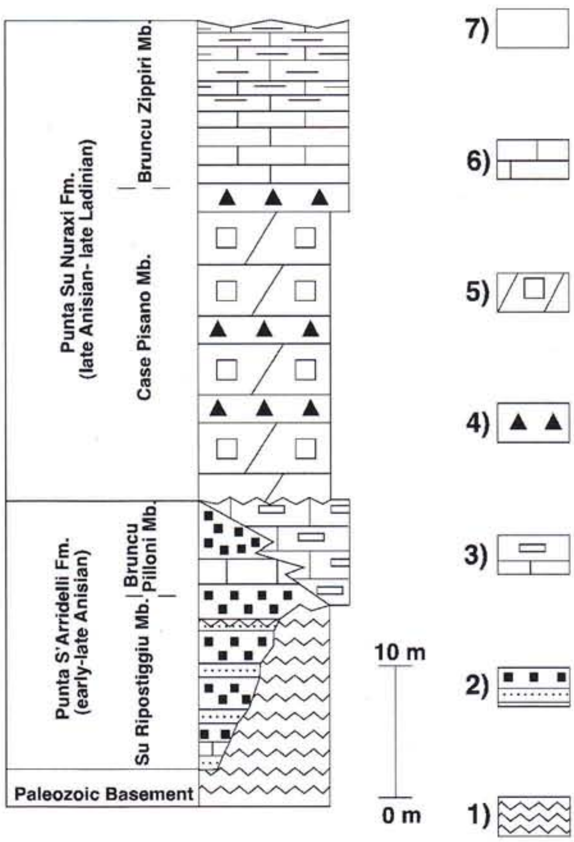


Fig. 4 - Scivu-Is Arenas (Arburese) (loc.1 in Fig.1), Middle Triassic succession. Legend - 1: Palaeozoic red-purple slates; 2: Conglomerates and conglomeratic sandstones; 3: Massive, cavernous dedolostones; 4: Collapse breccias; 5: Whitish, cavernous limestones; 6: Grey limestones; 7: Marly, bioturbated limestones.

Sardinian Triassic successions

The most important Sardinian Triassic successions are analysed in detail. They will be considered on the basis of their geographic location: SW Sardinia (Arburese, Iglesiente and Sulcis), SE Sardinia (Sarcidano, Gerrei) and NW Sardinia (Nurra).

Southwest Sardinia (Arburese, Iglesiente and Sulcis areas)

Arburese: Scivu-Is Arenas succession

The Triassic rocks in the Scivu-Is Arenas area (loc.1 in Fig. 1; Fig. 3.1) had already been described by other workers (Bornemann 1881; Damiani & Gandin 1973c; Chabrier & Mascle 1975) who merely distinguished among the various outcropping lithologies.

We have measured several sections of the Triassic succession in this area (Fig. 4). At Punta Su Nuraxi and Punta S'Arridelli detailed observations allowed to establish two new formations (Barca et al. 1995b): the Punta S'Arridelli Fm. and the Punta Su Nuraxi Fm.

Punta S'Arridelli Formation

The Punta S'Arridelli Fm., a transgressive (sensu Busson 1982) lithostratigraphic unit, rests disconformably on the Palaeozoic basement. This unit consists of a lower Su Ripostiggiu Mb. and an upper Bruncu Pilloni Mb.

The Su Ripostiggiu Mb. is formed of a fining-upward mixed sequence comprising reddish continental para- and orthoconglomerates and coarse sandstones, with few thin intercalations of calcitized carbonate layers gradually increasing upwards. Clasts consist of subrounded to subangular quartz grains, basement fragments and volcanic detritus, the latter probably originating from the outcropping Permian volcanic complex of Punta Acqua Durci (Barca et al. 1995c). Small outcrops of Permian-?Carboniferous sedimentary deposits are located about 2 km northwards (Tuppa Niedda siliciclastic sequence; Barca et al. 1995b), but they never come into direct contact with the Triassic successions. This member, where present, has varying thickness of up to 20 m. Maximum thickness has been measured at Punta S'Arridelli.

The Bruncu Pilloni Mb., a massive dedolomitized, locally cavernous, limestone, calcitized in its upper part, contains siliceous pseudomorphs after evaporites (producing a "chickenwire" structure locally) and scattered levels of dissolution-collapse breccias. The former

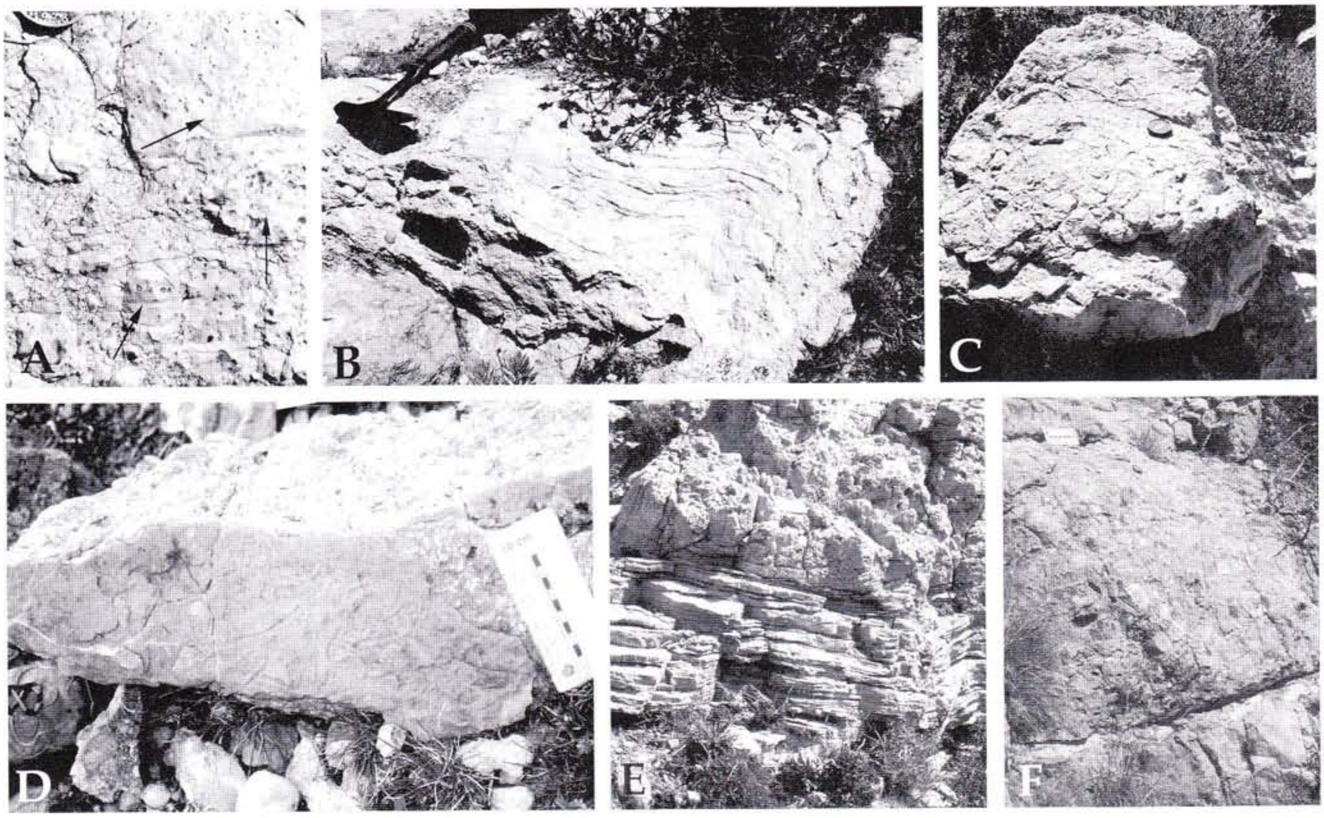


Fig. 5 - A) - Punta Su Nuraxi (Scivu-Is Arenas, Arburese), Punta Su Nuraxi Fm.: close-up of a collapse breccia with clasts containing evaporitic molds (arrows) in the Case Pisano Mb.: coin size 1.8 cm; B) - Punta Su Nuraxi (Scivu-Is Arenas, Arburese), Punta Su Nuraxi Fm.: folded carbonate layers due to evaporites early diagenesis in the Case Pisano Mb.. C) - Punta de Su Fenu (Scivu-Is Arenas, Arburese), Punta Su Nuraxi Fm.: mud-cracks in the Case Pisano Mb.. D) Funtanamare (Campumari, Iglesiente), Riu Is Corras Formation: bioturbation (*Palaeophycus* Sp.) in a reddish arenaceous siltite horizon sample. E) - Grifoneddu de S'Acqua stratigraphic section (Campumari, Iglesiente): Campumari Fm.: sudden passage between the Su Passu Malu Mb. laminated marly dolostones and the Grifoneddu de S'Acqua Mb. collapse breccia horizon. F) Rio Is Corras, Rio is Corras Formation conglomerate levels.

dolomitized nature of this carbonate rock is documented by calcitic pseudomorphosis on dolomitic crystals texture. It overlies the Su Ripostiggiu Mb., and is the lateral equivalent of its upper part. Locally angular clasts of quartz and lydite also occur. Occasionally the Bruncu Pilloni Mb. rests directly on the deformed Palaeozoic basement. The thickness of this member ranges from 1 to 7 m. Maximum thickness has been measured at Punta Su Nuraxi.

The age of the Punta S'Arridelli Fm. is partly controversial: the top is confined to an earlier age than late Anisian (Pelsonian/Illyrian) by a slightly unconformable mudstone well-dated through a rich palynological association (Barca et al. 1995b); however the base could not be dated. Based on facies considerations, an (early? to late) Anisian age could be tentatively suggested for the entire succession. The total thickness of the Punta S'Arridelli Fm. varies up to 20 m.

Punta Su Nuraxi Formation:

The Punta Su Nuraxi Fm., separated from the Punta S'Arridelli Fm. by a slight angular unconformity, is clearly distinguished from the latter by its lithological and sedimentological features and its overall lighter colour.

The Punta su Nuraxi Fm. is divided into the lower Case Pisano Mb. and the upper Bruncu Zippiri Mb..

The base of the Case Pisano Mb. begins with dark marly mudstones, passing laterally to a calichified palaeosoil which, together with a slight angular unconformity, indicates a brief hiatus in sedimentation and the subsequent progressive rise of the relative sea level.

The succession continues with one metre-thick whitish, massive, cavernous calcareous mudstones, with frequent siliceous pseudomorphs of evaporitic minerals, "molds" of sulphates and halite (Fig. 5A), alternated with whitish, well-layered calcarenites-calcilutites, containing parallel or, more rarely, cross laminations. Commonly, collapse-dissolution breccias composed of variously sized fragments (Fig. 5A) and metre-size folds occur (Fig. 5B) probably resulting from salt tectonics. Localized calcrete development phenomena are also present. Mud-cracks (Fig. 5C), low-angle cross laminations and scour marks related to rare storm deposits, have been also found.

This member is between 1 and 20 m thick. Maximum thickness has been measured at the Punta Su

Nuraxi section.

Overlaying the Case Pisano Mb. is the Bruncu Zippiri Mb. The boundary is often marked by a thick (2 to 4 m) horizon of dissolution-collapse breccias. The first facies of this formation is represented by a blue-grey limestone with rare reddish intercalations (bioclastic grainstones-packstones), locally showing cross, wavy and planar laminations, and containing bivalves, ostracodes, echinoderms, foraminifers and possibly algae. This facies passes rapidly first to massive calcarenite-calcilutite (packstones to wackestones), and finally to grey to grey-reddish marly, locally nodular, limestones (wackestones to mudstones). In its lower part the Bruncu Zippiri Mb. shows rare evidence of storm beds eroding the substratum, while strongly bioturbated beds are contained in the upper part with trail prints previously defined as *Rhizocorallium jenense* Zenker (Bornemann 1881) and now classified as *Planolites* and *Palaeophycus tubularis* (Moore 1962; Uchman A., pers. com.). The member is around 15 m thick.

At the base of the Case Pisano Mb., a rich microflora assemblage was detected in the dark mudstone layer (Barca et al. 1995b). Here, the occurrence of a palynological association containing *Cristianisporites triangulatus* Antonescu, marker of the Pelsonian substage (Antonescu et al. 1976), correlatable with the "Mu 1" palynological phase of Brugman (1986), suggests a Pelsonian/Illyrian age (late Anisian) (Barca et al. 1995b).

The presence of *Costatoria goldfussi* Alberti in Zieten (sensu Marquez-Aliaga 1985) at the base of the Bruncu Zippiri Mb., close to the boundary with the Case Pisano Mb., in agreement with the biostratigraphic setting of the Sephardic Realm of the "Germanic" Province (Hirsch 1972, 1977; Marquez-Aliaga 1985; Marquez-Aliaga et al. 1986; Hirsch 1987; Hirsch et al. 1987; Hirsch 1991) to which the Corsica-Sardinia block belonged during the Triassic (Hirsch 1972, 1977, 1987), probably indicates that the topmost part of the Punta Su Nuraxi Fm. belongs to the lower to middle part of the Longobardian (late Ladinian), before salinity crisis took place in the latest Ladinian (Kozur 1974; Haq et al. 1988; Hirsch 1991; Aigner & Bachmann 1992; Hirsch 1994). Total thickness of the Punta Su Nuraxi Fm. attains about 35-40 m.

Some remarks about the Scivu-is Arenas Triassic succession

The Scivu-Is Arenas Triassic succession clearly represents the transgressive evolution (*sensu* Busson 1982, relatively to Punta S'Arridelli Fm.) of the Triassic sedimentation in this area. It also exhibits significant thickness and facies variations locally, corresponding to interfingering and partially diachronous environments. In fact, the Triassic marine transgression probably extended over an area that was not totally peneplaned or was contemporaneously affected by synsedimentary tectonics.

Note also the presence of a slight angular unconformity, marked by calcretes and dark mudstone levels, between the Punta S'Arridelli and Punta Su Nuraxi Fms. These data, associated with the presence of faults cutting the Punta S'Arridelli Fm. but not the overlying Punta Su Nuraxi Fm., seem to corroborate the hypothesis of an ephemeral emersion, possibly associated with an extensional tectonic phase during the late Anisian (Pelsonian/Illyrian).

Total thickness of the Scivu-Is Arenas Triassic succession attains about 50-60 m.

Iglesiente: Campumari succession

Riu is Corras Formation

The Campumari succession (Cocozza 1966; Cocozza & Gandin 1976; Barca & Costamagna 1997b; Costamagna 1998) (loc.2 in Fig. 1; Fig. 3.2), resting in angular unconformity on the Hercynian basement, is represented at the base by the Riu Is Corras Fm. (Barca & Costamagna 1997b). This consists of alternating beds of coarse, polygenic conglomerates (Fig. 5F) from grain- to matrix-supported (ortho- and paraconglomerates after Tucker 1996), with rare, thin and discontinuous horizons of reddish, locally bioturbated (*Palaeophycus* sp., Fig. 5D) siltites and fine sandstones and variously calichified dolostones and limestones, frequently showing nodular structures, with very rare intercalations of calichified sandstones (Fig. 6). The matrix is usually carbonate. The clasts, subangular to subrounded in shape, have a maximum diameter of 15 cm and their mean size does not change upwards. On the other hand, the kind of clasts varies gradually towards the top and laterally: as a representative example, at the base carbonate clasts are frequent (Cambrian and locally Siluro-Devonian clasts), gradually petering out upwards, where only quartz and siliciclastic metamorphic rocks clasts are observed. Conglomeratic layers, again rarely calichified, usually exhibit chaotic structures, although a rough graded bedding is not infrequent, while well-developed graded bedding and imbrications are very rare. When the conglomerate layers overlay carbonates, the boundary surfaces are eroded, whereas they remain undisturbed when the conglomerate layers are underlain by carbonates. In some cases in the carbonate layers it is possible to observe complete soil profiles with calcretes development phenomena gradually increasing towards the top of the sequences (Cocozza & Gandin 1976; Colacicchi & Gandin 1978a). In some calichified reddish layers specimens of characeae algae have been found.

The formation is transgressive (sedimentary transgression sensu Busson 1982) over the Hercynian basement irregularly crossed by erosion channels. The lateral relationships between the described rock types (conglomerates and carbonates) change rapidly. Never-

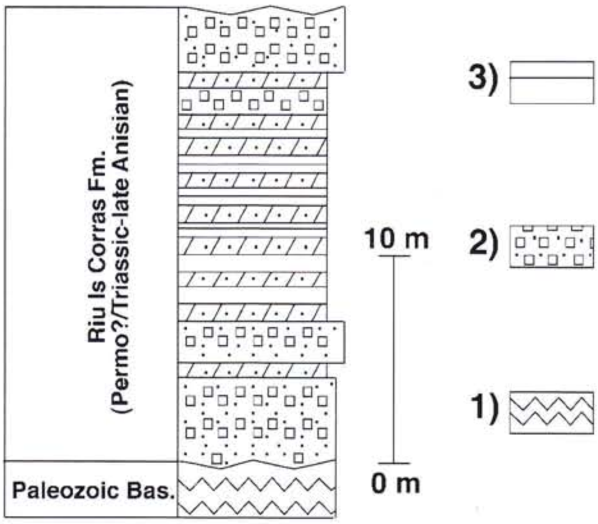


Fig.6 - Riu Is Corras (Campumari, Iglesiente) (loc.2 in Fig.1), Riu Is Corras Fm. type section (22 m). Legend - 1: Purple to greenish slates; 2: Polygenic conglomerates with rare sandstone layers; 3: Calcretes.

theless, comparison of several stratigraphic logs clearly indicates that the percentage of carbonate sediments in the succession increases what is now southwards.

The Riu Is Corras Fm. has a maximum thickness of 24 m on the west side of Riu Is Corras valley.

The age of this formation is controversial; the top of the formation, marked by a slight disconformity, is in fact overlain by the carbonates of the Campumari Fm. (Barca & Costamagna 1997b) characterized at the base by a discontinuous level of dark mudstones containing a late Anisian microflora (*Stellapollenites muelleri*; Pittau Demelia & Del Rio 1980). It is not possible to accurately date the base of the formation because of the absence of biostratigraphic markers. The presence, in the lower part, of a barite and chalcopyrite vein eroded by subsequent conglomeratic events of the upper part, suggests a correlation of the lower levels with the post-Hercynian Permian hydrothermalism (Fontana et al. 1982). The conglomeratic facies of the Riu Is Corras Fm. could be considered as a molassic Hercynian facies, aged between Permian and Middle Triassic, although several periods of erosion cannot be excluded. In addition, several similarities have been observed between the conglomerates in the lower part of this formation and the matrix-supported conglomerates at the top ("red beds" facies) of the Guardia Pisano Permian succession (Barca et al. 1992). In fact at least the lower part of the Guardia Pisano succession is Autunian in age (recent radiometric dating of zircons with U-Pb methods gave an age of 298±4 Ma; Pittau et al. 2002, in press), while the upper part ("red beds" facies) could be more recent (Late Permian?). So, the Riu Is Corras Fm. can only partially (upper part) and dubiously be attributed to the "Buntsandstein" facies group.

Campumari Formation:

The Riu Is Corras Fm. is overlain, through a disconformity surface, by a dolomitic unit, named Campumari Fm. (Barca & Costamagna 1997b), consisting of the Su Passu Malu Mb. and the Grifoneddu de S'Acqua Mb. (Barca & Costamagna 1997b).

At Grifoneddu de S'Acqua the Campumari Fm. (Fig. 7) has a maximum thickness of 27.2 m, the Su Passu Malu Mb. 13.5 m and the Grifoneddu de S'Acqua Mb. 13.7 m.

The Su Passu Malu Mb. consists initially of a thin marly-clayey greenish-blackish horizon, locally rich in plant debris. A level of dark, locally stromatolitic dolostones, some decimetres thick and containing numerous former sulphatic, now calcitic nodules with "chicken-wire structure" follows abruptly. These layers are overlain by yellowish, thinly stratified, laminated marly dolostones, rich in sulphate pseudomorphs and chert nodules. Locally, stromatolitic (rarely with fenestral fabric) facies also occur. The main feature of this rock type (and of all the Su Passu Malu Mb.) is the gradual increase of disturbance (folding) upwards, probably caused by gypsum tectonics (Colacicchi & Gandin 1978b). Near the upper boundary of the laminated dolostones the folds pass to chaotic structures, some similar to the better known "tepee". Rare mud-cracks and ripple marks structures have been also recognized.

The Grifoneddu de S'Acqua Mb. consists at its base of a 1 to 2 m thick collapse breccia horizon (Fig. 5E). The breccia is composed of angular clasts of blue-grey limestone and rarer prismatic yellowish marly-dolostone clasts embedded in a blue-grey carbonate matrix. Numerous chert nodules, up to a few decimetres in size, are present. Locally the breccia matrix contains pseudomorphs after sulphates. Finally grey, first massive and then well-stratified, dolostones follow. Some horizons, mainly those in the lower part of the member, are characterized by pseudomorphs after either gypsum or anhydrite and display planar and cross laminations while others (grainstones), higher up the succession, contain bioclasts (bivalves? echinoderms?). Grain size decreases upwards (wackestones) and close to the top of the succession (Riu Is Corras area) some layers show clear evidence of bioturbation (*Rhizocorallium jenense* Zenker; Cocozza & Gandin 1976). This bioturbated facies closes the dolomitic succession.

At the base of the Su Passu Malu Mb. the marly-clayey horizon, rich in plant debris, contains a palynomorph association of late Anisian age (*Stellapollenites muelleri*; Pittau Demelia & Del Rio 1980). Based on the palynological association, the bottom of the Campumari Fm. is attributed to the late Anisian, while the top is thought to be at least of early Ladinian age on account of the analogies with facies of other Triassic outcrops (Scivu-Is Arenas).

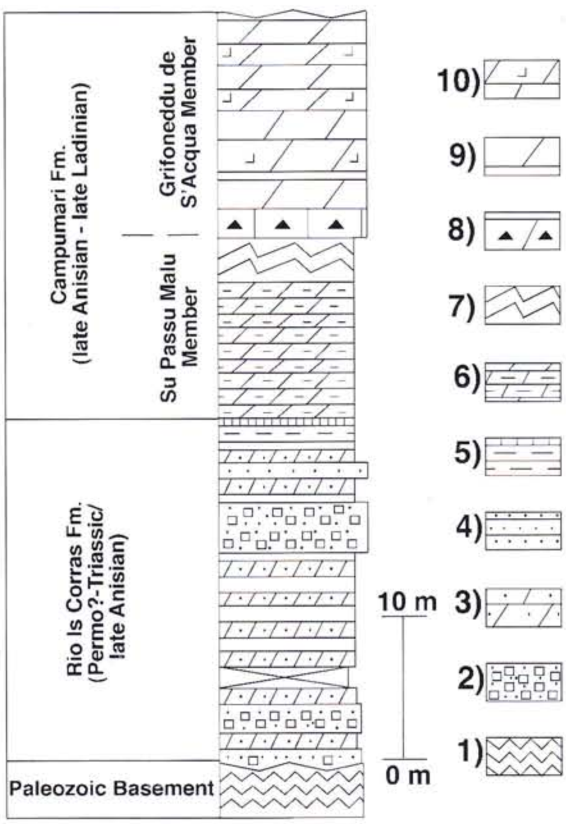


Fig.7 - Grifoneddu de S'Acqua (Campumari, Iglesiente) (loc.2 in fig.1), Campumari Fm. type section (26 m). Legend - 1: Purple to greenish slates; 2: Polygenic conglomerates with rare sandstone layers; 3: Calcretes; 4: Sandstones; 5: Green marly clays passing to black clayey dolostones; 6: Laminated clayey dolostones; 7: Clayey dolostones with folded carbonate layers due to evaporites early diagenesis, collapse dissolution breccias and tepee structures; 8: Collapse breccias; 9: Dolostones; 10: Dolostones with evaporitic pseudomorphs horizons.

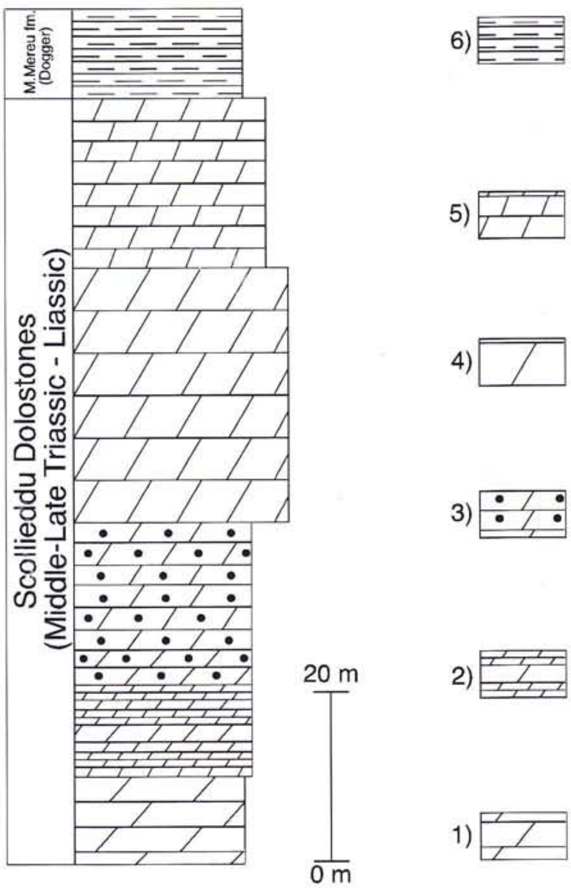


Fig.8 - Porto Pino (Sulcis) (loc.3 in Fig.1), Cala su Trigu Unit succession. Legend - 1: Fenestral bindstones, cross-laminated dolostones, intraclastic dolostones and cavernous dolostones; 2: Alternating beds of coarse to thin bioclastic dolostones with storm-layers; 3: Oolitic dolostones; 4: Calcareous dolostones; 5: Dolomitic limestones and dolostones; 6: Marly limestones.

Sulcis: Porto Pino Succession

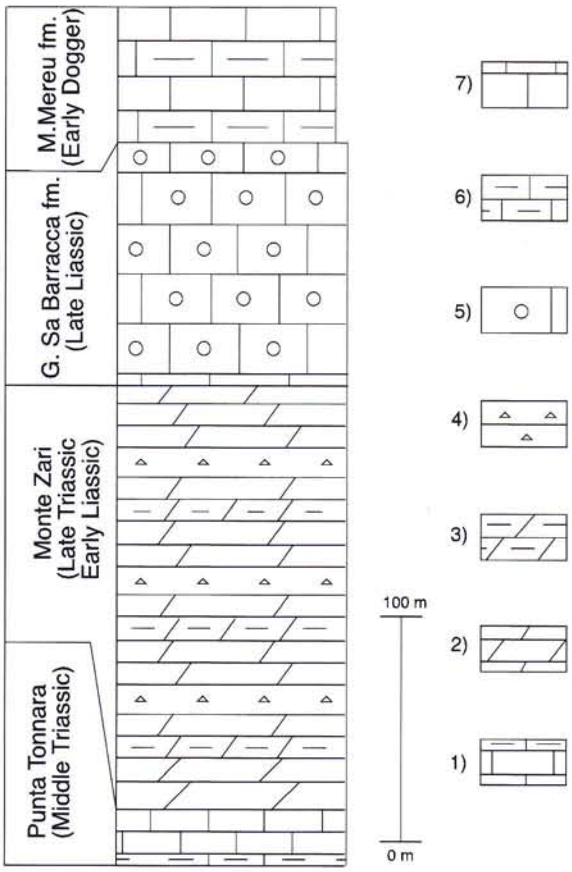
In the Porto Pino area (Martini et al. 1987; Barca & Costamagna 1997a; Costamagna 1998, 2000) (loc. 3 in Fig. 1) stratigraphical and sedimentological studies produced evidence of two distinct Mesozoic sequences, forming different structural units (Barca & Costamagna 1997a, 2000), affected by the "Alpine" Eocene tectonics (Pyrenean phase). This phase was the result of the transpressive to compressive movement of the Iberia plate against the European plate along the senestral North-Pyrenean fault. These tectonic units consist of Triassic to Jurassic sediments. These successions show well-distinct Triassic deposits, and contain different lithofacies that formed in distinct depositional environments.

Cala su Trigu Unit sequence

The westernmost Mesozoic sequence, corresponding to the "Cala Su Trigu Unit" (Barca & Costamagna 1997a) (Fig. 8), extends from the Middle?-Late Triassic to the Early Dogger; the Triassic to Liassic portion is composed at the base of the Scollieddu Dolostones Fm. (Barca & Costamagna 1997a; Costamagna 2000) concordantly overlain by the Middle Jurassic (Dogger) Medau Mereu Fm (Barca & Costamagna 1997a; Costamagna 2000).

Scollieddu Dolostones Formation

The Scollieddu Dolostones Fm. consists of grey, locally pinkish, frequently coarse dolostones passing gradually in the upper part to grey calcareous dolostones and dolomitic limestones. Rare red marly layers also occur. A variety of depositional textures and structures have been observed throughout the sequence; ooids, peloids, bioclasts, calcitic pseudomorphs after sulphates, cross and planar laminations and fenestral fabric are clearly visible. In the lower and, subordinately, middle part of the formation storm deposits are frequent and well-represented. Fossils (brachiopods, bivalves, corals,



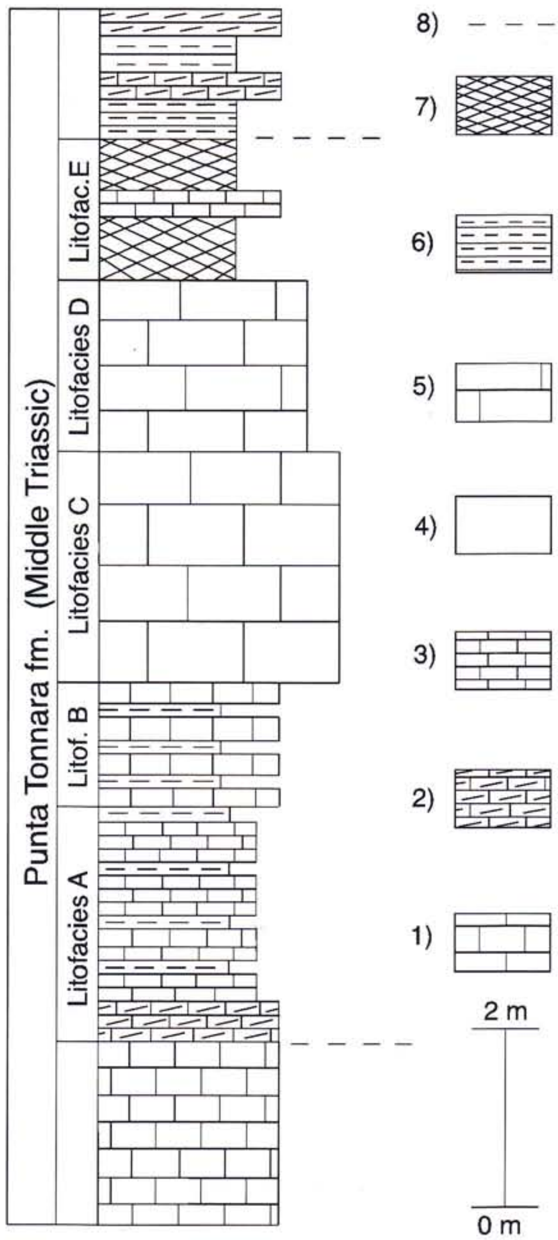


Fig. 10 - Porto Pino (Sulcis) (loc.3 in Fig.1), Guardia Sa Perda Unit succession. Legend - 1: Limestones and marly limestones; 2: Dolostones; 3: Marly dolostones; 4: Collapse breccias; 5: Bioclastic-oolitic limestones; 6: Limestones; 7: Marly limestones.

Fig. 11 - Pino (Sulcis) (loc.3 in Fig.1), Punta Tonnara section: Legend - 1: Dolomitic limestones; 2: Marly limestones; 3: Thinly stratified limestones; 4: Poorly stratified limestones; 5: Stratified limestones; 6: Marls; 7: Carbonatic-evaporitic crusts; 8) Erosion surfaces.

magna 2000), of Late Liassic-Early Dogger age.

Punta Tonnara Formation

At the base of the Guardia Sa Perda tectonic unit lies the Punta Tonnara Fm. (Barca & Costamagna 1997a; Costamagna 2000). This formation is composed of well-stratified, blue-grey limestones with marl intercalations, usually arranged in "shoaling upward" facies sequences a few tens of metres thick, defined by erosion surfaces. Scoured storm deposits are frequent at the base especially in the upper, shallowing part of each sequence. Bioclasts (bivalves, gastropods, echinoid spines, algal fragments, crinoids, ophiuroids, cephalopods?) and pseudomorphs after sulphates are concentrated especially at the base of the tempestites, frequently forming their basal lag.

The top of the formation is marked by an alternation of cavernous dolostones and dissolution-collapse breccias.

At Punta Tonnara the Punta Tonnara Fm. is characterized by a 14 m thick lithofacies sequence, composed from bottom to top (Fig. 11 and 12A) of:

Lithofacies A) - Dark-grey, locally foetid and laminated, frequently bioclastic, stratified calcilutites (wackestones with bivalves and foraminifera fragments) containing strongly bioturbated intercalations of marls and marly limestones (cylindrical horizontal reptation tracks: *Rhizocorallium* Auct.);

Lithofacies B) - Nodular marly bioturbated grey to dark-grey stratified limestones (wackestones);

Lithofacies C) - Blue, coarsely stratified limestones, with frequent internal lamination. Typical tempestites occur, characterized by rare thin basal lags followed by low- and high-angle cross-laminated calcare

Fig.9 - Porto Pino (Sulcis) (loc.3 in Fig.1), *Thecosmilia* sp. corals specimen in the Scollieddu Dolostones Fm..

algae, gastropods) are usually concentrated in a few horizons. Nevertheless, the strong and coarse dolomitization hinders their identification.

At Cala Su Trigu the Scollieddu Dolostones Fm. formed at the bottom first of about a 10 m thick sequence of dark, irregularly alternating fenestral-texture bindstones, cross-laminated dolostones, intraclastic dolostones, cavernous dolostones and dolostones containing calcitic molds of sulphates. Rare bioclastic horizons locally graded and clearly eroding the substrate (storm layers) occur. Several coral fragments (*Thecosmilia* sp., Ott, pers. com.), megalodontid bivalves and loxonematid gastropods are recognizable.

Towards the top coarsely stratified dolostones occur. These dolostones consists of alternating beds of massive, locally cavernous horizons containing calcitic molds of sulphates. Also well-graded, grey to dark-grey storm layers with scour marks occur at the base, mean thickness of each layer being 30-40 cm (Fig. 13A). The basal lag of the storm layers is formed prevalently of coral fragments. It is followed by cross laminated doloarenites gradually thinning and containing scattered, frequently fragmented, bivalves and gastropods. In the light of further recent observations and discussion we cannot entirely exclude the possibility that the latter horizons originated from repeated reworking of several high-energy episodes. Total thickness of this portion varies from 25 to 30 m.

As the intercalations of storm deposits decrease, grey, cross-laminated dolostones, 30 m thick, containing ooids and bioclasts (bivalves and brachiopods fragments), occur. Complete specimens (up to 70 x 40 cm in size) of branching corals (*Thecosmilia* sp.) have been found (Fig. 9). Upwards, calcareous dolostones, light grey in colour with little, well-rounded, 15-20 m thick quartz clasts are overlain by dark-grey, thickly bedded calcareous dolostones 15 m thick with siliceous nodular pseudomorphs after sulphates. In the latter layer the presence of *Vidalina* sp. (Liassic) has been evidenced.

The Scollieddu Dolostones Fm. continues through the Liassic with grey to dark-grey well stratified, dolomitic limestones and dolostones. Locally these contain fossiliferous horizons (brachiopods, bivalves) and discontinuous chert layers or nodules. The upper boundary of this formation is marked by the marls of the Medau Mereu Fm. (Barca & Costamagna 1997a; Costamagna 2000), dated to the Aalenian based on foraminifer content (*Ataxophragmidae; Lituolidae, Nautiloculina* cf. *oolithica*: pre-*Timidonella sarda* Aalenian after A. Cherchi, pers. comm.).

Estimated thickness of the Scollieddu Dolostones Fm. is 80-100 m.

The coexistence of megalodonts and *Thecosmilia* sp. corals in the lower part of this sequence confirms its stratigraphic attribution to the Upper Triassic, while the first appearance of *Vidalina* sp. (Sinemurian) in the thickly bedded calcareous dolostones indicates that the transition to the Liassic has already occurred, as evidenced by Faure & Peybernès (1983) in the Jurassic stratigraphic sections of Nurra region (NW Sardinia).

Guardia Sa Perda Unit sequence

Eastwards of the "Cala Su Trigu Unit", the "Guardia Sa Perda Unit" (Barca & Costamagna 1997a) crops out. This unit (Fig. 10) is formed of deposits from Middle Triassic to Early Dogger in age. The Middle Triassic to Early Liassic portion is represented at the base by the Punta Tonnara Fm. (Barca & Costamagna 1997a; Costamagna 2000), followed by the Monte Zari Fm. (Barca & Costamagna 1997a; Costamagna 2000). These are overlain by the Guardia sa Barracca Fm. and the Medau Mereu Fm. (Barca & Costamagna 1997a; Costa-

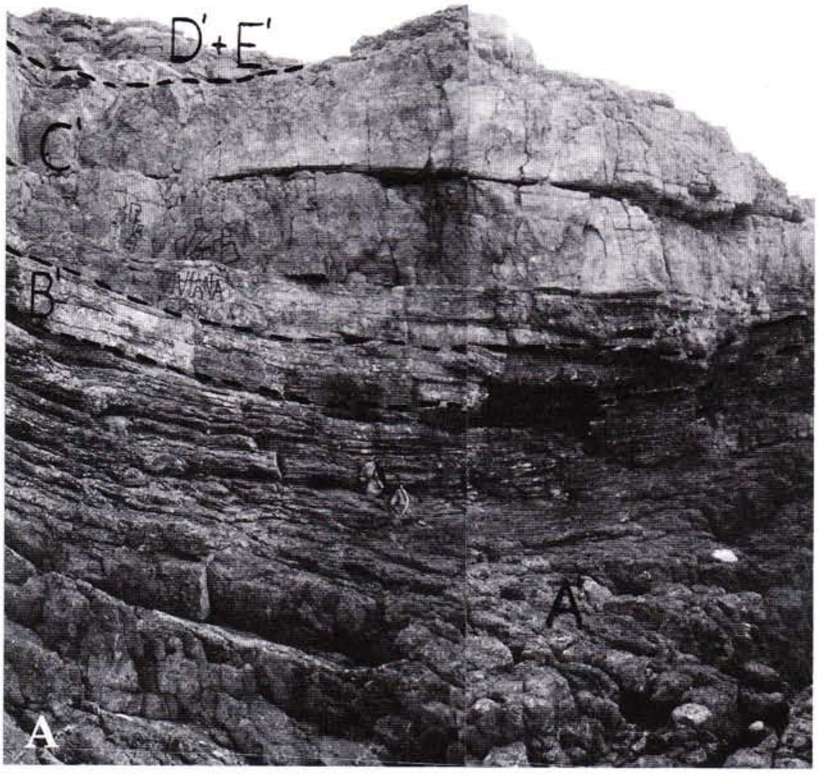


Fig. 12 - Porto Pino (Sulcis) (loc.3 in Fig.1), Punta Tonnara, Punta Tonnara Fm. (Porto Pino, Sulcis); Punta Tonnara W stratigraphic section: A: View of the Punta Tonnara W stratigraphic section (Porto Pino, Sulcis): from bottom to top are clearly visible the marly-calcareous alternating beds (lithofacies A' and B'), the massive calcareous layers (lithofacies C') and, partially, the carbonate-evaporitic layers (lithofacies D' and E') of the Punta Tonnara Fm.; B) Low angle cross laminations (HCS) in lithofacies C'.

nites (HCS; Fig. 12B) containing siliceous pseudomorphs after sulphates and bioclasts (from bioclastic wackestone to grainstone);

Lithofacies D) - Grey-blue, well-stratified limestones, arranged in alternating storm beds with variable features and thickness. Generally they consist of calcarenites composed of evaporitic crystals and bioclasts and containing HCS structures (bioclastic grainstones) with thin bioclastic-evaporitic(?) basal lags (rudstones) at the bottom. Rare thin layers of locally bioturbated calcilutites-calcarenites with planar lamination deriving from settling processes also occur;

Lithofacies E) - Cavernous, yellowish to reddish carbonate-evaporitic horizons ("Zellenkalk" Auct.), showing tepee structures (Fig. 13B), evaporitic folding and dissolution-collapse breccia horizons associated with evaporite diagenesis and, maybe, ephemeral emersion events.

In other sections of this formation the C facies can be replaced by oolitic, cross-laminated grainstones containing rare intraplasts ("plasticlasts", *sensu* Sanders, in Flügel, 1982).

Maximum thickness of this formation in outcrop, measured at the Monte Sarri section, is about 25 m.

The age of the Punta Tonnara Fm. is attributed to Middle-?Late Triassic based on the presence of *Agathammina* sp. foraminifera (Martini et al. 1987). Comparison and facies analogies with similar successions in Sardinia (Punta del Lavatoio: Gandin 1977; Scivu-Is Arenas: Barca et al. 1995b; Monte Maiore: Costamagna et al. 2000) with well dated palaeontological content suggests a late Ladinian age: the alternation of cavernous dolostones and dissolution-collapse breccias cropping at the top of the formation could be connected with the latest Ladinian-Ladinian/Carnian boundary salinity crisis.

Monte Zari Formation

The passage from the Punta Tonnara Fm. to the overlying Monte Zari Fm. (Barca & Costamagna 1997a; Costamagna 2000) is marked by a thick horizon of dissolution-collapse breccias and carbonate-evaporitic rock types (similar to "Cargneules" or "Rauchwacken" Auct.). Upwards this formation is composed of grey, monotonous dolostones containing rare layers of polychrome, locally gypsiferous, marls. The dolostones are usually well stratified and present a wide range of textural and structural arrangements (bindstones with fenestral texture; dissolution-collapse breccias; massive dolostones with casts deriving from dissolution of former evaporitic crystals; rare storm beds; rare oncolithic dolostones; oolitic, more rarely peloidal, grainstones with large scale cross lamination structures, Fig. 13C). Fossils and bioclasts are absent, except for algal mats and fragments thereof.

Relicts of evaporites such as molds in dolostones are found at the base or top of each depositional event. When the fragments are located at the base of the sequences, they are normally graded and lie along an erosional boundary (Fig.13D). Therefore it may be hypothesized that they originated from other more restricted areas of the platform (similar to "gypsum tempestites" described by Aigner & Bachmann 1989). On the contrary when evaporites occur at the top of the dolomitic sequences, they show inversely graded bedding structures, and lie beneath erosional surfaces. It is therefore possible to set them in a gradual lagoon evaporation cycle where the water level was not replenished during a single depositional episode. As such, in the absence of clear emersion evidence at the top, they could represent incomplete peritidal cycles.

The thickness of this formation measured at Monte Sarri section is 124 m.

The Monte Zari Fm. passes abruptly to the bioclastic-oolitic calcarenites of the Guardia sa Perda Fm., Late Liassic in age (Barca & Costamagna 1997a; Costamagna 2000). The Late Triassic-Early Liassic age of the Monte Zari Fm. is based on the stratigrafic position, taking into account the palaeontological data of the underlying (Punta Tonnara Fm., Middle to ?Late Triassic; Martini et al. 1987; Costamagna 2000) and overlying (Guardia Sa Perda Fm., Late Liassic; Costamagna 2000) formations.

Eastern Sardinia (Sarcidano - Gerrei area)

The Triassic of Eastern Sardinia (Damiani & Gandin 1973a,b,c; Pecorini 1974; Barca et al. 1997; Costamagna 1998; Costamagna et al. 2000) (loc. 4,5,6 in Fig. 1) consists of terrigenous sediments gradually passing upwards to carbonates. The thickness, facies architecture and variable age of the base measured in several stratigraphic sections, all testify a gradual transgression in the present-day W/NW direction on a peneplaned Hercynian continent, where, after the Hercynian orogenic climax only isolated lacustrine to red beds deposits of Permian age formed (S. Salvatore - Mulargia Lake basin: Pecorini 1974; Barca et al. 1995a; Cassinis et al. 1996a; Perdasdefogu basin: Cassinis et al. 1996a) localized in late-orogenic extensional basins. However, the

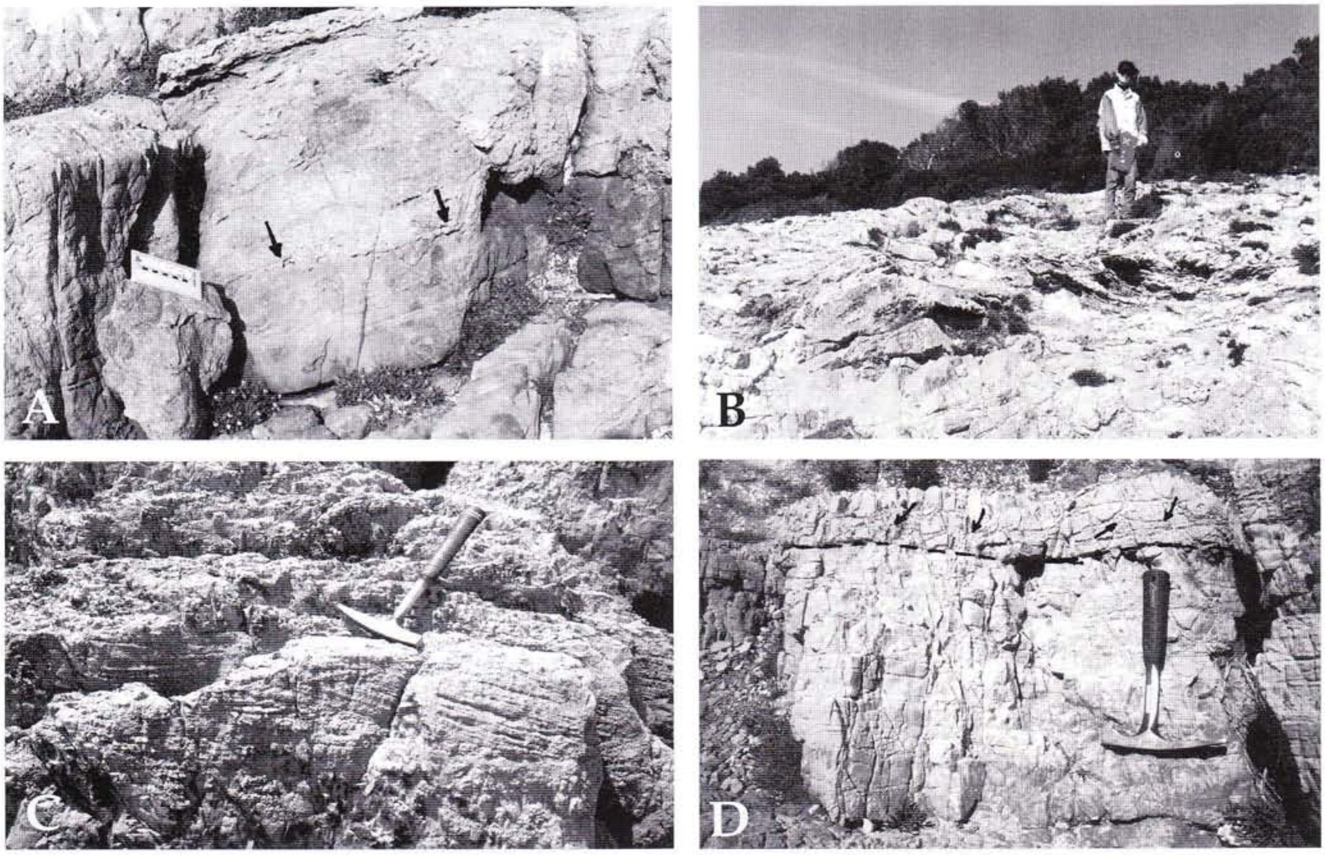


Fig. 13 - Porto Pino (Sulcis) (loc.3 in Fig.1): A) Cala su Trigu: Scollieddu Dolostones fm. (Porto Pino, Sulcis). Storm layers: the basal lag is composed of coral debris. The arrow marks the erosion surface; B) Punta Tonnara, Punta Tonnara fm. (Porto Pino, Sulcis); Punta Tonnara W stratigraphic section: tepee structures in lithofacies E'; C) - Punta Menga: Monte Zari fm. (Porto Pino, Sulcis). Oolitic layer with evident cross lamination; D) - Punta Sa Bua: Monte Zari fm. (Porto Pino, Sulcis). Dolostones with erosive surfaces and evaporitic molds (arrows).

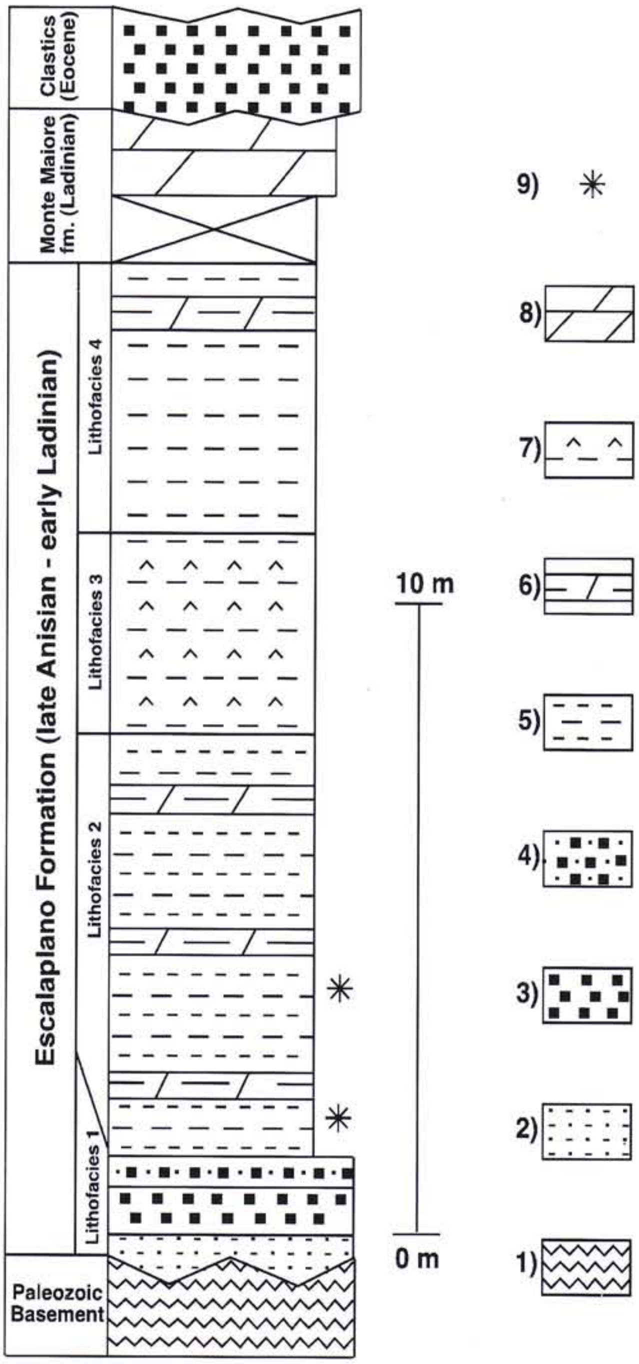


Fig.14 - Escalaplano (Gerrei, Eastern Sardinia) (loc.4 in Fig.1), Escalaplano Formation type section. Legend - 1: Reddish to greenish slates; 2: Siltites; 3: Conglomerates; 4: Sandstones and conglomerates; 5: Silts and clays; 6: Marls and rare arenaceous marls; 7: Silts, clays and evaporites; 8: Dolostones; 9: Palynomorph levels.

exact direction of the Triassic transgression is very difficult to establish, because of the faulting, uplift and consequent strong erosion of many areas. The post-Hercynian outcrops are commonly disrupted due to the strong extensional tectonics associated with repeated reactivation of the main Hercynian tectonic lines (Pasci 1997; Barca & Costamagna 1999).

The Triassic sedimentary cycle in Eastern Sardinia, comprised between Permian and Middle Jurassic-Early Cretaceous cycles, consists of two formations: the mainly siliciclastic Escalaplano Fm., and the carbonate Monte Maiore Fm.

Escalaplano Formation

The Escalaplano Fm. (Costamagna et al. 2000) from the bottom to the top consists of four lithofacies (Fig. 14):

Lithofacies 1) - Stratified, coarse matrix-supported, rarely clasts-supported conglomerates and sandstones, with frequent internal erosion surfaces. The lithologies are thicker in the depressions and channels cut in an irregular surface of the Palaeozoic basement often exhibiting calcretes development phenomena. Centimetre size, sub-rounded to sub-angular pebbles occur consisting of quartz grains and slates of basement source, and volcanic rocks from the Permian post-orogenic volcanics (Fontana et al. 1982; Cassinis et al. 1996a);

Lithofacies 2) - Cyclic alternating beds of dark grey to reddish, siltitic to clayey, thinly stratified sediments and yellowish marls (Fig. 15A), containing mud cracks, halite casts (Fig.15B), bioturbation and rare calcrete horizons. A few intercalations of wrinkled algal mats are also frequently found in the marls. In the easternmost outcrops of this lithofacies cross-laminated sandstone layers almost entirely replace marl intercalations. Dark clays horizons contain locally rich palynomorph associations (Pittau Demelia & Flaviani 1982b);

Lithofacies 3) - Cyclic alternating beds of black, subordinately reddish siltites and thinly stratified clays, and white-to-pink microcrystalline gypsum;

Lithofacies 4) - Dark-grey to black, subordinately reddish, thinly stratified silts and clays passing gradually to yellowish-greenish marly sediments testifying to the rapid passage to a carbonate sedimentation.

Maximum thickness of the Escalaplano Fm. measured at the Escalaplano village (loc. 4 in Fig. 1) is no more than 20 m.

In the lower black clay horizons, close to the boundary with the Palaeozoic basement, a rich palynological association has been found (Pittau & Flaviani 1982a,b; Costamagna et al. 2000). The data furnished show the age of the Escalaplano Fm. to be comprised between late Anisian and probable early Ladinian (*Cristianisporites triangulatus* is a marker of the *Balatonites balatonicus* Zone of Pelsonian Substage. - Antonescu et al. 1976).

The Escalaplano Fm. thins out progressively N/NW-wards. In the southeasternmost outcrops, the transition to the overlying carbonate formation varies from gradual to sharp. In the northwesternmost outcrops, where the Escalaplano Fm. peters out, the carbonate lithologies rest directly on the Palaeozoic basement, with only a limited terrigenous content formed of small, angular quartz clasts.

It is also interesting to note the variable composition of the carbonate intercalations in lithofacies (2) of the Escalaplano Fm. In fact, while the northwesternmost outcrops (Orroli- Sarcidano area) contain prevalently gypsum and dolomitic crystals, the southeasternmost ones (Escalaplano area) show wrinkled and fenestral algal mats, indicating a damper environment SE-wards.

Monte Maiore Formation

The carbonate Monte Maiore Fm. is only informally defined because of the lack of a continuous section. The best outcrops and the thickest sections (Fig. 16) are exposed at Monte Maiore (loc. 6 in Fig. 1), located on the northwestern edge of the Triassic outcrops of Eastern Sardinia.

The Monte Maiore Fm. consists of two members: the Yellow Dolostones Mb. at the bottom followed by the Blue Limestones Mb.

The Yellow Dolostones Mb. consists of massive to well-stratified yellow, locally yellowish to grey, dolostones. At the base, where the Monte Maiore Fm. rests directly on the Palaeozoic basement, they contain scattered terrigenous clasts (quartz, basement fragments). Where the Monte Maiore Fm. overlays the Escalaplano Fm., the terrigenous clastic fraction is absent. At Monte Maiore this member frequently consists at the base of matrix-supported conglomerates composed of subangular clasts derived from the Palaeozoic basement and quartz embedded in an abundant yellowish carbonate matrix. Upwards, it continues with dissolution-collapse breccia horizons, marly dolostones with folded carbonate layers due to evaporites early diagenesis, dolomitic horizons, containing several calcitic and siliceous pseudomorphs or molds after sulphates and scattered chert nodules, as well as dolomitic algal bindstones. Storm deposits (grainstones), with clasts consisting of reworked algal fragments (derived from cyanobacterial mats) and/or peloids frequently occur. Rare fossiliferous horizons rich in algal debris (dasycladacean algae, Fig. 15C) have also been found. No other fossils have been observed, apart from rare ostracods and bivalves (?) fragments.

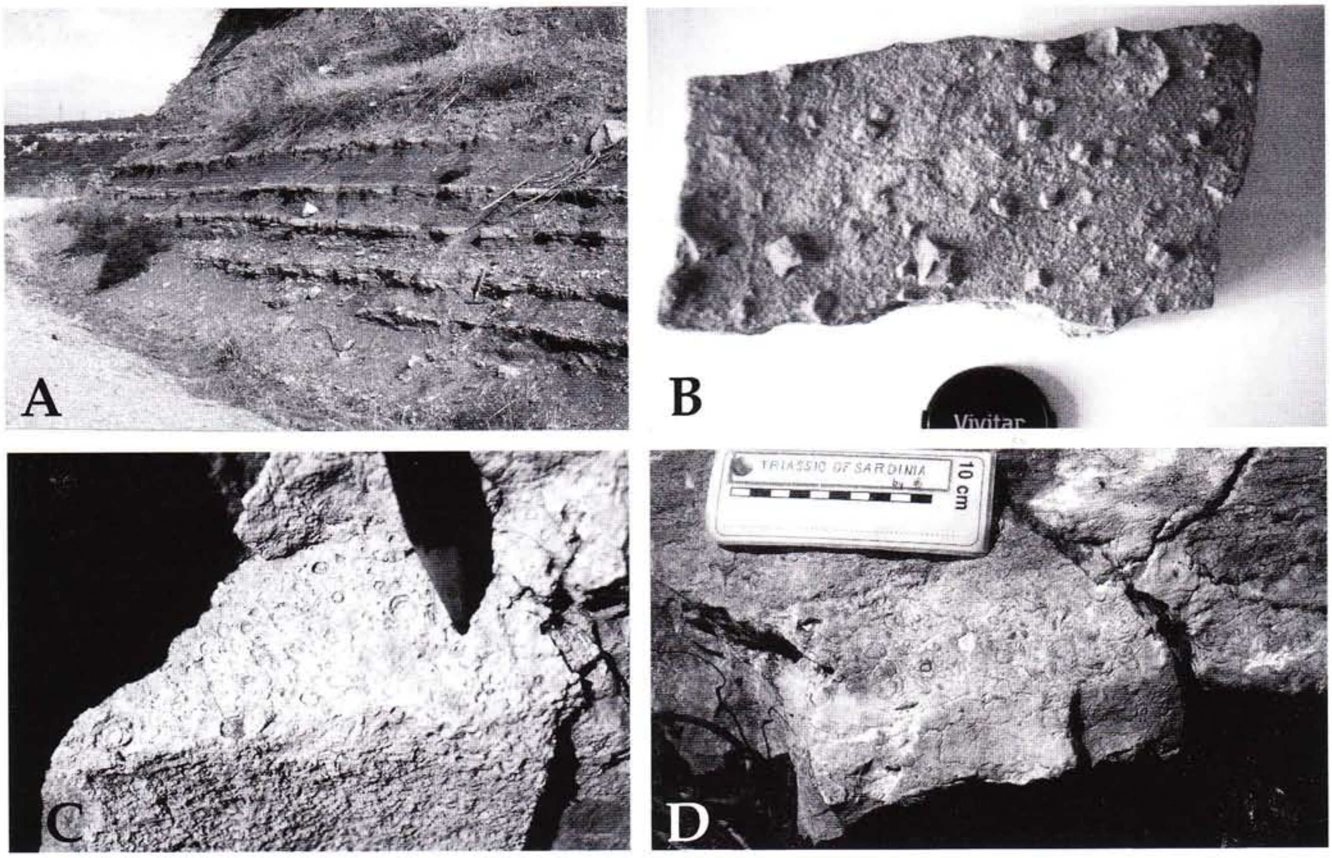


Fig.15 - A) Pran'e' Massa (Gerrei, Eastern Sardinia), Escalaplano Formation. Lithofacies B outcrop: cyclic alternations of marls and clays/siltitic clays are clearly visible; B) Arcu de is Fronestas (Gerrei, Eastern Sardinia), Escalaplano Formation. Lithofacies B: quartzose-felspatic sandstone with halite crystal molds on the lower surface. Lens cover 5 cm; C) Bruncu Geroni (Orroli, Gerrei, Eastern Sardinia), Monte Maiore Fm., Yellow Dolostones Mb.: dolostone bearing dasycladacean fragments; D) Monte Maiore (Sarcidano, Eastern Sardinia), Monte Maiore Fm., Blue Limestone Mb. Storm layer basal lag composed of *Costatoria goldfussi*.

The upper part of this member interfingers with the Blue Limestones mb.

The Yellow Dolostones Mb. varies laterally in thickness, but does not exceed 15 m.

The Blue Limestones Mb. usually lies on the yellow dolostones mb., but in some outcrops it rests directly on the Palaeozoic basement. It consists at the base of a thin layer of grey calcareous dolostones (oolitic to bioclastic, very rarely peloidal grainstones), followed by well-stratified, often laminated, blue-grey limestones made up of wackestones and subordinate grainstones, packstones and mudstones with peloids and bioclastic fragments (crinoids, foraminifers, gastropods, bivalves, ostracodes). Rare intraclasts also locally occur. The middle part contains intercalations a few metres thick of poorly outcropping marls and calcareous marls. At the top, pink dolostones (grainstones) occur, rich in algal debris and containing chert nodules and rare evaporitic remains. Limestones also frequently contain horizons and surfaces where evaporitic molds, quartz pseudomorphs of former sulphates and dissolution-collapse breccias are present.

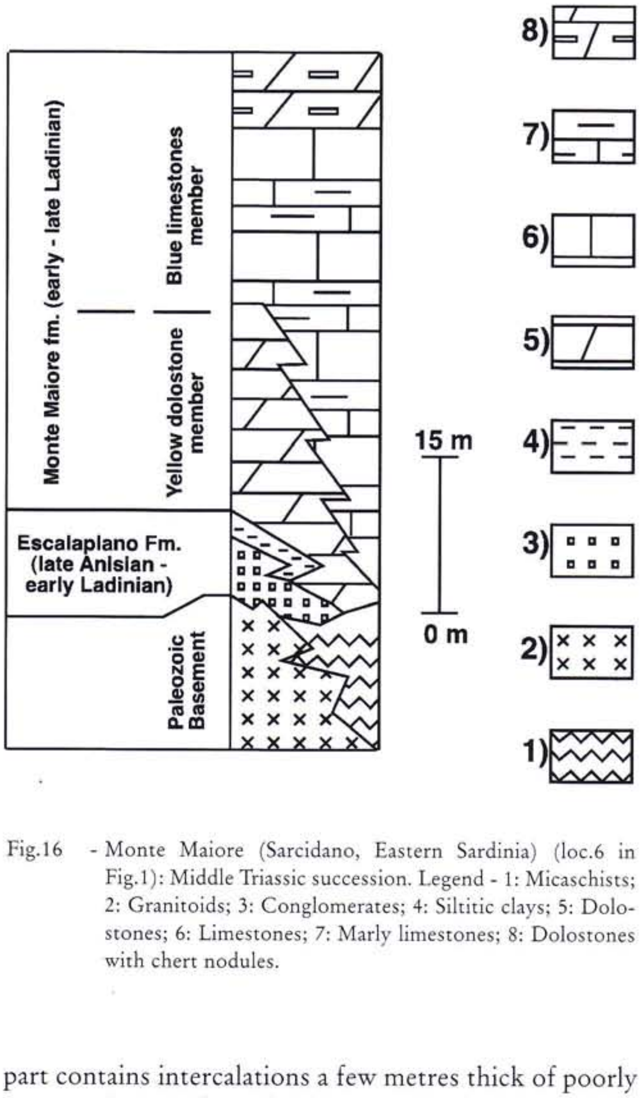


Fig.16 - Monte Maiore (Sarcidano, Eastern Sardinia) (loc.6 in Fig.1): Middle Triassic succession. Legend - 1: Micaschists; 2: Granitoids; 3: Conglomerates; 4: Siltitic clays; 5: Dolostones; 6: Limestones; 7: Marly limestones; 8: Dolostones with chert nodules.

Frequently the limestone layers display bioturbated calcilutites-calcarenites (*Rhizocorallium Auct.*- ichnogenera *Chondrites* and *Thalassinoides*, Damiani & Gandin 1973b) alternated with calcarenites with hummocky cross stratification structures (Fig. 17). Numerous fossils (Loxonematidae, *Costatoria goldfussi*) (Damiani & Gandin 1973a,b), scattered or concentrated in basal lags (Fig. 15D), are visible throughout the sequence in the storm beds.

This member is estimated to be 30 to 40 m thick.

Maximum thickness of the Monte Maiore Fm., measured roughly at Monte Maiore, and considering the interfingering of the members, is estimated at around 40-50 m.

The age of the Monte Maiore Fm. varies depending on the outcropping area, Based on the discovery of *Costatoria goldfussi* Alberti in Zieten (sensu Marquez Aliaga 1985) also close to the boundary with the Hercynian basement, the Monte Maiore Fm. at Monte Maiore has been dated by Costamagna et al. (2000) to the late Ladinian (probably middle part of Longobardian, before the salinity crisis of the latest Ladinian). The dasycladacean association (*Diplopora annulata, Diplopora annulata debilis, Macroporella* cf. *spectabilis, Solenopora* cf. *simionescui, Teutloporella peniculiformis, Teutloporella* cf. *nodosa*) does not contradict this age (Damiani & Gandin 1973b). In the southeastern area, not so well defined chronologically, the formation could probably be dated to the late Fassanian.

Some remarks on the Eastern Sardinia Triassic Succession

The upper part of the Escalaplano Fm., at least partially, probably interfingers with the lower part of the Monte Maiore Fm. In fact, in the easternmost Sardinian outcrops the base of the Triassic succession is composed of terrigenous deposits. NW-wards the Escalaplano Fm. gradually thins out and the Triassic sediments rest directly on the Palaeozoic basement with dolostones containing terrigenous clasts of the Yellow Dolostones Mb., or the lower dolomitic limestones of the Blue Limestones Mb. Moreover, at the village of Escalaplano the timing of the sedimentary transgression of the Escalaplano Fm. is marked by the Pelsonian (late Anisian) *Cristianisporites triangulatus* pollen (Pittau & Flaviani 1982 a,b), found in the black clay horizons situated 2 and 4 m above the base of the sequence. The age of the base of the Monte Maiore Fm. in the Blue Limestones mb. at Monte Maiore is determined by the presence in the storm beds of Costatoria goldfussi Alberti in Zieten (sensu Marquez-Aliaga 1985) close to the lower boundary with the Palaeozoic basement. As remarked in earlier works (Virgili 1958; Marquez-Aliaga 1985; Marquez Aliaga et al. 1986) this fossil is typical of the Upper Ladinian of the Sephardic Realm, to which Sardinia belongs (Hirsch 1972, 1977). The latest Ladinian is characterized by a salinity crisis, while the upper part of the Monte Maiore succession could again be dated to the middle part of the Longobardian. However, here evidence of a first regressive trend (testified by the algal, selciferous dolostones with evaporitic remains) at the top of the sequence might indicate the imminent latest Ladinian evaporitic crisis, and a higher chronostratigraphic level than the top of the Scivu Is Arenas and Campumari sequences.

Following the initial transgression, dominated by clastic sediments, a carbonate platform environment progressively extended over the whole shelf. The main cause of this sedimentary change probably lies in the lack of clastic input (due to peneplanation of the Hercynian chain). The northwesternmost Triassic outcrops in the Monte Maiore area are very often composed entirely of carbonates. The late Anisian-early Ladinian? clastic sedimentation never took place in this area, so the Hercynian basement was exposed and underwent strong alteration (local presence of laterites; Marini 1984). Thus carbonate sedimentation occurred directly, with sporadic episodes of terrigenous input.

Northwestern Sardinia (Nurra area)

The most complete Triassic stratigraphic succession is found in Northwestern Sardinia, though a continuous outcrop does not exist. In numerous places (loc. 7, 8, 9, 10, 11, in Fig. 1) it has only been possible to measure and describe incomplete sections. These have been compared by means of palaeontological and lithostratigraphic correlations, using as reference section the sequence of the Cugiareddu drill core (Pomesano Cherchi 1968), that crosses the entire Permo-Triassic succession down to the Hercynian basement.

Based on the Cugiareddu core data the thickness of the whole Triassic was estimated at about 335 m (Pomesano Cherchi 1968; Cherchi & Schroeder 1986), considering the presence of diagenetic folding due to evaporites of "Keuper". However, it was not possible to establish a boundary between "Buntsandstein" Triassic facies and "Rotliegendes" Permian facies, because of the absence of fossiliferous levels. On the contrary, in some outcrops (e.g. Punta Lu Caparoni) it is possible to observe the "Triassic" succession resting unconformably on thin (no more than 15 m) Permian (Autunian: Pecorini 1962; Gasperi & Gelmini 1979) deposits (Punta Lu Caparoni Fm.; Gasperi & Gelmini 1979; Cassinis et al. 1996a, b). A chronological synthesis of the Triassic succession in the Nurra can be found in Pittau Demelia & Flaviani (1982b).

Buntsandstein Facies group

"Verrucano Sardo" Auct. formation

Along the coast between Cala Viola, Porto Ferro/Torre Negra and the Punta Lu Caparoni cliff, north of Capo Caccia (Pecorini 1962; Gasperi & Gelmini 1979; Cassinis et al. 1996a,b) (loc. 9 in Fig. 1) (Fig. 18A), crops out the best and most continuous succession of the Sardinian red beds "Buntsandstein" facies overlaying with slight disconformity the Autunian Punta Lu Caparoni Fm. (Gasperi & Gelmini 1979), in turn unconformably resting on the Palaeozoic basement. The sequence, divided into four lithofacies and named informally "Verrucano sardo" by Gasperi & Gelmini (1979), consists of almost 300 m of alternating matrix- and clast-supported conglomerates, coarse sandstones and sandstones frequently cross-laminated with intercalations of siltites and argillaceous siltites, and rare volcanics and volcanoclastites prevalently contained in the lower to middle part of the sequence and gradually decreasing upwards (Neri et al. 1999). The colour of the lithotypes usually varies from grey to greenish, to red and finally to purple. The sandstones range from well to poorly sorted, but sorting is more mature and less variable towards the top of the sequence. The siliciclastics mineralogy also matures upwards. The rare centimetre-sized clasts contained in the sandstones generally consist of angular-subangular to rounded quartz. Hercynian metamorphic clasts, pelitic reddish clasts deriving from the coeval erosion of the same sequence, and more frequently, fragments of Permian volcanic rocks are also present, especially in the lower part of the sequence. In addition, in the sandstones of Gasperi & Gelmini's unit

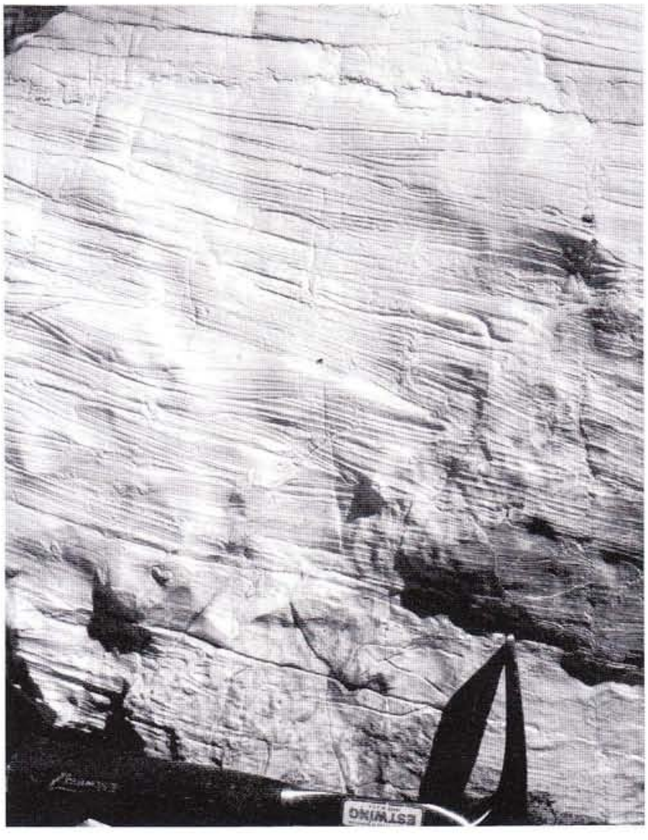


Fig. 17 - Monte Maiore (Sarcidano, Eastern Sardinia) (loc.6 in Fig.1): 5) - Monte Maiore (Sarcidano, Eastern Sardinia); Monte Maiore Fm., Blue Limestone Mb.: hummocky cross stratification.

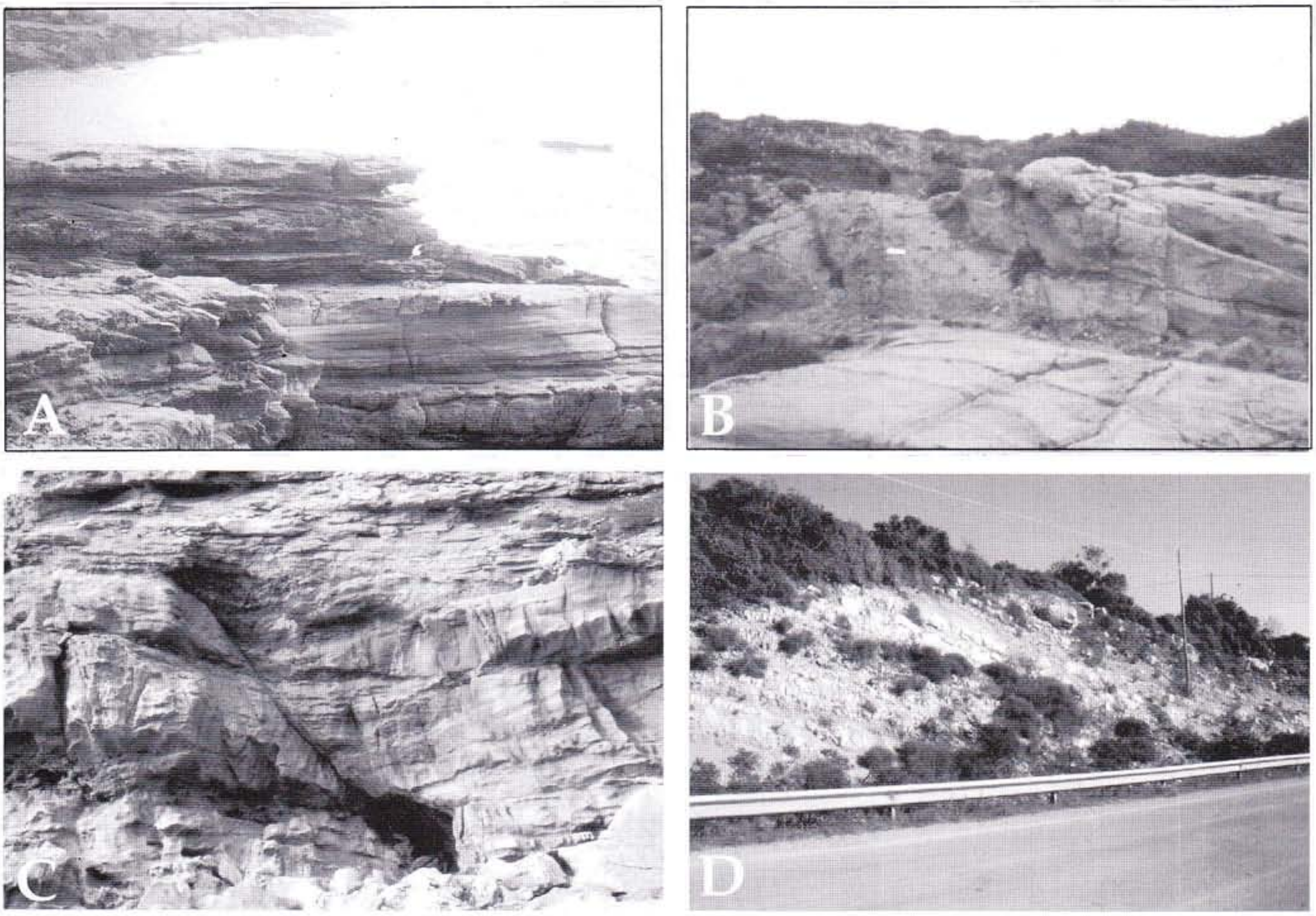


Fig.18 - Nurra, Northwestern Sardinia: A) Cala Viola, upper "Verrucano sardo" Auct. Fm. outcrop. B) Porto Ferro,"Verrucano sardo" Auct. Fm. outcrop: sinsedimentary metric fracture filled by coarse material: the discordance with the stratification surface on the right is evident; C) Porto Ferro,"Verrucano sardo" Auct. Fm. outcrop: sinsedimentary fracture in coarse sandstones enhanced by the following over-position of reddish siltes; D) Monte Corredda northern edge, "Keuper" Fm. l.s., Monte Corredda Mb.: alternances of well stratified marly dolostones, dolostones and argillaceous marls.

2 (1979) frontal accretion structures (probably tidal bars), well-washed conglomeratic beds and synsedimentary faults (Fig. 18B,C), the latter testifying to a syndepositional extensional tectonics, have also been observed.

In this succession, the only clear lithological marker bed could be the "Conglomerato del Porticciolo" level (Cassinis et al. 2001), a coarse orthoconglomerate occurring in the upper part of the sequence, about 2 m thick, composed of up to decimetre-size rounded quartz clasts embedded in a reddish matrix, resting on an erosional surface cut in reddish siltites. This surface represents the boundary between Gasperi & Gelmini's units 3 and 4 (1979). Neri et al. (1999) and Cassinis et al. (2001) claim that it could be a sequence boundary disconformity.

Rare fossiliferous levels (macroflora, ostracodes, conchostracans of Early Triassic age: Pecorini 1962) and bioturbations are also present in the upper levels of the "Verrucano sardo" succession. Based on these findings and considering similarities with the palynological data of the "Buntsandstein" facies sampled in the Cugiareddu drill core (Pittau Demelia & Flaviani 1982b), this sequence is probably dated to an interval between the Early? Permian and early Anisian. The presence of sedimentary hiatuses in the Permian succession cannot be entirely excluded (Pecorini, pers. comm.).

We propose to name this succession "Verrucano sardo" Auct. Fm., and to divide it into two lithofacies: the Porto Ferro lithofacies, about 200 m thick and the Cala Viola lithofacies, no more than 8 m thick, delimited by the Conglomerato del Porticciolo of Cassinis et al. (2001).

Recently Cassinis et al. (2001) proposed dividing the "Verrucano sardo" Auct. Fm into 4 lithostratigraphic units, respectively named, from the bottom to the top, Pedru Siligu Fm., Porto Ferro Fm., Cala del Vino Fm., and Conglomerato del Porticciolo - Arenarie di Cala Viola fm.. This distinction has been made on sequential and facies criteria and on correlations with the Toulon-Couers Permian Basin. However, in our opinion, this precise division of an on the whole fining upward homogeneous continental/transitional succession, based on poor biostratigraphic data, is controversial and not sufficiently substantiated by data.

In addition new evidence of the involvement of the Corsica-Sardinia block in the "Alpine" deformations (Laramic and Pyrenean Phase: Barca & Costamagna 1997a, 2000) in our opinion has revived the term "Verrucano sardo", recently rejected (Cassinis et al. 1996a) as it was considered inapplicable to successions not strictly related to the "Alpine" Domain. Actually the term "Verrucano" was usually reserved for the successions forming the base of the "Alpine" tecto-sedimentary cycle (Cassinis et al. 1979).

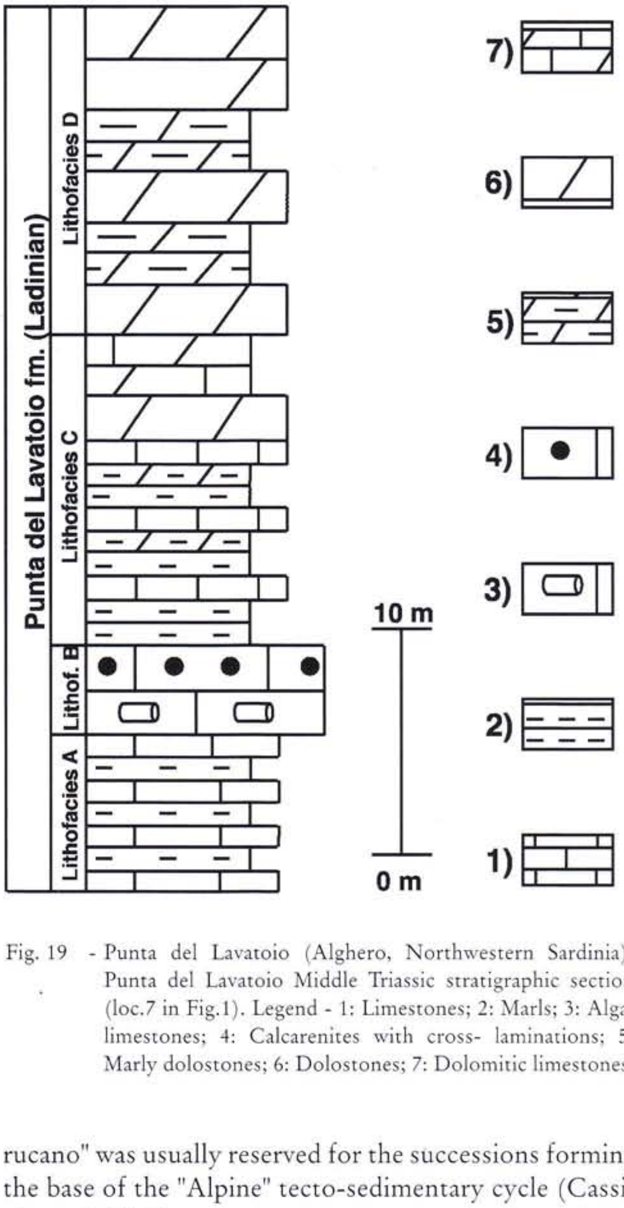


Fig. 19 - Punta del Lavatoio (Alghero, Northwestern Sardinia): Punta del Lavatoio Middle Triassic stratigraphic section (loc.7 in Fig.1). Legend - 1: Limestones; 2: Marls; 3: Algal limestones; 4: Calcarenites with cross- laminations; 5: Marly dolostones; 6: Dolostones; 7: Dolomitic limestones.

Other minor outcrops of the "Verrucano sardo" Auct. Fm. are visible in localities in the Nurra region. The most significant ones are found on the western slopes of the Monte Santa Giusta hill (Neri & Ronchi 1999). Here red, quartzitic sandstones and rare conglomerates of the "Buntsandstein" facies occur (Cassinis et al. 1996 a,b; Carillat 1997; Carillat et al. 1999; Neri et al. 1999). The facies is over 50 m thick and contains volcanoclastic intercalations (rhyolitic tuffs and ignimbrites, Lombardi et al. 1974; alkalirhyolitic pyroclastites, Fontana et al. 1982; welded tuffs, Cassinis et al. 1996a,b), passing abruptly to the carbonates of the Muschelkalk facies.

Muschelkalk Facies group

The most complete and continuous sections of "Muschelkalk" facies carbonate rocks of the Middle Triassic in Northwestern Sardinia lie along the Alghero coast (Punta del Lavatoio: Gandin 1978a; Posenato 1995) (loc.7 in Fig. 1) and in the Monte Santa Giusta hills (Carillat 1997; Carillat et al. 1999) (loc.10 in Fig. 1). In the latter locality is visible the only direct and well defined "Buntsandstein" to "Muschelkalk" facies transition still preserved in outcrop.

Punta del Lavatoio Succession:

At Punta del Lavatoio (Fig. 19 and 20A) (loc.7 in Fig. 1) four lithofacies could be distinguished in the succession, from bottom to top:

Lithofacies A) - Yellowish to greenish nodular limestones and marls;

Lithofacies B) - Grey to pinkish, thickly stratified limestones, locally slightly dolomitic;

These two lithofacies correspond to the "upper member" described by Gandin (1978a) and Posenato (1995). However, from a modern perspective of the stratigraphic-depositional units (Bosellini et al., 1988), we preferred to divide this "member" into two separate lithofacies as it represents two well-differentiated depositional environments.

Lithofacies C) - Well-stratified marly limestones, marls and subordinate dolomitic limestones, generally from dark-grey to greenish-yellowish in colour.

This lithofacies corresponds roughly to the "middle member" of Gandin (1978a) and Posenato (1995).

Lithofacies D) - Grey dolostones and marly dolostones. The latter portion is very similar to the "Keuper" facies dolostones of Monte Zari Fm. (Porto Pino) (Barca & Costamagna 1997a; Costamagna 2000).

This lithofacies corresponds to the "lower member" of Gandin (1978a) and Posenato (1995).

The Punta del Lavatoio Succession is overturned (Simone, pers. comm. and personal observations), likely due to the "Pyrenean phase" tectonics (Barca & Costamagna 1997a; 2000). The intense folding in the "Muschelkalk" limestones outcropping along the whole coast of the Alghero town is also indicative of this phenomenon.

Lithofacies A is about 8 m thick and consists initially of nodular limestones, followed by light, faintly stratified marls and marly siltites terminating with thin alternating beds of marls and nodular limestones. Only restricted outcrops of this lithofacies could be studied in detail because of its steepness (not accessible). The limestone layers are bioturbated at the boundary with marl layers. Reworked fossils have also been found

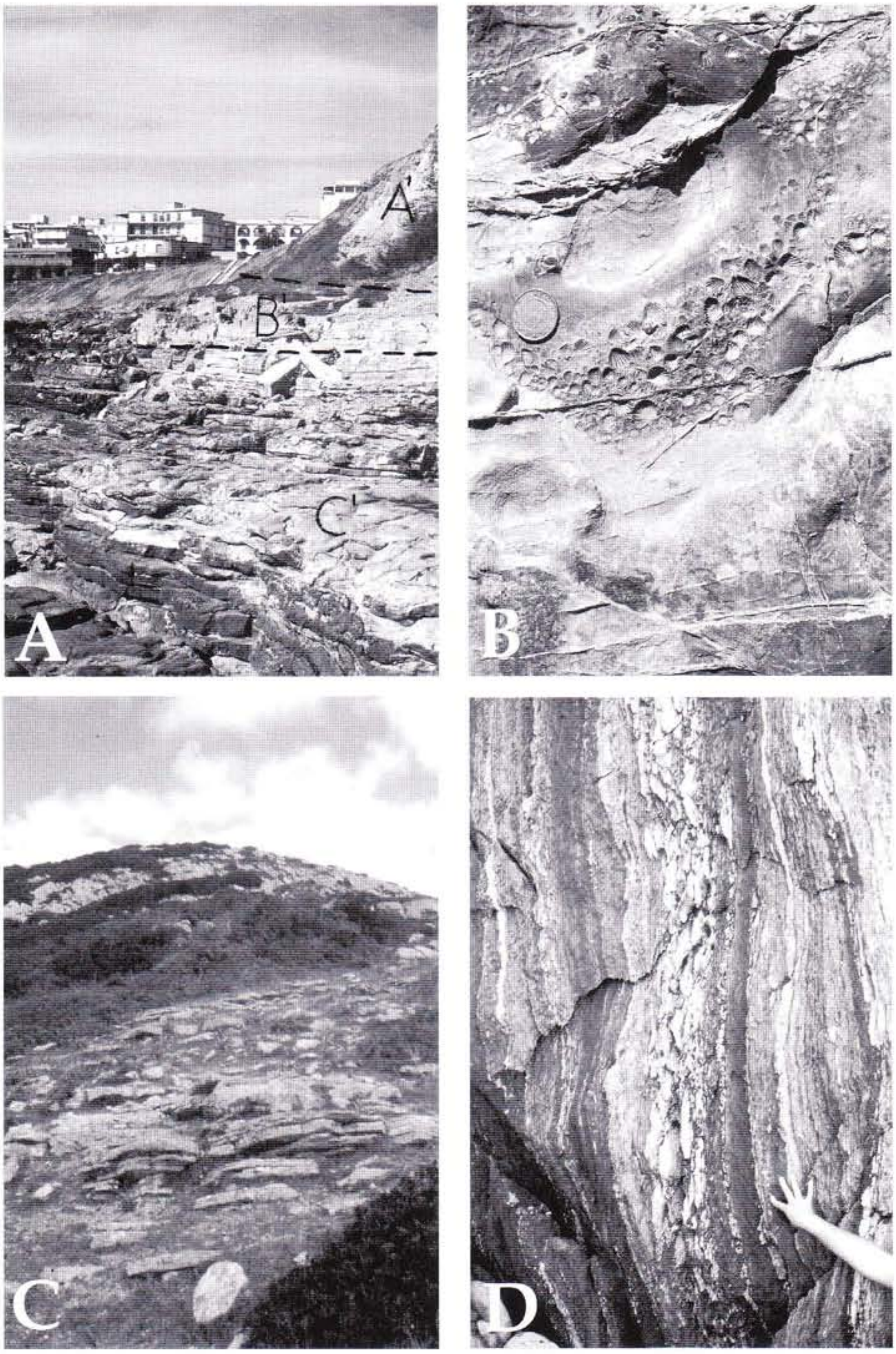


Fig. 20 - Northwestern Sardinia: A) Punta del Lavatoio (Alghero), Punta del Lavatoio Fm.: view of the stratigraphic section. Lithofacies A, B and C are shown. The sequence is tectonically overturned by the "Pyrenean" Alpine Phase; B) - Punta del Lavatoio (Alghero), Punta del Lavatoio fm.: *Costatoria goldfussi* shelly bed; C) - Monte Santa Giusta: laminated dolomites of the base of the Ghiscera Mala mb. of the "Keuper" Fm. s.l.; in second view the light limestones of the Punta del Lavatoio Fm.; D) - Ghisciera Mala, Ghisciera Mala Mb. (lower Keuper Fm. s.l.); thin alternations of siltites, argillaceous siltites, and pinkish to grey gypsum both in levels and nodules.

(foraminifers, echinoderms: Gandin 1978a; gastropods, ammonoids, bivalves, and brachiopods: Posenato 1995). Owing to the locally chaotic arrangement of the bioclasts, the normal gradation and possible scour marks at the base of the nodular limestone layers (at the upper boundary of the calcareous strata) a tempestite origin has been considered for these layers. There is a sharp transition to limestones in the overlying strata.

Lithofacies B, consisting of grey to pinkish dolomitic limestones, is generally thickly stratified, and about 4 m thick. It can be divided into two parts: the lower one consists of bioclastic grainstones rich in dasycladacean debris. In some layers scattered bivalves (*Costatoria goldfussi* Alberti in Zieten sensu Marquez-Aliaga 1985) also occur. Scour surfaces delimiting single high-energy depositional episodes are also visible. A high-energy depositional environment could also be inferred from the chaotic arrangement of the algal fragments along the erosion surfaces. Between these bioclastic deposits are layers of fine-grained limestones, containing some terrigenous matrix but lacking evident bioclasts. The upper part of this horizon, separated from the former bioclastic layers by a sharp, erosive boundary, is composed of laminated calcarenites, frequently containing both high- and low-angle cross laminations. The latter may be locally inferred as HCS structures. At the base of these beds, flat pebbles and reworked fossil fragments have been found, probably forming basal lags of tempestites. Ripple mark structures are also visible, and are frequently associated with rapid vertical variations of the sediment grain size. At the top of this lithofacies is a horizon containing numerous convolute structures. These structures, interpreted by Gandin (1978a) as slumpings or reversed density gradient phenomena, could also be referred to drag folds due to alpine tectonics (?).

Lithofacies C, about 12-13 m thick, is made up of alternating well-stratified nodular limestones and marls, intercalated towards the top with rare dolomitic limestones. A layer of nodular, grey limestones about 1 m thick containing progressively thicker intercalations of yellowish marls marks the transition from the underlying lithofacies B. The lithofacies C is characteristically arranged as a metre-scale alternation of sets of grey to dark grey strata of marly nodular limestones with rare, thin intercalations of yellowish marls, in turn alternating with thinner layers (about 10 cm) of greenish-yellowish marls and marly nodular limestones. Load casts are present locally. The base of some calcareous layers show strong bioturbation (*Spongeliomorpha suevica* Rieth; *Rhizocorallium jenense* Zenker: Gandin 1978a). The layer of bioturbated sediment is often no more than 2-3 cm thick. Thin accumulations of bioclastic debris, composed mainly of bivalves (*Costatoria goldfussi*; *Hoernesia socialis*: Gandin 1978a; Posenato 1995) also occur, locally forming erosion surfaces on the substratum. These accumulations strongly resemble the "shelly beds" of the Muschelkalk facies in the South German Basin (Aigner 1984, 1985), and represent here lag deposits of tempestite episodes (Fig. 20B). It is also interesting to note that the "shelly beds" containing *Costatoria goldfussi* always lie along the upper surface of the carbonate layers close to the sharp boundary with the marly layers, forming the basal lag of storm beds. In this lithofacies, reworked fragments of brachiopods, echinodermates, foraminifers; (Gandin 1978a), ammonoids, bivalves, and gastropods (Posenato 1995) have also been found.

The lithofacies D consists of a roughly 15 m thick succession of dark grey limestones and dolomitic limestones passing to grey to dark-grey, locally partially silicified dolostones and marly dolostones. These are stratified to thickly stratified, locally laminated. Some layers contain evaporite molds, along with rare chert nodules. Convolute lamination has been observed in some horizons interpreted by the authors as slumping. Isolated *Costatoria goldfussi* valves have also been found here (Gandin 1978a, b).

This part of the succession is lithologically and sedimentologically quite similar to the Monte Zari Fm. (Barca & Costamagna 1997a; Costamagna 2000) outcropping in the Porto Pino area.

Measured thickness of the Punta del Lavatoio succession is about 40 m, much less than the 70 m reported by Gandin (1978a).

This succession has been dated on the basis of palynomorphs (Pittau Demelia & Flaviani 1982a), conodonts (Bagnoli et al. 1985) and macrofauna association (Gandin 1978a; Posenato 1995). The palynomorph association gave an age ranging from late Anisian to early Ladinian (Pittau Demelia & Flaviani 1982a). After Bagnoli et al. (1985) the conodont assemblage can be attributed to the early Ladinian (late Fassanian). As for the macrofauna assemblage, whereas Gandin (1978a) dates the Punta del Lavatoio succession to no earlier than the early Ladinian, Posenato (1995), dates it to the early-late Ladinian transition (late Fassanian - early Longobardian), based on the presence of *Ceratites muensteri*.

For the reasons discussed elsewhere in this paper (association of *Costatoria goldfussi* in the Iberian Chain and in the Catalanides with the conodont *Pseudofurnischius murcianum* and the ammonoid *Protrachyceras hispanicum*; correlation with the *Protrachyceras archelaus* zone: Parnes et al., 1985; Marquez-Aliaga et al., 1986; Hirsch, 1987), the extensive presence of *Costatoria goldfussi* Alberti in Zieten (sensu Marquez-Aliaga 1985) suggests a late Ladinian (Longobardian) age for this succession. The recording of *Protrachyceras longobardicum* in the middle part of the section (Tornqvist, 1902) (referable to *Protrachyceras longobardicum* substage of the *P. archelaus* zone: Gradstein et al., 1995; Hardenbol et al., 1998) could confirm this attribution and could also indicate the middle part of the Longobardian, before the latest Ladinian salinity crisis.

Monte Santa Giusta succession

Other outcrops of the "Muschelkalk" facies are located along the Monte Santa Giusta hill (loc. 10 in Fig. 1). Here a nearly complete section of the Triassic succession of NW Sardinia crops out, from the "Buntsandstein" transgressive on the Hercynian basement, to the "Keuper" carbonate-evaporitic lithofacies (Fig. 21 and 3.3). The sharp transition from the siliciclastics of the "Verrucano sardo" Auct. Fm. to the "Muschelkalk" carbonate facies is perfectly visible. The "Muschelkalk" is formed here of a whitish dolostones lithofacies, composed of locally thinly laminated (stromatolitic?) dolostones 7-8 m thick, containing some terrigenous sediments (small, mm-sized, rounded to sub-rounded clasts of quartz) near to the lower boundary. These dolostones, locally with the typical aspect of "Cargneules" Auct., contain evaporitic molds and scattered chert nodules. The upper transition to a blue limestones lithofacies, composed simply of grey-blue limestones, is fairly abrupt and is marked by a laminated calcareous facies consisting of thin, red to blue-grey laminae containing small chert nodules. This is followed first by a massive limestone facies, consisting of alternating tempestite calcarenites and bioturbated ("*Rhizocorallium*" Auct.)

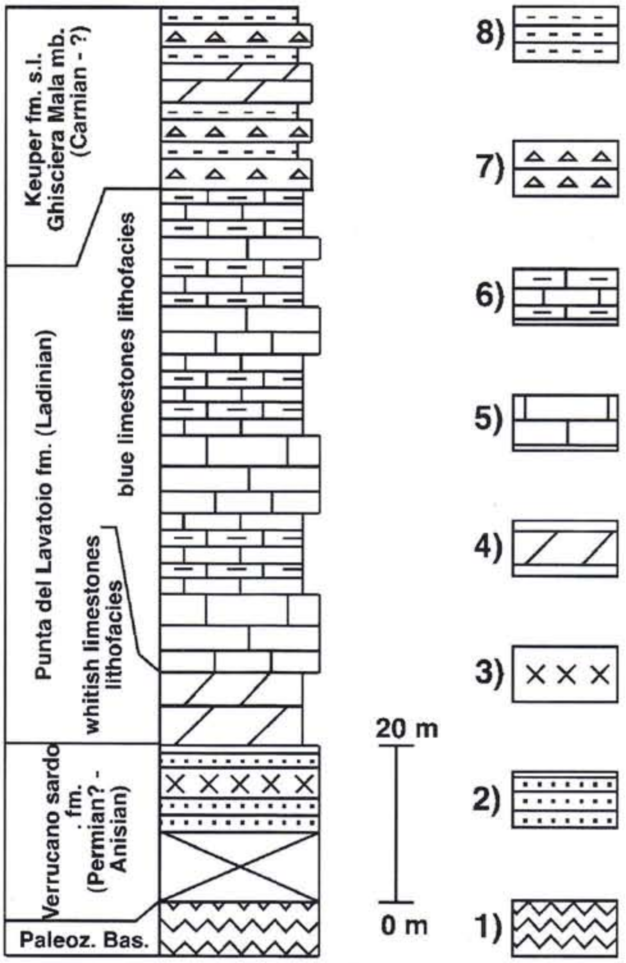


Fig. 21 - Monte Santa Giusta (Nurra, Northwestern Sardinia): Triassic succession (loc.10 in Fig.1). Legend - 1: Greenish slates; 2: Conglomerates and sandstones; 3: Volcanic rocks; 4: Dolostones; 5: Limestones; 6: Marly limestones; 7: Collapse breccias; 8: Clays.

calcilutites. The storm beds are marked by low-angle cross lamination and erosive surfaces on the calcilutitic intercalations. Upwards, the succession continues with alternating beds of massive limestone beds, a few metres-thick, composed of calcarenites/calcilutites, containing poorly visible cross-lamination structures and locally passing to crinoidal grainstones, and layers of marly nodular limestones and strongly bioturbated marls a few tens of cm- thick, often containing abundant fossils (bivalves, crinoids, gastropods, rare oncoliths). The thickness of this facies is about 60-70 m. The succession is harply overlaid by the to "Keuper" facies with alternating beds of well-stratified, grey to yellowish dolostones (Fig. 20C) and calcareous dolostones, locally containing horizons with siliceous pseudomorphs after sulphates and chert nodules, and dolomitic dissolution-collapse breccias, which terminate the succession. Here thin clays levels are also present. This last facies is 20 m thick.

Total thickness of the Monte Santa Giusta succession is estimated to be about 100 to 110 m. Carillat (1997) and Carillat et al (1999) on the other hand report a thickness of less than 60 m. The difference in altitude between the base and top of the stratigraphic section (about 100 m) with that the rock strata dipping eastwards, contradicts this figure.

The unpublished thesis of Flaviani (1980) attributes the whole Monte Santa Giusta succession to the lower part of the Middle Muschelkalk.

Based on an analysis of palynomorph and conodont assemblages observed in some horizons, Carillat (1997) and Carillat et al. (1999) assigned the "Muschelkalk" and "Keuper" facies succession to an interval between the early Ladinian (*Gladigondolella truempyi, Gondolella constricta*: Fassanian) and the Carnian (*Camerosporites secatus*: Cordevolian-Julian). However, Carillat et al. (1999) attribute the entire sequence to the "Muschekalk" facies. This is inconsistent with the lithostratigraphic characteristics of the upper part of the succession, that may be better attributed to the "Keuper" facies. Because of the age of the Muschelkalk and Keuper complexes, the siciliciclastic "Buntsandstein" succession underlying the carbonate sequence is older (Anisian?).

Keuper Facies group

Ghisciera Mala succession:

At Ghisciera Mala (loc. 9 in Fig. 1), near Cala Viola, a typical "Keuper" facies section crops out. Generally, it is not possible to set this succession in a more complete Triassic section because of tectonic deformation. In fact, at its base the "Keuper" is tectonically in contact with the "Buntsandstein" sandstones (Vardabasso 1966), while at the top the Liassic carbonates tectonically overlap. Beds dip at angles of between 40° and 80° NW-wards. Nevertheless, the absence of other better exposed "Keuper" successions in Northern Sardinia make this one significant.

The succession consists initially of yellowish dolostones (possibly correlatable with the higher dolomitic lithologies of the Monte Santa Giusta succession), locally containing horizons with evaporitic molds, passing suddenly to thin, well-stratified cm thick alternating beds of red and grey-to-dark grey shales, rare siltitic shales and whitish to pinkish gypsum layers (Fig. 20D). The latter contain enterolithic folds; m thick folded carbonate layers due to evaporites early diagenesis are also present. The shales frequently contain a widely varying percentage of evaporite nodules, from 1 to 10 cm in size, pinkish to white in colour, usually forming a proper chickenwire structure. Frequently small fractures of rocks are filled by recirculated evaporitic minerals.

Because of tectonic deformations, the thickness is hard to establish, but is estimated to be about 100-120 m.

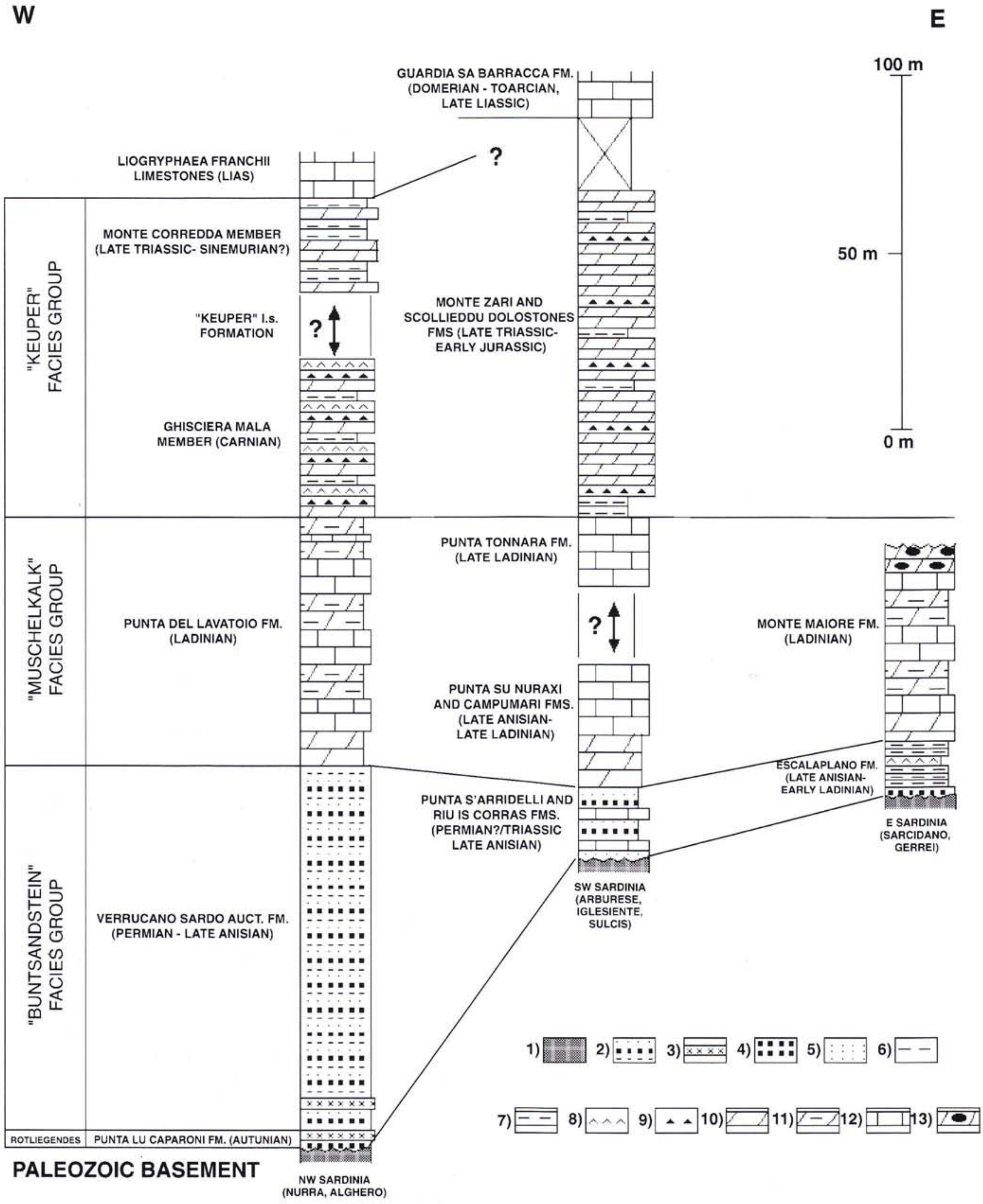


Fig. 22 - Stratigraphic correlations between the Triassic successions in Sardinia. Legend - 1: Palaeozoic Basement; 2: Alternating beds of conglomerates, sandstones, siltites and clays; 3: Volcanic rocks; 4: Conglomerates; 5: Sandstones; 6: Siltites and argillaceous siltites; 7: Marls and argillaceous marls; 8: Evaporites (prevalently gypsum); 9: Collapse breccias; 10: Dolostones; 11: Marly dolostones; 12: Limestones; 13: Selciferous dolostones. The stratigraphic section of the Northwestern Sardinian Triassic has been compiled after authors' field surveys and after Oosterban 1936; Pomesano Cherchi 1968; Gandin 1978; Gasperi & Gelmini 1979; Flaviani 1980; Bartusch in Cherchi & Schröeder 1986; Carillat 1997.

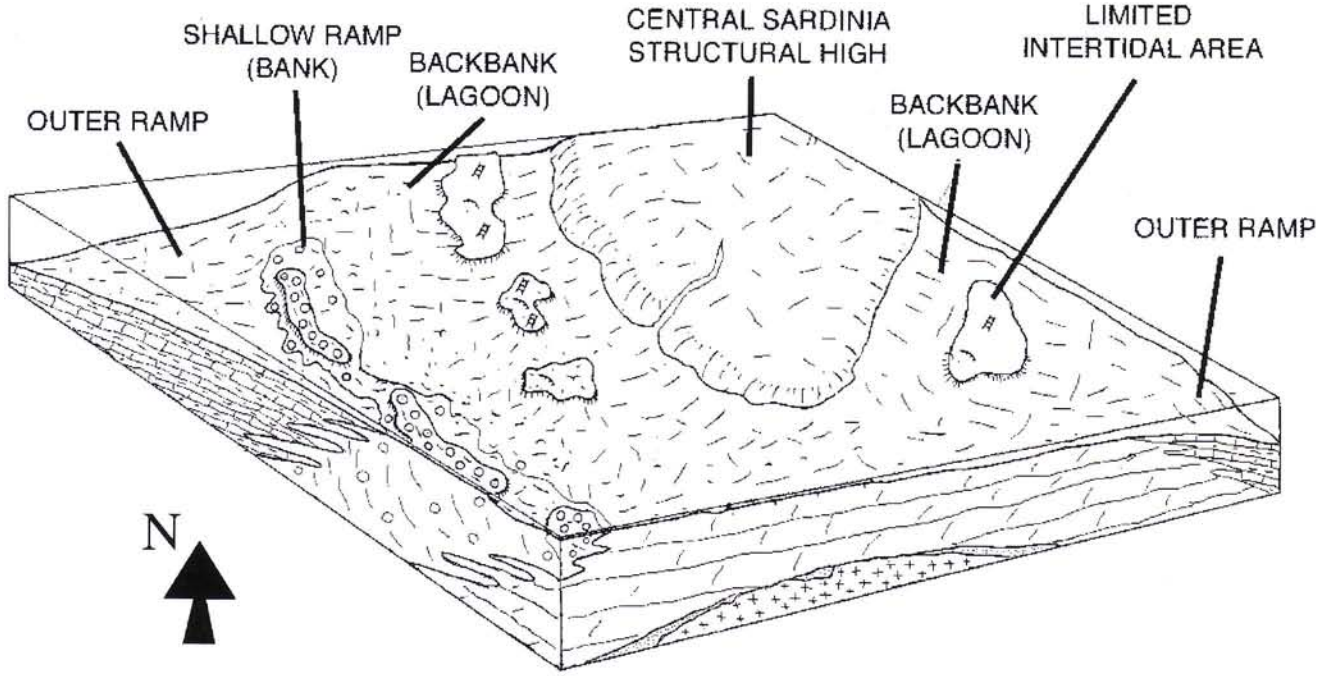


Fig. 23 - Sketch of the Sardinian carbonate ramp: hypothetical paleogeographic situation in the early Ladinian in Central-Southern Sardinia: the Central Sardinia Structural High is completely surrounded by the Triassic sea probably submerging it gradually during maximum eustatic flooding in the late Ladinian. Note the progressive landward shift of the outer ramp facies.

Facies cropping out upwards with respect to the "Muschelkalk" lithostratigraphic units could be grouped into an informal "Keuper" formation, in the absence of a precise reference section. We propose calling this lithofacies the Ghisciera Mala Mb. of a "Keuper" facies.

Based on the palynological content in the siltitic horizons (*Camerosporites secatus*) a late Ladinian to Carnian age has been assigned to this succession (Pittau Demelia & Del Rio 1980).

Monte Corredda succession

Based on the Cugiareddu drill core stratigraphy (Pomesano Cherchi 1968; Cherchi & Schroeder 1986), the Ghisciera Mala Mb. could be attributed to the lower "Keuper" facies association. An upper "Keuper" facies association is partially visible at the northwestern edge of Monte Corredda (loc. 11 in Fig. 1), near Contrada Renuzzo, 15 km east of Sassari. The succession is made up of poorly visible alternating whitish dolostones, grey to greenish marls and clayey marls (Fig. 18D). The dolostones frequently contain algal bindstones locally with fenestral structures and dissolution-collapse breccia horizons. Upwards, the succession passes suddently to dark-grey limestones containing *Liogryphaea franchii*, strongly suggesting a Liassic age (Sinemurian: Faure & Peybernès 1983).

We propose informally naming this part of the "Keuper" Monte Corredda Mb.. Combining the Ghisciera Mala Mb. and the Monte Corredda Mb. could give rise to an informal "Keuper" formation s.l. in the "Keuper" facies group.

The "Germanic" Triassic of Sardinia: discussion and final remarks.

Correlations between the successions in NW, SW and SE Sardinia

Comparisons between the Triassic successions in different areas of Sardinia (Fig. 22, 23) may be made based on the data presented previously.

The oldest Triassic sediments crop out in NW Sardinia (Nurra), where the "Buntsandstein" alluvial to transitional facies of the Verrucano sardo Auct Fm., up to 300 m thick, rests directly (slightly unconformably) on the Permian (Autunian) continental sediments of Punta Lu Caparoni Fm. (Gasperi & Gelmini 1979; Cassinis et al. 1996a,b; Neri et al. 1999). Based on macroflora, ostracodes (Pecorini 1962) and pollens (Pittau Demelia & Flaviani 1982b), the age of the upper portion is confined to Early Triassic-early Anisian. No biostratigraphic data are available for the lower "Buntsandstein" beds.

Nowhere else in Sardinia is the Triassic sedimentary cycle complete. The "Buntsandstein" facies in NW Sardinia has an older base compared to the other "Buntsandstein" outcrops of the island. In fact, at Scivu-Is Arenas (Arburese) in SW Sardinia the continental to transitional Punta S'Arridelli Fm. is not as thick (no more than 20 m) and it is younger. Given the similarities in thickness, stratigraphy and facies, the siliciclastics, also composed of reworked Permian volcanic rocks, are probably no older than early Anisian. By contrast, the Riu Is Corras Fm. at Campumari (Iglesiente) which is also about 20-25 m thick (this is still controversial chronologically), may likely be, at least in part, a Permo-Carboniferous continental to transitional complex. On the other hand, the Escalaplano Fm., the oldest unit of the Triassic successions in SE Sardinia (Sarcidano - Gerrei), has a late Anisian age. Thus, the Triassic sedimentation cycle is heterochronous in different areas of Sardinia.

These siliciclastic units may be gathered into a "Sardinian Buntsandstein Group". It is interesting to note that the time lag in the "Buntsandstein" deposition increases gradually eastwards, in general at the beginning of the Triassic depositional cycle in Sardinia, in contrast to the Triassic of the German Basin. On the contrary, the Sardinian succession shows more litho- and chronostratigraphic similarities with the Triassic successions of the Iberian Range (Gandin et al. 1982), that belongs to Hirsch's Sephardic realm to which the Sardinian Triassic also may be attributed.

The reasons for the considerable thickness and earlier age of the "Buntsandstein" facies in NW Sardinia in comparison to other parts of the island, are still unclear palaeogeographically. Perhaps they may be correlated to a subsiding intra-Hercynian range area, associated with the late- to post-Hercynian extensional tectonics. Northwestern Sardinia (Nurra) could be the only remaining area where the Triassic sedimentation rests directly on the pre-existing, strongly subsiding, Permian extensional basins. This raises a new question concerning the precise boundary between the Permian and Triassic in the "Verrucano sardo" Auct. Fm. succession. Is the Triassic succession particularly thick or is the main part of the Cala Viola succession composed of Permian deposits? Does a disconformity surface exist between Permian and confirmed Lower Triassic sediments in the upper portion of this succession, as hypothesized by Pecorini (pers. com.)?

The marine transgression of the "Muschelkalk" carbonate facies occurs gradually and generally on the siliciclastic "Buntsandstein" facies sediments. The age of this episode generally is comprised between late Anisian, as recorded by the lower pollen associations of Monte Santa Giusta, Scivu-Is Arenas, Campumari, and late Ladinian (*Costatoria goldfussi* "shelly beds" of Monte Maiore resting almost directly on the Hercynian basement). Usually, the first marine deposits are composed of dolostones with abundant evaporitic relics, enabling the lithostratigraphic correlation of all the dolomitized deposits that formed at the base of the Muschelkalk carbonate facies . Only in certain parts of the Monte Maiore area (East Sardinia) did partially calcareous sediments (Blue Limestones Mb. of the Monte Maiore Fm.) first deposit on the Hercynian bedrocks and this may be related to the complete submersion of neighbouring highlands. The Blue Limestones Mb. is younger and partially interfingered with the Yellow Dolostones Mb.. The Sardinian dolomitic members of the "Muschelkalk" facies are also diachronous from W to E, as demonstrated by biostratigraphic data of pollens. Indeed, during the late Anisian the basal portion of the dolomitic members was deposited in NW and SW Sardinia, while the mainly siliciclastic Escalaplano Fm. formed in SE Sardinia. Only later (early Ladinian?) did carbonate deposition occur in the SE part of the island.

On the basis of their sedimentological features, the upper calcareous members of the "Muschelkalk" facies formations also may be correlated lithostratigraphically.

The facies similarities between all of these lithostratigraphic units allow us to introduce tentatively a "Sardinian Muschelkalk Group".

The end of the carbonate "Muschelkalk" facies sedimentation is, as usual, not clearly distinguishable chronologically due to lack of a complete Triassic sedimentation record in most of the island. Only at Monte Santa Giusta (NW Sardinia) and Porto Pino (SW Sardinia) a well-defined transition from the "Muschelkalk" to the "Keuper" facies is visible. At Monte Santa Giusta a palynological association (*Camerosporites secatus*) found in the lower "Keuper" facies levels (Ghisciera Mala Mb.) likely indicates the presence of the early Carnian (Carillat 1997; Carillat et al. 1999). On the other hand, at Porto Pino there are no fossils to mark the transition from the "Muschelkalk" facies limestones to the "Keuper" facies dolostones, whose age thus remains undetermined (but probably no younger than the late Ladinian, considering facies analogies). However, a strong depositional change emerges during the late Ladinian from NW to SW Sardinia. In the NW, the carbonate sedimentation passes to an essentially evaporitic-siliciclastic sedimentation, while in the SW this transition is recorded only in the Monte Zari Fm. carbonates by dolomitization phenomena, i.e. rare thin levels of marls and marly clays and a minor amount of evaporites in the sedimentation.

Only at Porto Pino in SW Sardinia and in some places of NW Sardinia (e.g. Monte Corredda) does the transition from the "Keuper" facies to "Jurassic" carbonate sediments crop out clearly, but again an exact date is very difficult to establish. At Monte Corredda the boundary between the well-stratified dolomitic-marly-clayey upper "Keuper" facies sediments of the Monte Corredda Mb. and the Liassic dolostones is well-defined. The passage to the Liassic is marked by the presence of *Liogryphaea franchii* but, as reported by Faure & Peybernès (1983), the absence of precise biomarkers hinders an accurate dating. Consequently, the upper dolomitic deposits are attributed to the Sinemurian after Faure & Peybernès (1983). Thus, the "Keuper" deposition of the Monte Corredda Mb. also should continue during the early Liassic (Hettangian). At Porto Pino the dolomitic "Keuper" facies (Monte Zari Fm.) does not contain fossils, but it lies between the Ladinian calcareous sediments of the Punta Tonnara Fm. ("Muschelkalk" facies) at the bottom, and the oolitic-bioclastic sediments of the Guardia sa Perda Fm., Domerian? to Toarcian in age (belemnites, brachiopods and crinoid assemblages; Barca & Costamagna 1997a; Costamagna 2000), at the top. Therefore, the passage from Triassic to Jurassic is contained in the "Keuper" facies sediments (Monte Zari Fm.) and here, as in the French Aquitanian basin (Stévaux & Winnock 1974) and in the eastern part of the Iberian Peninsula (Orti Cabo 1987), the "Keuper"- facies should continue up to the end of the Early Liassic (pre-Domerian?).

Depositional environments and palaeogeography

"Buntsandstein" Facies group

The lithostratigraphic units of the "Buntsandstein" facies group ("Verrucano sardo" Auct. Fm., Punta S'Arridelli Fm., Escalaplano Fm.) were deposited in continental to transitional environments, with a gradual, locally stepwise ("Verrucano sardo" Auct. Fm.) decreasing energy level, up to the passage to the marine realm. In the upper part of the "Verrucano sardo" Auct. Fm. Neri et al. (1999) observed a tidal influx marked by flaser-bedding at the top of unit 4 of Gasperi & Gelmini (1979), close to the transition to the marine environment. In general, the depositional environments of these sediments probably could be set in the braided river facies association. Nevertheless, the sedimentological features exhibited at well-defined stratigraphic levels of Gasperi & Gelmini's unit 2 (1979) suggest the reworking of these deposits by marine processes. Thus, they can be better interpreted as having formed in (ephemeral?) distal fan delta environments. Some local accumulations of conglomerates at the base of the successions (Escalaplano Fm.) tentatively could be interpreted, geologically rather than sedimentologically, as small,discontinuous and ephemeral alluvial fans developed in the earliest stages of the Triassic (Permo?-Triassic for NW Sardinia outcrops) sedimentation cycle. In fact, the development of truly significant fan-delta complexes in Early to Middle Triassic times probably was hindered by the low landforms, in the past repeatedly peneplaned by several erosion cycles (Late Carboniferous; Middle Permian; Permian/Triassic). From this viewpoint the exception is the Riu Is Corras Fm., clearly representing a fan-delta complex with frequent mass- and debris-flow depositional episodes, interfingering with a marine (episodically lacustrine?) depositional system. In some cases (Scivu-Is Arenas: Punta S'Arridelli Fm.; Campumari: Riu Is Corras Fm.) the carbonate intercalations, often variously calichified, revealing early repeated ephemeral

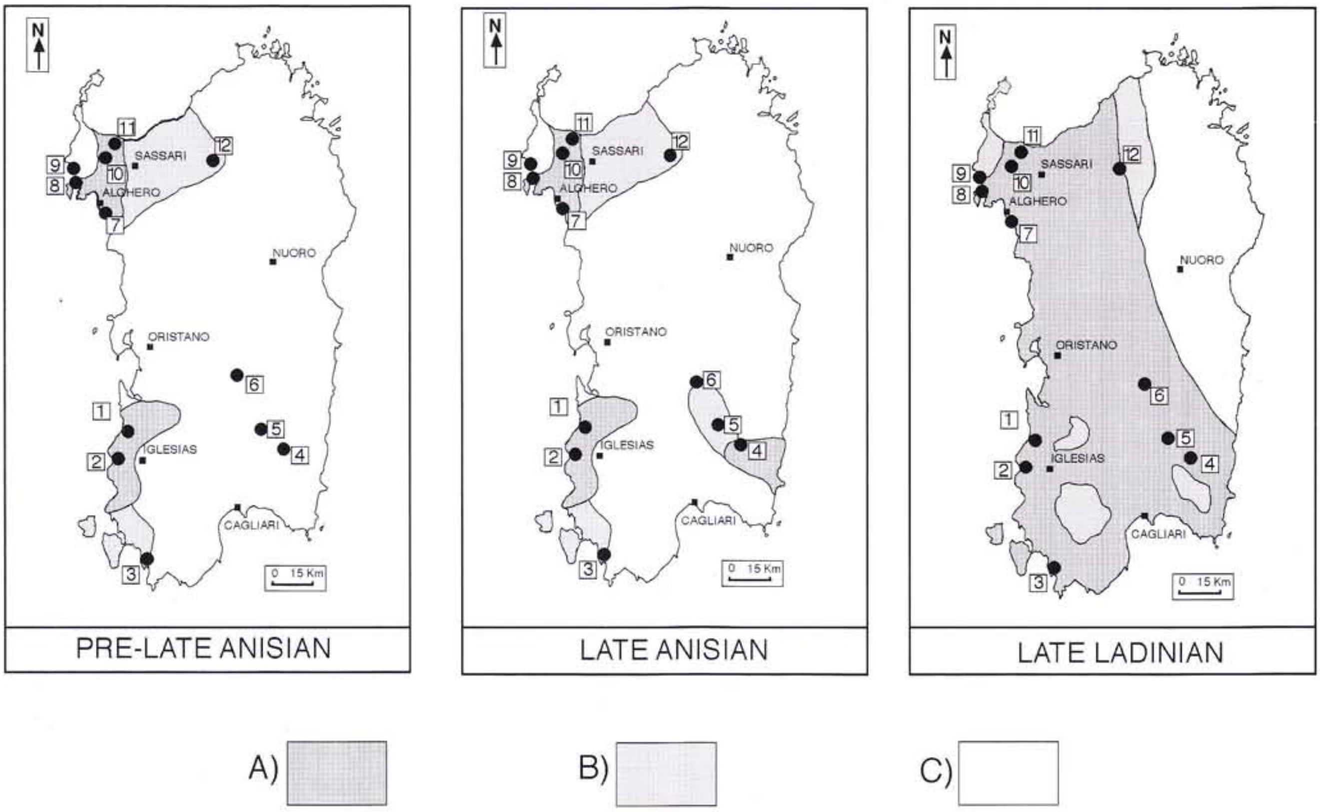


Fig. 24 - Three-stage reconstruction of the sedimentation areas in Sardinia during the Triassic. A) Areas of sedimentation; B) Areas of possible or partial sedimentation; C) Site of erosion or non deposition. Location numbers as in Fig.1.

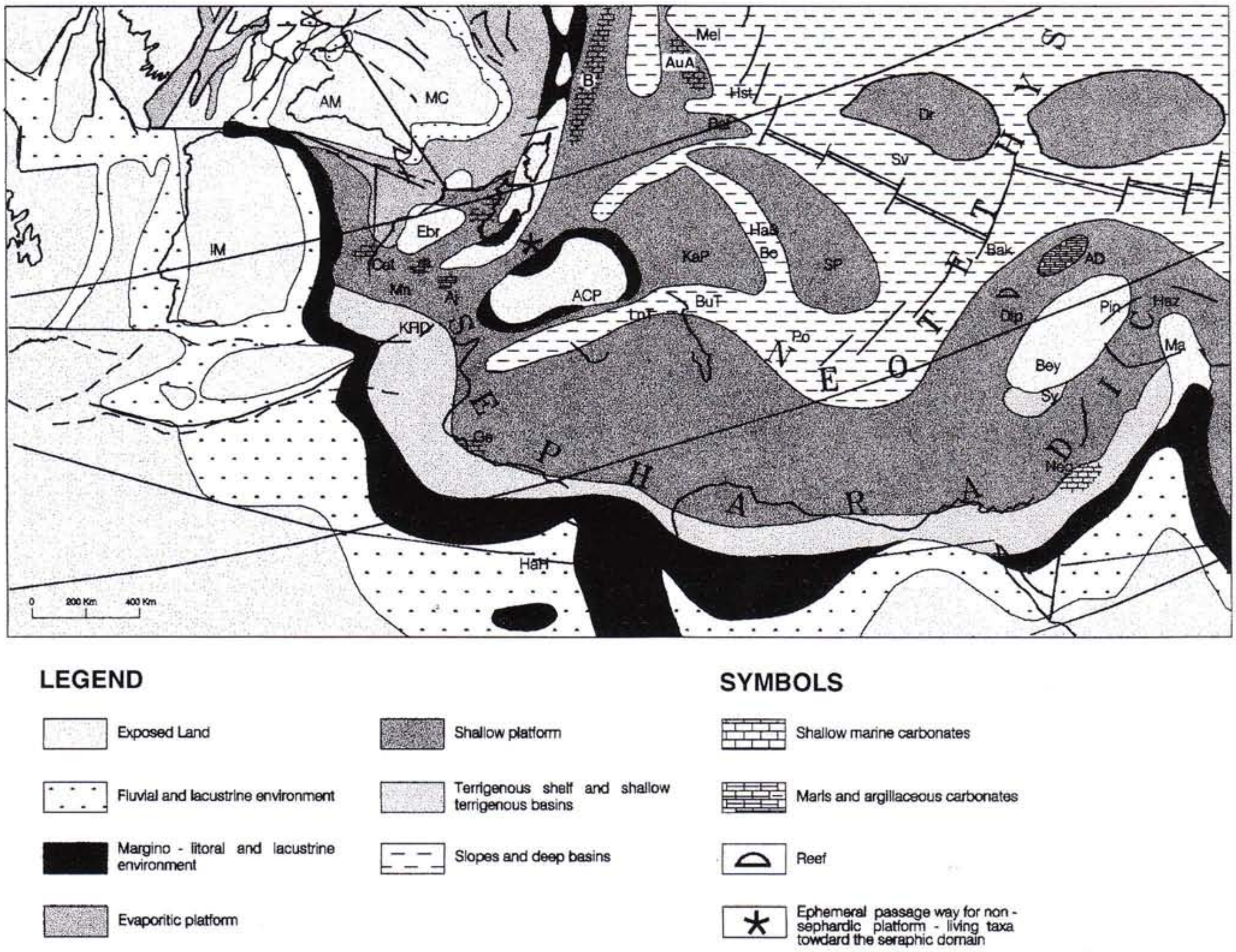


Fig. 25 - Setting and depositional environments of Sardinia in the late Anisian Paleogeographic context of the Western Tethys (modified from Marcoux et al., 1994). ACP = Apennine Carbonate Platform; AD = Ala Dag; Aj = Alpujarride; AM = Armorican Massifs; AuA = Austroalpine; B = Briançonnais; Bak = Bakirh; Bat = Balaton; Bey = Beysehir; Bo = Bosnia; BuT = Budva Through; Cat = Catalogne; Dip = Dipoyraz; Dr = Drama; Ebr = Ebro Massif; Gef = Gefara; Hst = Hallstatt; KaP = Karst Platform; KRD = Kabile-Rifaine dorsale; HaB = Han Bulog; Hah = Hammada al Hamra; Haz = Hazro; IM = Iberian Meseta; LnT = Lagonegro Through; Ma = Mardin; MC = Massif Central; Mel =Meliata; Mn = Makian; Neg = Neguev; Pin = Pinarbas; PO = Pindos - Olonos; SP = Serbo-Pelagonian Massif; Sy = Seydisehir; Sv = Svoula.

sea ingressions in a continental environment, are present in the topmost portion of these lithostratigraphic units, indicating a gradual transition to the marine environment. In other cases (NW and SE Sardinia), the transition is more sudden, a few metres of marls quickly passing to the dolostones of the "Muschelkalk" facies. In SE Sardinia the likely first effects of the marine environment are also visible in the lower calcareous-evaporitic intercalations of the Escalaplano Fm. (lithofacies 2), containing wrinkled algal mats.

"Muschelkalk" Facies group

The first clear marine ingression in Sardinia is marked everywhere, except for a very few sectors of the Monte Maiore area (E. Sardinia), by generally yellowish dolostones containing evaporitic relics. The dolostones pass upwards gradually to blue-grey limestones with frequent marly and marl intercalations. Those outcrops where the Triassic succession is sufficiently continuous upwards (Porto Pino; M. Maiore; Monte Santa Giusta) show a return to carbonate dolomitized sediments related to restricted, shallow conditions following the alternations of limestones and marls. These characteristics of the succession record the rise and expansion, on a former continental depositional system, of a gradually deepening carbonate homoclinal ramp (Fig. 23) extending at its climax (late Ladinian) over almost the entire island (Fig. 24). First a lagoonal, low energy, restricted inner ramp environment developed ("back-bank" of Aigner 1984, 1985; "back-ramp" of Tucker & Wright 1990) (Barca & Costamagna 1998). Later, as the transgression progressed, narrow, discontinuous and limited oolitic-bioclastic bars (shallow ramp) followed, prograding on the lagoon. Finally, alternating beds of calci-

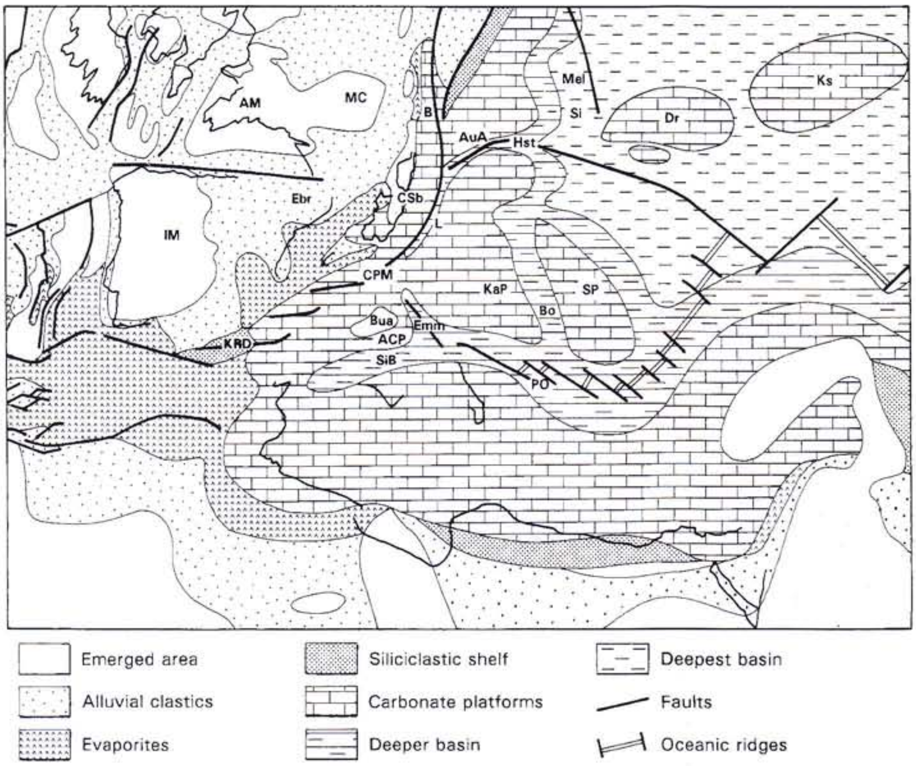


Fig.26 - Setting and depositional environments of Sardinia in the late Norian Paleogeographic context of the Western Tethys (modified from Gaetani et al., 1998). ACP = Apennine Carbonate Platform; AM = Armorican Massifs; Aua = Austroalpine; B = Briançonnais; Bo = Bosnia; BuA = Burano; CPM = Calabria-Peloritani Massif; CSb = Corso-Sardinia block; Dr = Drama; Ebr = Ebro Massif; Emm = Emma; Hst = Hallstatt; KaP = Karst Platform; KRD = Kabile-Rifaine dorsale; Ks = Kirsheir IM = Iberian Meseta; L = Lombardy; MC = Massif Central; Mel =Meliata; PO = Pindos - Olonos; Si = Sicilicum; SiB = Sicanian Basin; SB = Serbo-Pelagonian Massif.

lutites, marly calcilutites and marls, containing HCS structures deposited, recording the onset of an outer, deeper ramp environment (Barca & Costamagna 1998). The upper part of the succession, that crops out at Porto Pino and Monte Maiore, indicates a probable return to inner ramp (backramp, lagoon) conditions. Along the entire "Muschelkalk" carbonate succession the ramp conditions appear to have improved as indicated by the absence of continuous, major barriers and of significant slump deposits. These data, together with the gradual passage from shallow to deeper deposits, support a homoclinal ramp model (Ahr 1972; Read 1982, 1985). In addition, the Sardinian Middle Triassic carbonate environment (Fig. 23, 25) shows clear similarities with the homoclinal ramp depositional model (Aigner 1984, 1985) developed for the "Germanic" Triassic in Germany.

In particular, the abundance of storm layers in the "Muschelkalk" facies group, especially in the upper part, compared to the overall thickness of the outcropping sequence should indicate a "Storm Depositional System" (Aigner 1985), with a variable degree of temporal and spatial restriction. The HCS structures are cyclically disturbed or completely destroyed by bioturbation, perhaps recording periods of variable storm frequency. However, sea-level fluctuations, modifying the position of the storm-wave base, could also be responsible for the variation of bioturbation intensity and storm structures. Moreover, it should be noted that the limited thickness of the succession, as indicated by biostratigraphic data, could overstress the importance of storm deposition over time. Furthermore, Calvet & Tucker (1988) described the depositional features of the Catalonian Ladinian carbonatic ramp which is palaeogeographically close to the Sardinian Triassic ramp (Fig. 25). The Catalonian ramp is not storm-dominated, due to the position of the Iberian Peninsula far from the Triassic Hurricane zone, orprotected from the source of Tethyan storms.

"Keuper" Facies group

Hypothesis about the depositional environment of the upper portion of the Triassic could only be inferred in those areas where the succession is sufficiently complete, such as NW Sardinia (Nurra), Porto Pino (Sulcis) and Monte Maiore (Sarcidano-Gerrei) pro parte. In fact, in spite of the limited thickness, already at Monte Maiore the dolomitized, chert-bearing sediments of the topmost part of the succession, locally rich in algal debris, indicate the return to shallow conditions. At Porto Pino, where just the upper "Muschelkalk" facies and "Keuper" facies crop out, only the regressive portion of the Triassic succession may be described. These successions (Punta Tonnara and Monte Zari Fms.) represent the gradual evolution from an open ramp with cyclical variation of depth in an overall regressive trend, through an evaporitic lagoon transition episode, indicated by the "Cargneules" and the dissolution collapse breccias horizons, to a stable, shallow, restricted, and probably lagoonal sub-environment of an inner carbonate ramp. Here the depositional environment does not change until the Late Liassic, when the transgression caused the superposition of the bioclastic bars of the Guardia Sa Barracca Fm. (Barca & Costamagna 1997a; Costamagna 2000). In this setting the Triassic to Liassic Scollieddu

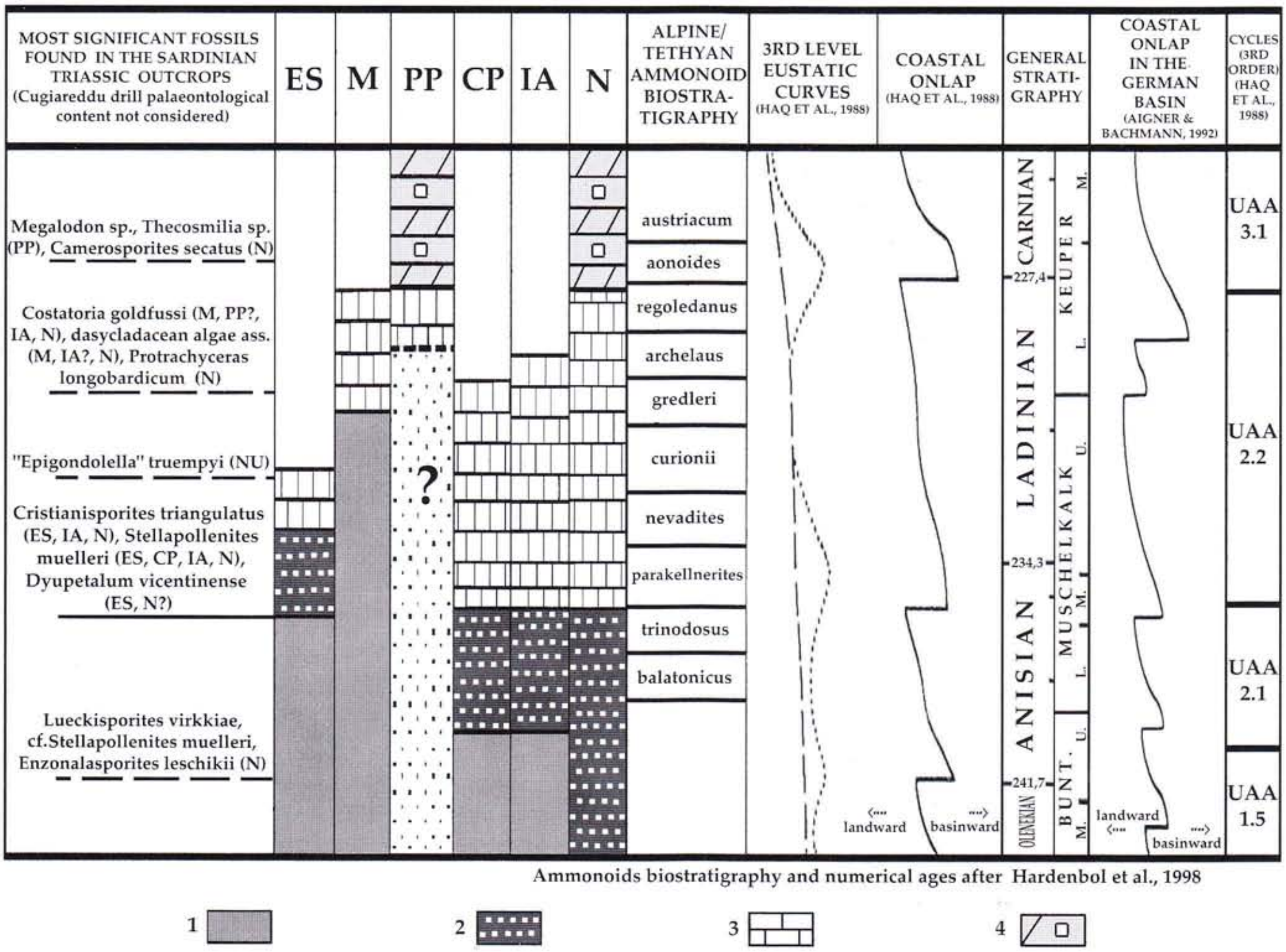


Fig. 27 - Attempt of correlation between the Stratigraphy and the Chronology of the Triassic (Olenekian to Early Carnian) successions of Sardinia and the 3rd order Eustatic Cycles after Haq et al. 1988. Paleontological data from: Damiani & Gandin 1973a, b; Pittau & Flaviani 1983b; Bagnoli et al. 1985; Barca et al. 1995b; Barca & Costamagna 1997; Carillat et al. 1999; Costamagna, 2000; Costamagna et al. 2000. Legend: 1) - Paleozoic Basement; 2) - Escalaplano, Riu Is Corras, P. S'Arridelli, and "Verrucano sardo" Auct. Fms. ("Buntsandstein" facies group); 3) - M. Maiore, P. Tonnara, Campumari, P. Su Nuraxi and P. del Lavatoio fms. ("Muschelkalk" facies group); 4) - Monte Zari, Scollieddu and Keuper Fms s.l. ("Keuper" facies group); 5) - Quaternary Cover. ES = Escalapiano; M = Monte Maiore; PP = Porto Pino; CP = Campumari; IA = Scivu - Is Arenas; N = Nurra.

Dolostones fm. might only represent a more open and distal environment. The depositional setting in N. Sardinia is rather different. Following the regression of the Punta del Lavatoio Fm. on the carbonate ramp, the sedimentation attributed to "Keuper" facies is dominated by mixed siliciclastic-evaporitic-carbonate (Lower "Keuper" facies: Ghisciera Mala Mb.) evolving to siliciclastic-carbonate deposits (Upper "Keuper" facies: Monte Corredda Mb.). Deposition likely occurred in an arid to subarid restricted sabkha-mudflat environment, gradually evolving to a less restricted mixed siliciclastic-carbonate shelf(sub- to intertidal(?) environments), that wanes only when the Early Jurassic transgression (Sinemurian?; Faure & Peybernés 1983) prompts the development of an open carbonate platform.

The differences between Late Triassic evolution in southern and northern Sardinian successions may be significant. In fact, while the essentially siliciclastic-evaporitic sedimentation in Northern Sardinia is characteristic of the "Germanic" Late Triassic (see Aigner & Bachmann 1989), the predominance of carbonate sediments and the minor amounts of clastics and evaporites in Southern Sardinia resemble more strongly the "Alpine" Late Triassic succession. Thus, a progressive transition to an "Alpine" Tethyan domain from N to S Sardinia might be inferred during the Late Triassic. However, the "transitional" nature of the Upper Triassic in Southern Sardinia finally may be demonstrated. This transitional character assigns to Sardinia a key position in the palaeogeography of the Western Tethyan domain during the Late Triassic (Fig. 26). The arid to subarid, mixed-flat, "Germanic" environment likely changed, in the present-day north-south direction, to a more marine, albeit still slightly restricted, carbonate environment resembling those of the Tethys.

The absence in Sardinian Triassic lithologies of well defined and frequent fossiliferous horizons acting as chronostratigraphic markers makes it difficult to

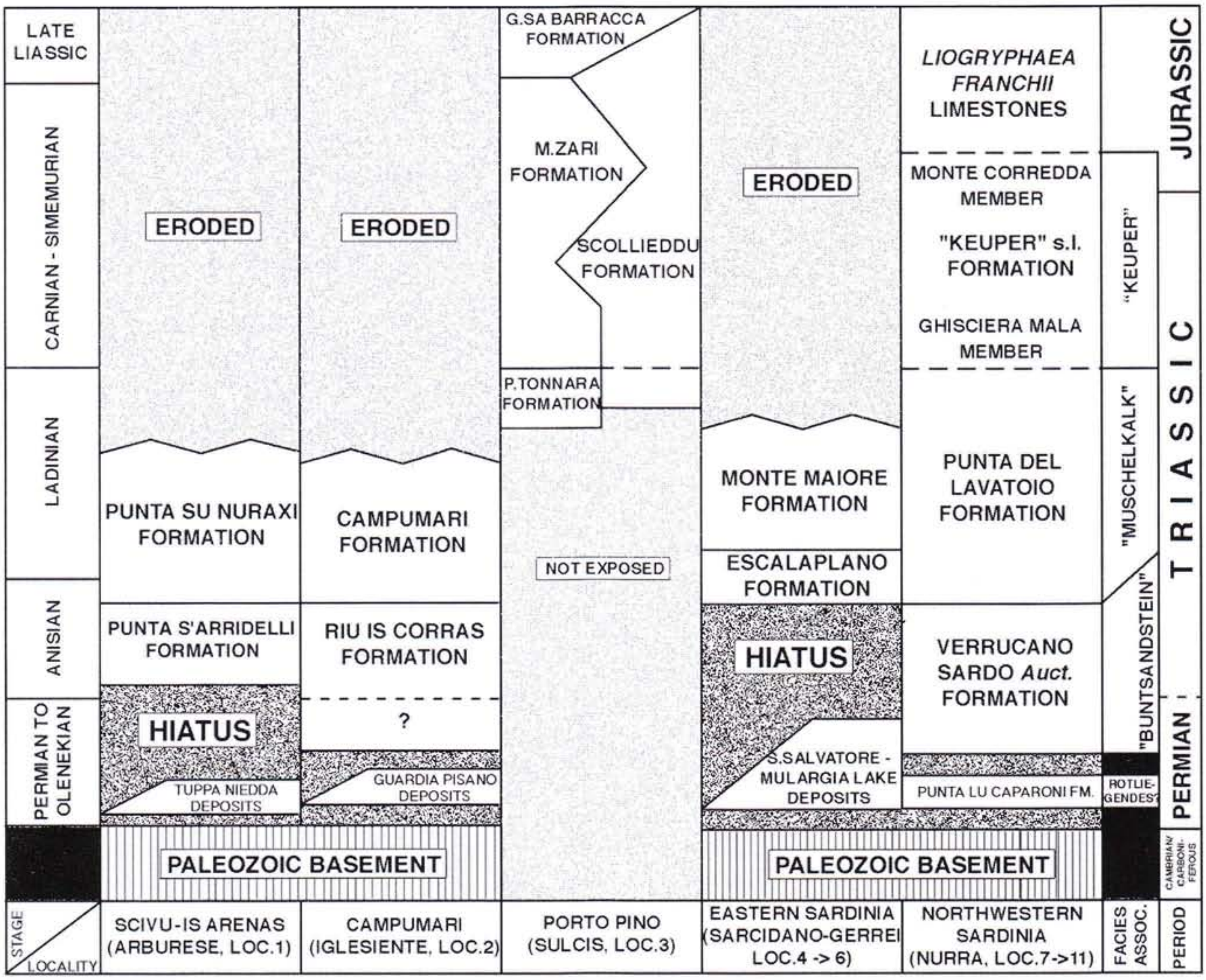


Fig. 28 - Facies-based scheme of correlation and relationships among the Triassic lithostratigraphic units, the Permian deposits and the Palaeozoic basement in Southern, Eastern and Northwestern Sardinia.

reconstruct the course of the transgression, its age, and relative direction (Fig. 24). The presence of "shelly beds" containing *Costatoria goldfussi* at the base of the succession at Monte Maiore (E. Sardinia) resting directly on the Hercynian basement suggests a late Ladinian age for the transgression, compared to a late Anisian (Pelsonian/Illyrian) palynological age found at Campumari, Scivu-Is Arenas and in N. Sardinia. This implies at least a partial eastward encroachment of the Triassic transgression on a Palaeozoic metamorphic high located in Central Sardinia (Fig. 24, 25). In addition, evidence of late Anisian sedimentation, with minor marine influence in the Escalaplano area (SE of Monte Maiore) suggests the progressive surrounding of a Hercynian Central-Northern? Sardinia structural high by the Triassic sea. Furthermore, in E. Sardinia the progressively decreasing thickness north-westwards of terrigenous sediments (Escalaplano Fm.) and their absence in some parts of the Monte Maiore-Tacco del Sarcidano area at the base of the Triassic succession, might indicate the gradual disappearance, with the encroachment of the Triassic transgression, of major relief-producing debris due to erosional processes, and thus the almost total flooding of the Central Sardinia Hercynian basement during the late Ladinian.

Sequential hypothesis

The stratigraphic data support the hypothesis that the Triassic sedimentation in Sardinia took place under the influence of 3 superimposed eustatic sub-cycles (third-order cycles) (Fig. 27). The transgressive continental depositional system, where present, was emplaced during sub-cycle UAA2.1 (early- late Anisian) (Haq et al. 1988; Hirsch 1991), and this was followed by a first sedimentation hiatus. This cycle is clearly visible in the Scivu-Is Arenas and Campumari successions (Punta S'Arridelli and Riu Is Corras Fms.), and is bound at the top by the slight intra-Anisian unconformity. Sub-cycle UAA2.2 (late Anisian - late Ladinian) (Haq et al. 1988; Hirsch 1991) followed in sequence. After a brief depositional hiatus, rapid flooding occurred, prompting carbonate deposition and the progressive landward shift of all the carbonate ramp facies (lithostratigraphic units of the "Muschelkalk" facies group). The lagoonal dolomitic facies ("back-bank") gradually retrograded towards the interior of the island, now the Monte Maiore and surrounding areas, that resulted in a widening of the shallow and deep ramp facies throughout the island. This 3rd order sub-cycle ended with an abrupt regression, recorded in S. Sardinia by a revival of the shallow, restricted areas. Carbonate sediments containing minor but significant amounts of evaporites were deposited, resulting in the formation, during diagenesis, of some collapse-dissolution breccia horizons, while in northern. Sardinia an arid to subarid restricted sabkha-mudflat environment developed. In sub-cycle UAA 3.1 (late Ladinian - Carnian) (Haq et al. 1988; Hirsch 1991), a renewed progradation of the ramp in the southern part of the island (SW Sardinia, Monte Zari Fm.) occurred, through the expansion and opening of a lagoonal, but still frequently restricted, environment. In contrast, in northern Sardinia the transgression related to this sub-cycle occured much more slowly, going from sabkha-playa lake environments (northern Sardinia, Ghisciera Mala Mb., Carnian), to carbonate-siliciclastic-evaporitic (ramp?) deposits (Monte Corredda Mb.), and finally to the formation of the Liassic carbonate platform.

In addition, the limited thickness of the Sardinian Triassic successions, well-documented by both the thickness of the stratigraphic sections and sedimentary/biogenic structures, highlights the pattern of third-order sequences, frequently masked elsewhere by higher order cycles, thus facilitating correlation with the eustatic curves of Haq et al. (1988).

The "Germanic" Triassic of Sardinia: conclusion

In Sardinia the Triassic period is characterized by a second-order transgressive-regressive megacycle (Haq et al. 1988).

A detailed stratigraphic and sedimentological study of the entire Triassic sedimentary megacycle is attainable only in the NW part of the island, where almost complete sections, or small, but easily correlated neighbouring sections occur. Here it is easier to highlight the comprehensive transgressive nature of the succession, from the "Buntsandstein" facies up almost to the top of the "Muschelkalk" facies, and the comprehensive regressive evolution of the remainder of the succession, represented by upper "Muschelkalk" facies and the "Keuper" facies, up to and beyond the boundary with the Jurassic.

In southern Sardinia it is generally only possible to study the lower, transgressive (Scivu-Is Arenas, Arburese; Campumari, Iglesiente; eastern Sardinia) or the upper, regressive portion (Porto Pino) of the Triassic megacycle. Hence, in this area the reconstruction of the evolution of the entire Triassic megacycle may be more controversial.

Comparison with other "Germanic" Triassic areas (Germany; Spain), where successions are 1000 to 3000 m thick, clearly shows the reduced nature of the Sardinian Triassic, whose thickness averages a maximum of 300 m (in the NW it probably attains 500 m locally, including the "red beds" Buntsandstein facies). The succession probably deposited on a structural high which acted as a stable area with a low subsidence rate between Western Europe, Central Europe and the Tethyan basins.

Variations in the sedimentologic characteristics of the Triassic stratigraphic sections from the north to the south of the island seem to indicate a progressive shift of the depositional conditions (and consequently of the paleogeography) from typically "Germanic" to more "Alpine" facies. This occurred mainly during the Late Triassic (and probably not actually during the Middle Triassic, as suggested by Baud et al. 1977, and Gandin et al. 1982), especially in southern Sardinia. Thus, during the Late Triassic Sardinia performed the function of a transitional area between different paleogeographic domains. During the Ladinian almost the entire island was subjected to generalized marine conditions (Fig. 23, 24), as suggested by the homogeneity of the carbonate facies. On the other hand, during the Late Triassic the island was probably crossed by a paleogeographic boundary, between a true "Germanic" domain (where the "Keuper" facies formed, in paralic to transitional, frequently restricted depositional conditions) and the shallow open marine carbonate Tethyan domain (Fig. 26), whose most significant remains in Sardinia are probably the Upper Triassic carbonate successions of Porto Pino (Sulcis, Southern Sardinia). However, the proximity and the (episodic?) communication between different domains (Germanic and Alpine) in Sardinia might also be demonstrated during the late Anisian by the discovery at Escalaplano, in eastern Sardinia (Pittau Demelia & Flaviani, 1982b), of pollen associations containing both *Cristianisporites triangulatus* Antonescu 1969, a typical form of the "Germanic" Triassic basin, and *Samaropollenites speciosus* Dolby 1976 and *Dyupetalum vicentiniense* Van Der Eem 1993, belonging to the "Alpine" domain. This finding enables a correlation between the *thiegartii-vicentiniense* alpine phase of Brugman (1986) and the "Germanic" basin, proving some form of communication between the two (Costamagna et al. 2000).

Sedimentological features of the Sardinian Middle Triassic carbonates reflect a homoclinal ramp geometry for all the depositional environments described. However, the persistence of an almost coeval carbonate ramp environment from North to South Sardinia, and the absence of an outcropping of true Middle Triassic deep basin (possibly located between the Corsica-Sardinia ridge and the Iberian peninsula -i.e. the Catalan-Sardinian graben of Gandin et al. 1982 -, as indicated by the centripetal, mirror-like distribution of the Iberian and Sardinian Triassic facies before the Cenozoic drifting of the Corsica-Sardinia block: Costamagna 1998) suggest, from a general perspective, a more extensive epeiric platform setting of carbonate deposition on the island (epeiric ramp sensu Wright & Burchette 1998). This platform was possibly linked (in present-day northern direction?) to neighbouring European carbonate shelves. Nevertheless, a true link between the Sephardic Realm (including the Corsica-Sardinia block of the Sardo-Provençal sub-domain) and the southern Germanic basin via the Burgundy gate during the early Ladinian, as suggested by Dercourt et al (2000), is arguable. In fact, the individuality of the taxa of the Sephardic community during almost the entire Ladinian (showing no mixing with the germanic taxa), associated with the marine transgression time-shift and the depositional facies analysis of the transgression in several places of SE and SW France (Courel et al. 1984), suggest a gradual progradation of the shallow sea facies during the Ladinian from N (Jura) to S (Chaînes Subalpines) and from W ("Coulour Rhodanien") to E (Alpes meridionales). These data indicate the presence of a significant emerged ridge hindering free communications (more probably ephemeral and episodic) between the two basins during the early Ladinian and the lower part of the late Ladinian. Only in the late Ladinian a continuous communication between Germanic basin and Sephardic basin took place and was maintained . The Anisian-Ladinian paleogeographic map published by Szulc (1999) support this statement, indicating a true gate (the "Burgundian gate") only during the late Ladinian.

Thus, dominant epeiric platform depositional conditions, frequently from slightly to strongly restricted because of the extent of the shallow area (low wave energy and low tidal ranges), especially during the deposition of the dolomitic members of the "Muschelkalk" facies, could also explain the scarcity, and local absence, of marker levels and, more generally, of fossils. The deposition of the prevalently inorganic carbonates of the dolomitic, lagoonal members may also be hypothesized at this time. The carbonates are composed mainly of mudstones almost totally devoid of bioclasts, frequently with planar bedding due to settling, and containing acicular and nodular sulphate pseudomorphs.

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