Geological Field Trips

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The Triassic and Jurassic sedimentary cycles in Central Sardinia: stratigraphy, depositional environment and relationship between tectonics and sedimentation

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The Triassic and Jurassic sedimentary cycles in Central Sardinia: stratigraphy, depositional environment and relationship between tectonics and sedimentation

85° Congresso Nazionale della Società Geologica Italiana, Sassari 6-8 settembre 2010

Luca G. Costamagna*, Sebastiano Barca**

* Dipartimento di Scienze Chimiche e Geologiche, Via Trentino, 51 - 09127, Cagliari (Italy)
** Via P. Sarpi, 18 - 09131, Cagliari (Italy)

Corresponding Author e-mail address: lucakost@unica.it

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Abstract

This field trip presents a general overview of the stratigraphical, sedimentological and paleogeographic evolution of the Middle Triassic and Middle Jurassic successions in che Central Sardinia Tacchi area (Gerrei, Sarcidano, Barbagia, Ogliastra). These successions are divided by an unconformity and are both laid down under active extensional tectonics conditions.

The Triassic Eastern Sardinia succession belongs to the Germanic Triassic Domain (Buntsandstein and Muschelkalk facies group), so showing strict affinites with the Iberian and Mid-European successions. It is featured by transgressive siliciclastic to carbonate deposits not more than few tens of meters thick: they represent the evolution from a continental, middle to low-energy environment to a restricted shallow marine one. This succession deposited along the stretching southern margin of the Paleo-European Plate under a hot-arid climate: it represents the last remain of the first Mesozoic depositional cycle in the area.

The Middle Triassic deposits pass upward through an disconformity to the Middle Jurassic transgressive siliciclastic to carbonate succession that is some houndreds of meters thick. The represented depositional environments are all those comprised between high-energy fluvial deposits (fluvial fan) and carbonate shelf margin ones. These sediments deposited under a hot-humid climate and correspond to the second Mesozoic depositional cycle of Central Sardinia. They are directly linked to the opening of the Alpine Tethys that triggered in the Eastern Sardinia area the uplift of a wide tectonic high leading to the dismantling of the main part of the previous Mesozoic (Triassic-lowermost Jurassic) to Permian successions.

Key-words: *Alluvial depositional systems, Carbonate depositional systems, Triassic, Jurassic, Extensional tectonics, Eastern Sardinia.*

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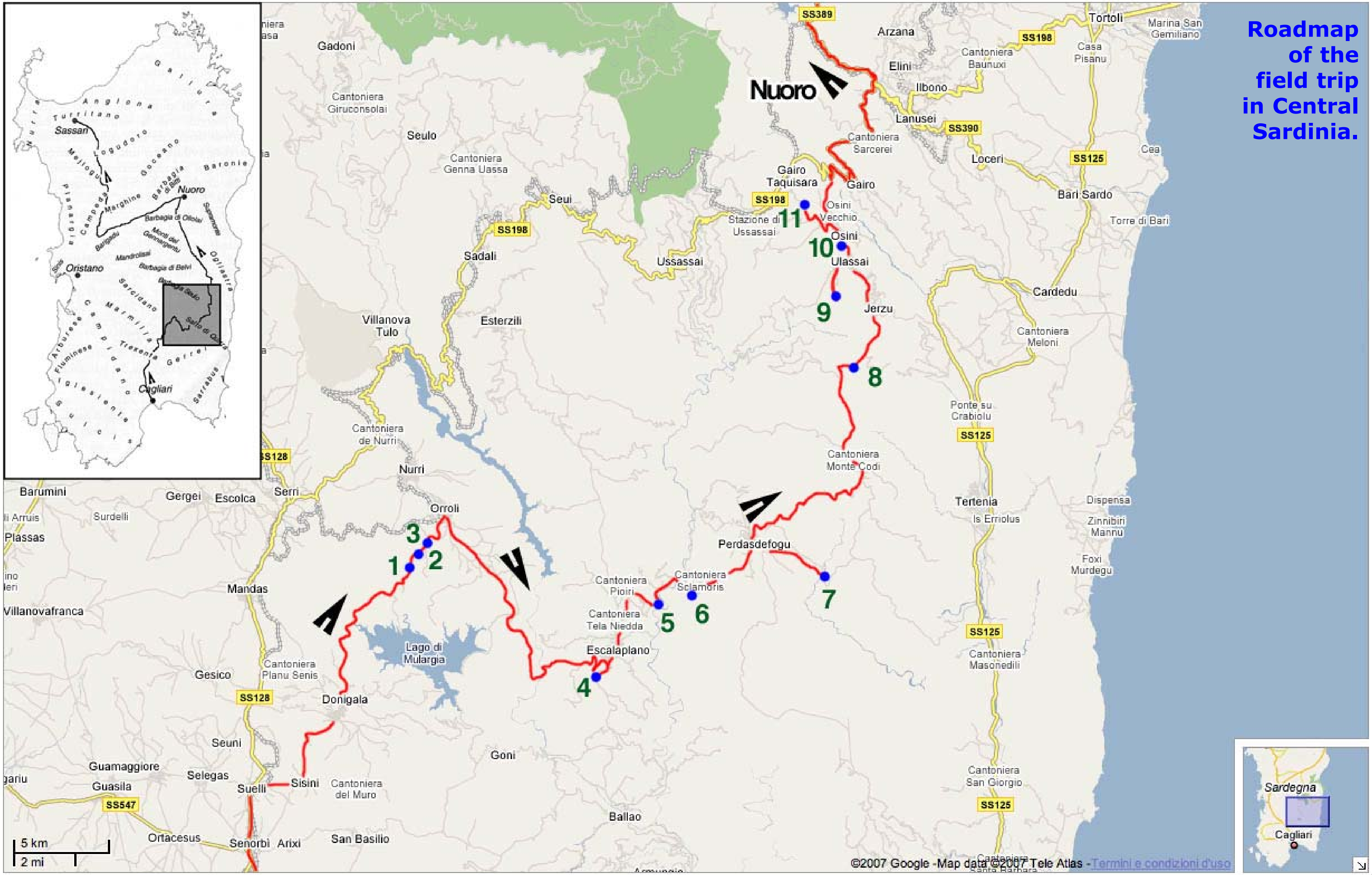
Riassunto

In questa escursione viene presentata una panoramica generale dell'evoluzione stratigrafica, sedimentologica e paleogeografica delle successioni del Triassico Medio e Giurassico medio localizzate nel settore dei Tacchi (Gerrei, Sarcidano, Barbagia, Ogliastra), nella Sardegna centrale. Tali successioni sono separate da una disconformità e si sono deposte in condizioni di tettonica estensionale attiva.

La successione medio-triassica è riferita al dominio triassico in facies germanica (gruppi di facies Buntsandstein e Muschelkalk), e mostra affinità con le successioni iberiche e dell'Europa centrale. Essa è caratterizzata da una successione trasgressiva, a litologia da silicoclastica a carbonatica, dello spessore di non più di poche decine di metri, e rappresenta l'evoluzione da un ambiente continentale di energia da media a bassa ad un ambiente marino ristretto di bassa profondità. Questa successione si è depositata lungo il margine meridionale in estensione della placca paleo-europea sotto un clima caldo-arido: essa rappresenta la sola testimonianza, lasciata dall'erosione medio-giurassica, del primo ciclo deposizionale Mesozoico nel settore.

I depositi triassici passano verso l'alto, tramite una *disconformity,* alla successione trasgressiva, anch'essa da silicoclastica a carbonatica, del Giurassico medio, dello spessore di alcune centinaia di metri. Gli ambienti deposizionali in essa rappresentati sono tutti quelli compresi fra il contesto fluviale di alta energia ed il margine di piattaforma carbonatica. Questi sedimenti si sono depositati sotto un clima caldo-umido e rappresentano il secondo ciclo deposizionale mesozoico della Sardegna Centrale. Essi sono direttamente legati all'apertura della Tetide alpina, apertura che ha attivato nella Sardegna orientale lo sviluppo di un esteso alto strutturale che ha portato allo smantellamento della parte principale delle precedenti successioni da mesozoiche (Triassico-Giurassico inferiore pp.) a permiane.

Parole chiave: *Sistema deposizionale alluvionale, Sistema deposizionale carbonatico, Triassico, Giurassico, Tettonica distensiva, Sardegna orientale.*



Roadmap of the field trip in Central Sardinia.

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Safety

Every partecipant should wear a safety shiny jacket to be worn during the stops along the motorways. The best times to make the trip are from March to May and from September to November. In this case clothing should be light, with perhaps a raincoat to spare for possible rare drizzles. All participants require comfortable walking boots. A small rucksack is needed for daily use. This needs to be at least big enough to carry a spare T-shirt (and maybe a fleece/sweater), a bottle of water and small snacks. Sun protection is needed: hats are pretty useful. Short pants are not advisable: ticks, fleas and others annoying insects are still in the field. Mobile/cellular phone coverage is good although in same place it can be absent. The emergency telephone number for ambulance is **118**. The emergency telephone numbers for police is **112** and **113**.

Hospitals

CUP Ospedale San Giuseppe - 1, Via Emilia - Isili, CA 08033 – Tel. 070 474747
P.A Croce Verde Escalaplanese - Via Santa Barbara, Escalaplano, CA 08043 – Tel. 070 8001123
Clinica Tommasini S.p.A. Via Ospedale 08044 Jerzu OG – Tel. 0782 7616

Service stations

Loc. Siurgus, Orroli, Nurri, Escalaplano, Perdasdefogu, Jerzu.

Accommodations

Omu Axiu Hotel - Via Roma, 46, 08030 - Orroli NU Tel. 0782 845023
Albergo Su Tettioni - Loc. Su Tettioni 08046 - Perdasdefogu – Tel. 0782 94190
Rifugio d’Ogliastra - Spalto 13 Km. 5, 500 - 08044 Jerzu OG – Tel. 320 606 3728

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General information about the itinerary

The field trip develops only on paved roads. Long walks will be not needed: all the outcrops will be reached by bus, plus 5 minutes of walking at most. The risk level is very low. So, people can make this trip alone or accompanied by the authors of this guidebook. The complete itinerary needs 2 days. We may spend the night of rest in a welcoming agritourism located between Perdasdefogu and Jerzu in the hearth of the Southern Ogliastra, standing right on the Variscan peneplain, whose flat continuity is broken up by the sudden rise of Jurassic carbonate mesas and plateau.

Cagliari Elmas is left behind and the motorway SS131 "Carlo Felice" running along the NW/SE oriented Plio-Quaternary Campidano graben is taken. At the Km 20 (Sardara exit) we turn to Northeast proceeding along the National Road SS128 to Senorbi. Along the travel we cross the Trexenta territory: here nearly horizontal miocenic deposits of the Tertiary Sardinian Rift crop out. We go through Senorbui, Suelli and Siurgius Donigala and keep toward East to Orroli: a few Km before reaching this little village, in the Gerrei territory, we reach the Mesozoic outcrops representing the topics of our field trip (Fig. 1): here they cover unconformably the Variscan basement outcrops pertaining to the "granitoid" batholith or to the metamorphics of the Variscan chain. The itinerary will take us in two days through the landscapes of the Gerrei and Ogliastra, with an overnight stay in a confy little residence close to Jerzu (OG).

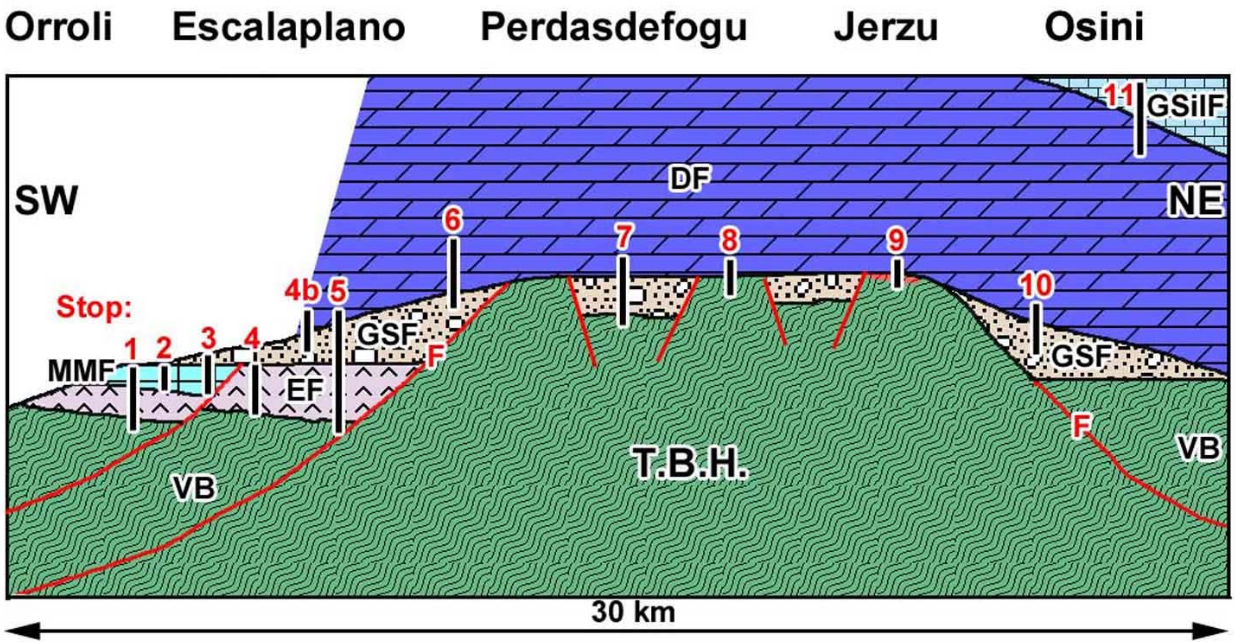

Fig. 1 - Stratigraphic and geographic location of the field trip stops: **VB**: Variscan Basement; **EF**: Escalaplano Fm.; **MMF**: Monte Maiore fm.; **GSF**: Genna Selole fm.; **DF**: Dorgali fm.; **GSilF**: Genna Silana fm; **T.B.H.**: Tectonic Barbagia High.

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Recommended cartography

Geological maps

Geologic Map of Sardinia, scale 1:200.000 (Carmignani et al., 2001);
Sheet 218 “Isili”, scale 1:100.000 of the Carta Geologica d’Italia;
Sheet 226 “Mandas”, scale 1:100.000 of the Carta Geologica d’Italia;
Sheet 541 “Jerzu”, scale 1:50.000 of the Carta Geologica d’Italia (CARG Project);

Topographic maps

Topographic Regional Map; scale 1:25.000

Touristic maps

Sardegna Carta Stradale e Turistica Scala 1:200.000 – Touring Club Editore (Italiano)
Sardinia Regional Map, Touring Club Italiano, Folded Map, Scale 1:200.000 (English)

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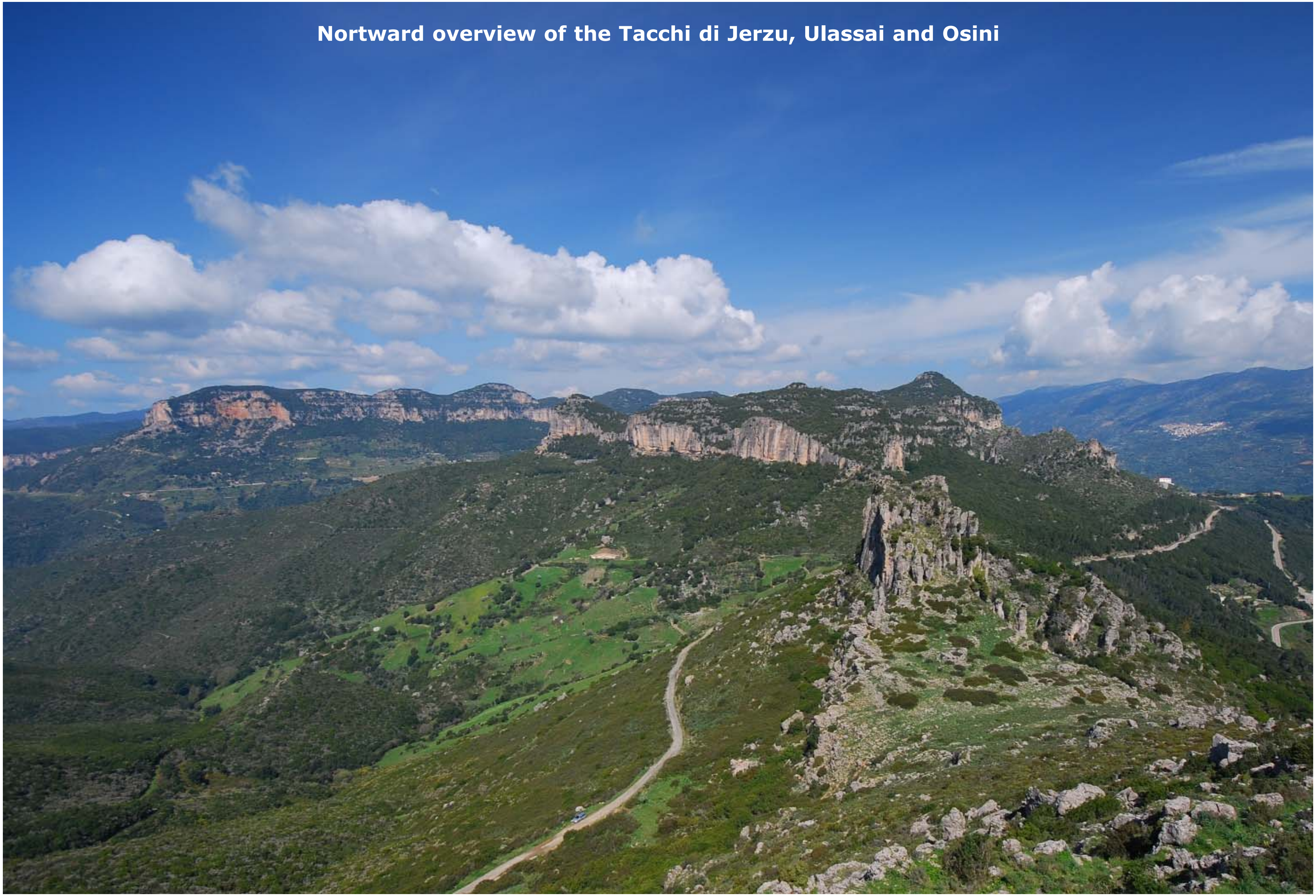

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General framework

The Tacchi area (Central Sardinia): geomorphological and paleogeographical premise

In Central-Eastern Sardinia (Gerrei, Barbagia, Ogliastra, Sarcidano), a peculiar scenery appears to the traveller: dubtless the Jurassic "Tonneri" or "Tacchi" (Plateau) area is a natural landscape showing one of the most peculiar morphological varieties in the multifaceted Sardinian geological area. This landscape is marked by flat-topped highlands, plateau, mesas and buttes which top is built of horizontal Jurassic (and rarely, Triassic) carbonate rocks resting over Variscan metamorphics (Fig. 2). These relieves are often separated from each other by deep gorges and they are located at different topographic levels rising gradually from 350 m (Tacco di Escalaplano) in the South to 1300 m (Tacco di Seui) to North. This is due to the Tertiary uplifting tectonic movements of the area. This tectonics, together with the coeval Cenozoic-Quaternary erosion, determined the present scattered distribution of the Jurassic outcrops. These outcrops represent the remnants of a former widespread and uninterrupted Mesozoic continental to marine cover, which deposited most likely over the whole Sardinia Island: this assumption is suggested by the correlatable, similar rocks of the Jurassic of Eastern - Northeastern Sardinia (Supramonte, Golfo di Orosei, Isola di Tavolara, Capo Figari), of the the Mesozoic succession of the Nurra N and E of Alghero (NW Sardinia) and of the Triassic to Jurassic rocks of the Sulcis area (Porto Pino, S. Antioco: SW Sardinia).

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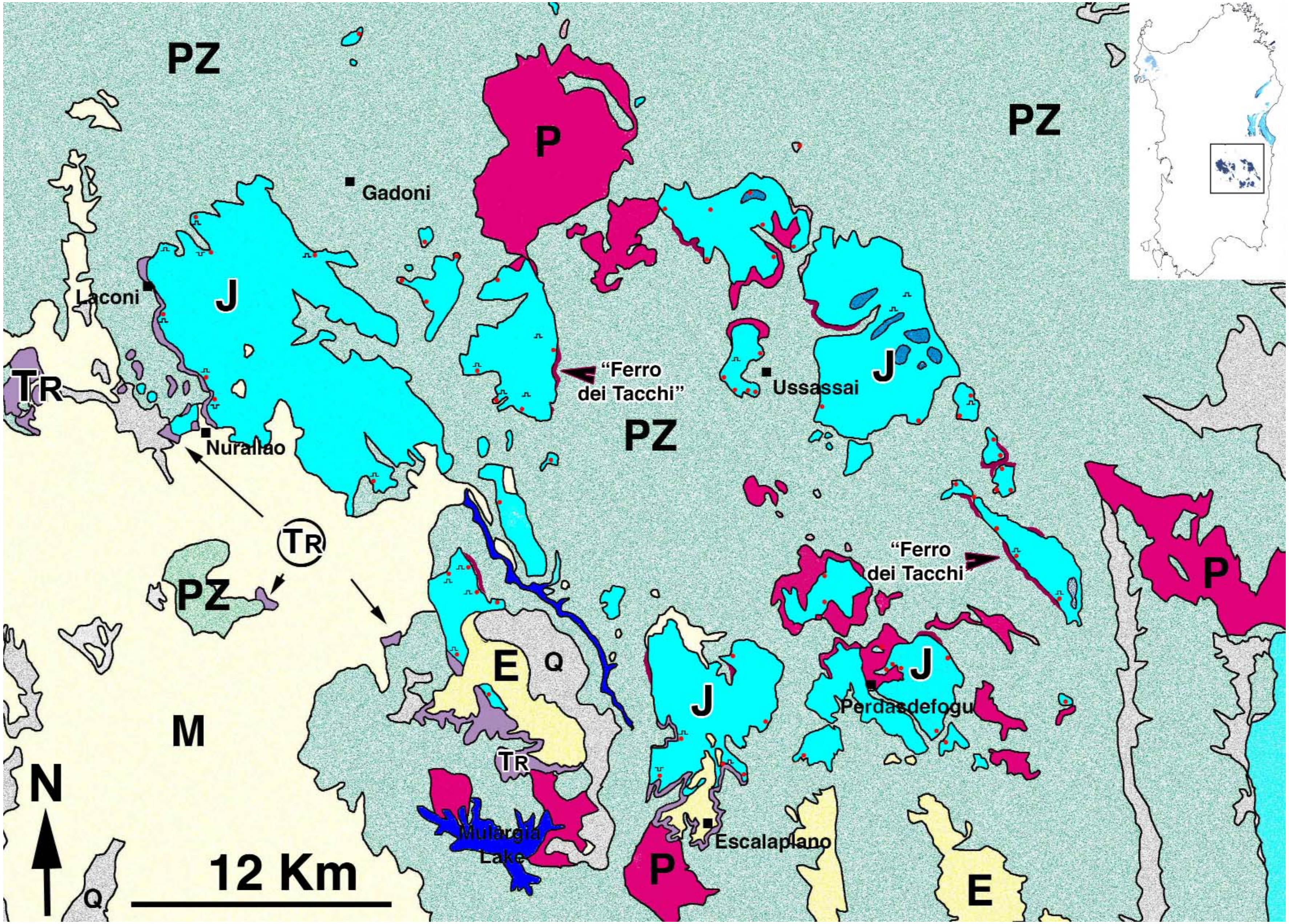

Fig. 2 – Geological map of the Tacchi area; **PZ** = Paleozoic Variscan Basement; **P** = Permian; **TR** = Triassic; **J** = Jurassic; **E** = Eocene; **M** = Miocene; **Q** = Quaternary; **Red dots** = stratigraphic sections. The Ferro dei Tacchi level and inactive and active quarries are also signed.

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Geological setting

1. Variscan Paleozoic Basement and Permo-Carboniferous covers

In Central Sardinia (Fig. 3) the Mesozoic deposits cover mainly the Variscan metamorphics through an angular unconformity. More rarely, they could be posed unconformably over Permo-Carboniferous post-Variscan molassic sediments.

In Central Sardinia the Variscan lithologies (Late Cambrian-Early Carboniferous) are assigned to different tectonic units: their metamorphic degree grows up northward. Those tectonic units pertain to the "Inner Nappe Zone" and to the "Outer Nappe Zone" (Carmignani et al., 1992; 1994). As sketched before, the Variscan metamorphics may be locally covered unconformably also by little remains of molassic sediments belonging to the limnic sediments cycle (Late Carboniferous – Early Permian) and/or to the red beds sediments cycle (Permian): they reach a maximum thickness of 400 m (Cassinis et al., 2000).
The allochton Variscan units are formed by low- to middle grade metamorphics deriving mainly from terrigenous deposits: volcanics and carbonates are subordinate protoliths.

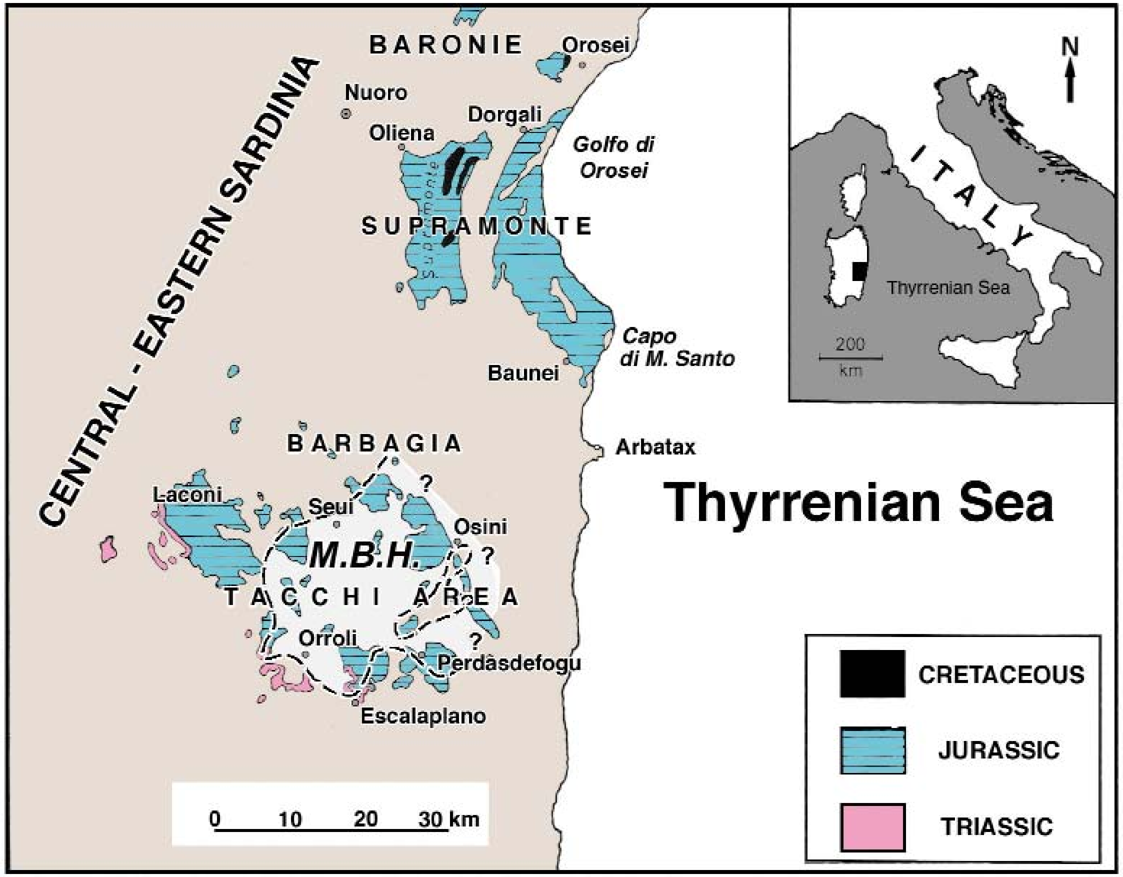

Fig. 3 – Geological sketch of the Tacchi area with evidenced the Mesozoic outcrops: the location of the tectonic Barbagia paleohigh is evidenced (M.B.H.) (modified after Costamagna et al., 2007).

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2. Post-variscan geological evolution: Triassic

2.1. Triassic successions: regional frame and stratigraphy

During Late Carboniferous and Permian times the Variscan chain gradually collapses. Intra-chain molassic basins developed. These basins were filled by erosive deposits (Cassinis et al., 2000; Cassinis & Ronchi, 2002). Afterwards, the extensional tectonic cycles break up the Pangea (Ziegler, 1990): the extension spreads down to the southern subsiding border of the Paleo-Europe where the Sardinia-Corsica block was located (Fig. 4). Thus the first Mesozoic depositional cycle started: it is referable to the lower part of the wider Alpine tectono-sedimentary cycle.

The Sardinian area was located on the southern edge of the Paleo-Europe (Costamagna & Barca, 2002). It is characterized by Triassic deposits belonging to the Germanic facies.
In Central Sardinia the Middle Triassic starts with continental (red beds facies) to transitional-lagoonal–littoral sediments belonging to the Escalaplano Fm. (late Anisian – early Ladinian?) (Sardinian Buntsandstein group) (Costamagna et al., 2000; Costamagna & Barca, 2002). These sediments are the base of the sedimentary cycle and forecast the marine trasgression induced by the extensional movements of the Alpine tectonics.

Following the peneplaning and the almost complete flooding of the Variscan basement, the Escalaplano Fm. mainly siliciclastic sediments are covered by the Monte Maiore fm. (Sardinian Muschelkalk group), built of carbonate shelf deposits aged late Middle Triassic (Ladinian).

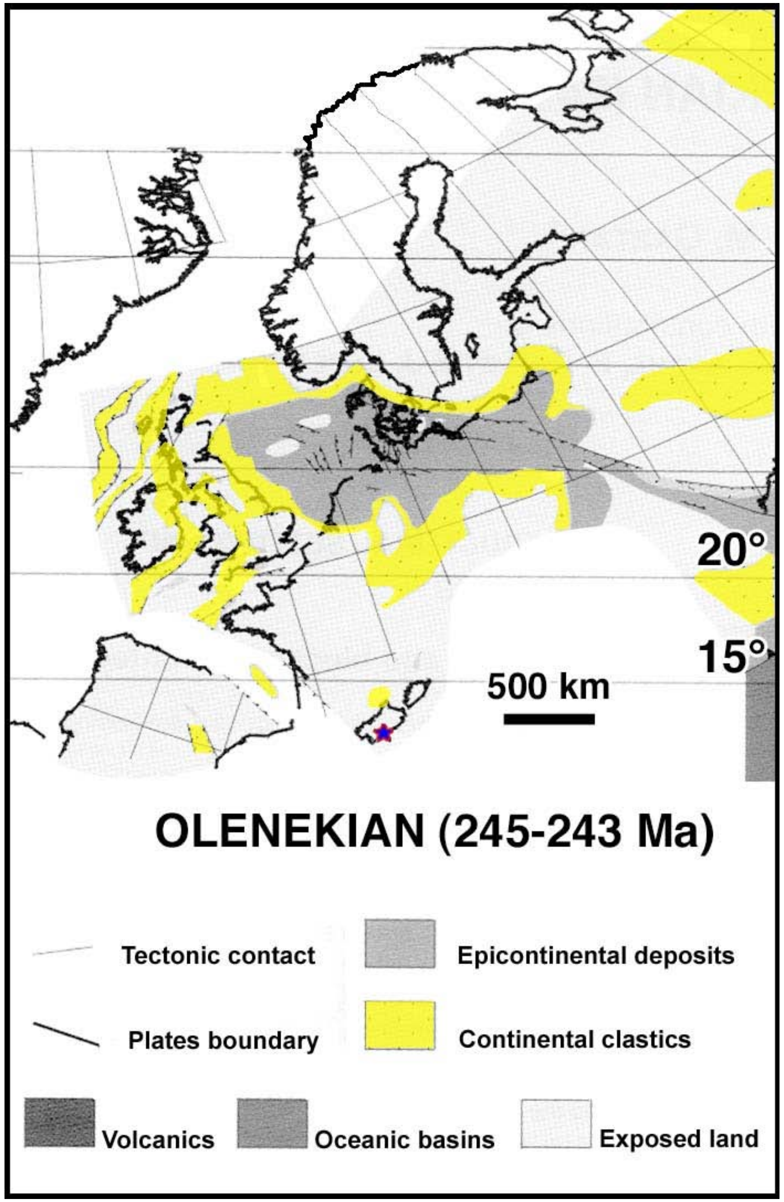

Fig. 4 – Olenekian (Lower Triassic): European paleogeography and Sardinia: the star marks the field trip area. (modified after Dercourt et al., 2000).

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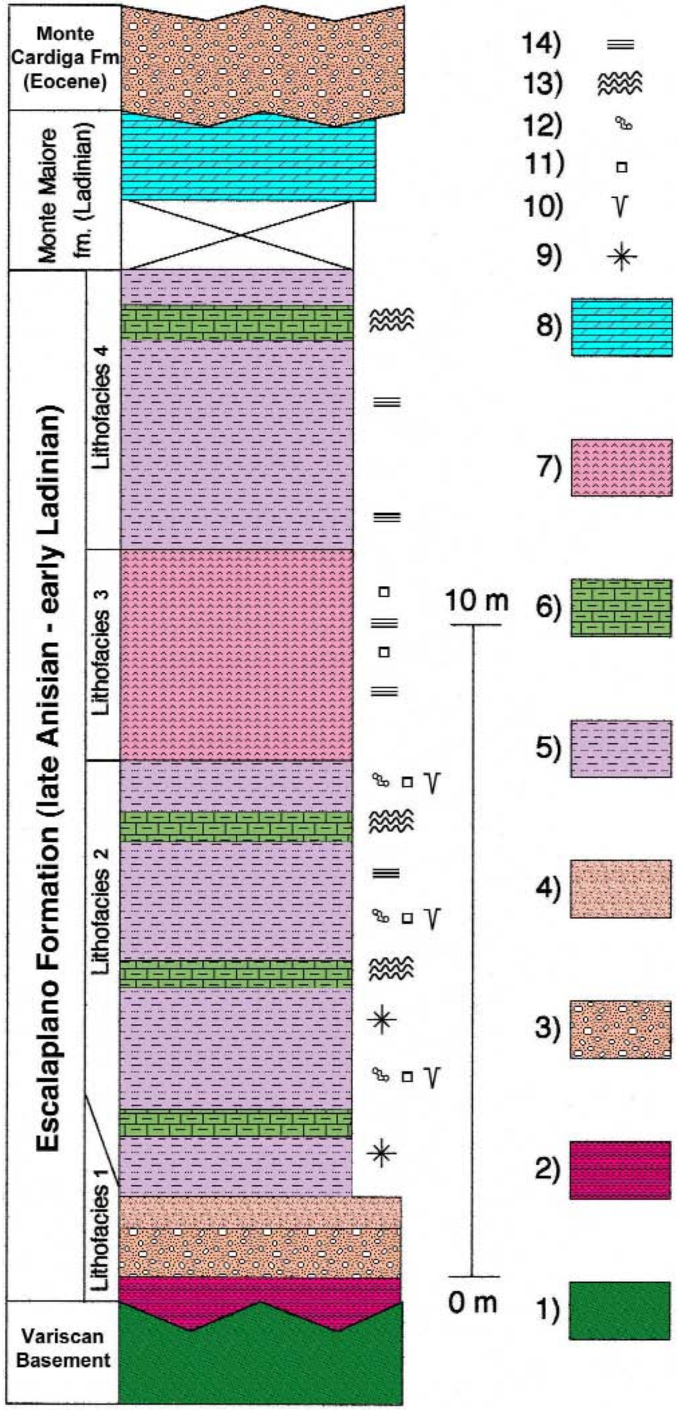

2.1.1. *Escalaplano Fm. (Middle Triassic: late Anisian – early Ladinian?)*

The Escalaplano Fm. (Fig. 5), from 0 to 20 m thick, shows at Escalaplano (Gerrei) a well-exposed type section. This unit can be subdivided into 4 lithofacies. The Formation is validated by the Italian Commission on Stratigraphy (Delfrati, 2006a).

Litofacies 1

The lithofacies 1, the thinnest one, is formed by conglomerates, rare breccias and sandstones, and lies unconformably over the Variscan basement. The conglomerates can be matrix- or clast-supported, rarely with cross bedding or graded bedding. They are formed by pebbles made up by quartz, metamorphics and rare reworked Permian volcanics. The sandstones are immature.
This lower lithofacies shows up evidently only in the southeasternmost outcrops of the Escalaplano Fm.: elsewhere, it can be very thin and discontinuous, or be no present at all.

Litofacies 2

The lithofacies 2 is built of rhythmic alternations of clays, siltites and marls showing plane-parallel laminations and bedding. Rare, thin sandstone layers are also present. This lithofacies can be reddish to grey, rarely blackish in colour. In the blackish levels a rich palynological association referable to the late Anisian is contained. In the reddish

Fig. 5 - Escalaplano (Gerrei, Central Sardinia) type section of the Escalaplano Fm. Legend – **1)** Reddish to greenish metasandstones (Variscan basement; **2)** Basal pedogenization of the basement; **3)** Conglomerates; **4)** Sandstones and conglomerates; **5)** Siltites and clayey siltites; **6)** Carbonate sandstones and marls; **7)** Siltites, clays and evaporites; **8)** Dolostones; **9)** Palynomorphs-bearing horizons; **10)** Mud-cracks; **11)** Halite – casts; **12)** Bioturbation; **13)** Microbialitic mats; **14)** Plane-parallel laminations (mod. after Costamagna & Barca, 2002).

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clay levels mud-cracks, bioturbation structures and halite-casts can be found. In the blackish to yellowish marly levels, wrinkled microbialitic mats and chaotic algal envelopes have been observed frequently. In the easternmost outcrops of the lithofacies 2 the marls gradually fade out and are replaced by sandstone layers locally showing cross lamination structures.

Litofacies 3

The lithofacies 3 is formed by alternations of fissile blackish and purplish clays and thin levels of pinkish gypsum locally filling late fractures connecting the different levels. The gypsum has a satin spar appearance that suggests it is now mainly due to ricirculation of sulphate solution.

Litofacies 4

The lithofacies 4 is usually constituted by silty-marly to marly-carbonate lithologies. In the Escalaplano area this lithofacies is made by grey-greenish, infrequently reddish, clays and silty clays. Rarely, thin fine sandstones layers are present. In this lithofacies the gypsum beds vanish suddenly and pass to carbonate sediments. This change foretells the close passage, throughout green-yellowish clayey marls, to the dolostones of the Monte Maiore fm.

The lithofacies 2 and 3 of the Escalaplano Fm. are clearly separated only in the Escalaplano area. In the westernmost areas (Orroli, Nurri, Escalaplano, M. Maiore) they instead form a single unit made by silty clays and clayey siltites: while in its lower part the purplish colour prevails, in the upper part it changes to grey-green. The blackish deposits, the marls and the evaporites are very scattered. Nonetheless, mud cracks and halite casts are still present in the reddish siltites and clays. Rarely, in the lithofacies 2 thin nodular calcrete horizons have been observed.
In the northern areas (Orroli, Tacco del Sarcidano) the passage to the carbonate Monte Maiore fm. may take place throughout a dark grey-greenish lithofacies at most 1 m thick: here suddenly the carbonates appear and rapidly came to be dominant.
The age of the base of the Escalaplano Fm. is marked by microfloristic assemblages found in the lithofacies 2 and referred to the Pelsonian – Illirian (late Anisian: *Cristianisporites triangulatus* Antonescu 1969: Pittau Demelia & Flaviani, 1983; Costamagna et al., 2000). Due to the missing of palaeontological reliable data, the top of the unit is tentatively referred to the early Ladinian.

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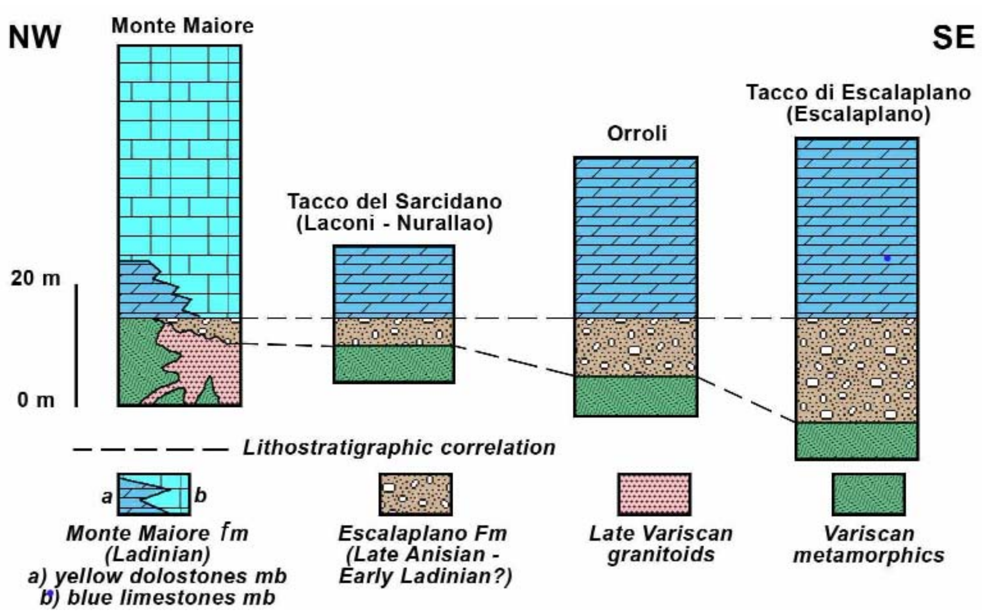

The Escalaplano Fm. thins out gradually towards NW (Fig. 6): it vanishes almost completely in the northern area of Laconi and Monte Maiore (Nurecci). At Monte Maiore the Mesozoic deposits may even start with sandy to pebbly dolostones of the Monte Maiore fm covering directly the Variscan basement. Close to the the base of the unit, limestone beds contain storm layers with basal lags bearing the Germanic Triassic marker *Costatoria goldfussi*, so dating the marine transgression to the early late Ladinian.

Fig. 6 – Lateral correlations of the Triassic succesions in Eastern Sardinia from NW (Monte Maiore) to SE (Escalaplano): note the northwestward thinning of the Escalaplano Fm. (mod. after Costamagna et al., 2000).

2.1.2. Monte Maiore fm. (Middle Triassic: early – late Ladinian)

The Escalaplano Fm. is followed by the dolostones and limestones of the Monte Maiore fm. (Fig. 7) (Costamagna et al., 2000; Sardinian Muschelkalk group, Costamagna & Barca, 2002). This unit is only informally defined for the lack of a well-exposed and continuous type section. The best outcrops are located at Monte Maiore. The Monte Maiore fm. is constituted by two members: the yellow dolostones member and the blue limestones member. The yellow dolostones member developes upwards differently depending to the location of the outcrop.

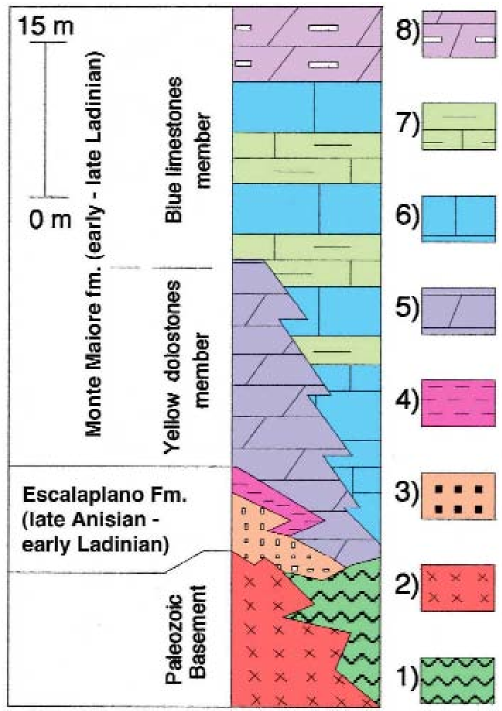

Fig. 7 - Monte Maiore (Sarcidano, Central Sardinia): Middle Triassic succession.
Legend: **1)** Variscan micaschists (Variscan basement); **2)** Late-Variscan granitoids; **3)** Conglomerates; **4)** Silty clays; **5)** Dolostones; **6)** Limestones; **7)** Marly limestones; **8)** Dolostones containing chert nodules.

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Southwestward, where the Monte Maiore fm. rests over the Escalaplano Fm., the transition from the lower unit is gradual. Lacking the Escalaplano Fm., the base of the Monte Maiore fm. is built of yellowish dolostones containing scattered quartz and rare cm-sized angular pebbles of metamorphic rocks. Thin layers of quartzose matrix(dolomitic)-supported conglomerates intercalate.
At Monte Maiore the yellow dolostones member, 0 to 25 m thick, is formed by grey-yellow to yellowish stratified dolostones. Where the Escalaplano Fm. misses, the lower terrigenous-carbonate cobbly basal facies is covered by irregular alternations of dolomitic lithofacies as 1) Collapse breccias horizons; 2) Halokinetic-featured levels; 3) Thickly stratified dolostones containing evaporitic molds, calcitic pseudomorphs after sulphates and scattered nodules of chert; 4) Laminated algal bindstones locally with fenestral texture; 5) Finely dolomitized peloidal mudstones and fine mudstones. Rare thin storm layers intercalate: the basal lag is formed by bioclasts (microbial mats and green algae fragments, bivalves, gastropods, ostracods) and peloids. In this member the fossil remains are rare.

Upwards and aside the upper part of the yellowish dolostones member, the blue limestones member appears (Fig. 7). Usually the passage between the two members is gradual: it takes place through grey calcareous dolostones (oolitic-bioclastic, rarely peloidal grainstones), followed by blue, well-stratified limestones rich of bioclasts and peloids. The fossil rests are crinoids, gastropods, bivalves, ostracods. The intermediate part of this member contains bluish limestones with intercalations of grey-greenish calcareous marls and marls. Frequently the limestone beds are built of alternations of bioturbated calcarenites-calcilutites and storm layers provided of a coarse basal lag containing fragments of gastropods and bivalves, followed by calcarenites with HCS structures (Hummocky Cross Stratification). Thin calcareous storm layers are infrequently contained in the marly beds too.
The top of the blue limestones member is featured first by the vanishing of the marly intercalations, and afterwards by pinkish dolostones with algae (Damiani & Gandin 1973 a, b, c), containing nodules of chert. The thickness of this member is estimated 35-40 m. So, the total thickness of the formation in the Monte Maiore area reaches about 50 m.
The age of the Monte Maiore fm. may differ depending to the locality: as the Escalaplano Fm., it becomes younger towards NW, this way following the Middle Triassic transgression progress over the peneplaned Variscan continent. In the Monte Maiore area, the age of the transgression is marked by calcareous layers containing remains of *Costatoria goldfussi*: they suggest an early late Ladinian age. Otherwise, in the Escalaplano area, the beginning of the carbonatic sedimentation could be referred to the early Ladinian.

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2.2 Depositional environment of the Triassic succession

2.2.1 Escalaplano Fm.: alluvial fans and mudflats

The Escalaplano Fm. begins with small, thin, short-lasting alluvial fans with low relief (litofacies A). They are built of scattered flood lobes deposited by streams flowing out from the valleys outlets located behind. Alternatively, for the waning tectonic activity, mild alluvial slopes *sensu* Smith (2000) (Fig. 8) run by stream floods could be hypothesized.

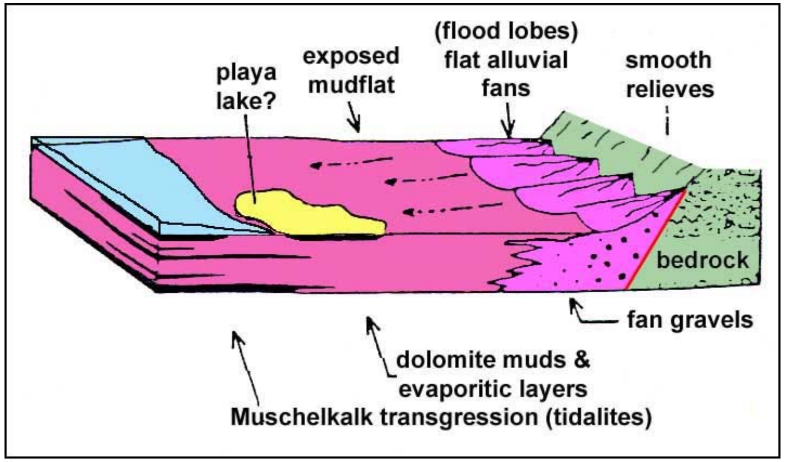

Fig. 8 – Depositional environments of the Escalaplano Fm. (late Anisian – early Ladinian) (mod. after Costamagna et al., 2009).

These higher energy depositional bodies withdraw gradually and disappear. Over these, firstly a mudflat with scattered playa lakes and slack water mirrors (lithofacies 2, 3 and 4 of the Escalaplano Fm., Costamagna et al., 2000), perhaps interested by weak tidal processes, takes place. This environment is often characterized by the deposition of dark muds rich of organic matter intercalated periodically by evaporitic episodes. Spotted bioturbations, mud-cracks, halite-casts and thin layers of gypsum support this reconstruction. Rare marly limestones with microbial mats intercalate in the middle-upper part of the unit: this suggests ephemeral marine ingressions before the ultimate marine flooding.

2.2.2. Monte Maiore fm.: homoclinal ramp sub-environments

The Monte Maiore fm. is initially featured by a transgressive trend. With the vanishing of the terrigenous input and the rise of the sea level, the continental-transitional Escalaplano Fm. environments are replaced by sabkha supratidal facies (Costamagna & Barca, 2002), followed later by tidal flat / shallow, low-energy, restricted lagoon environments. Here lay down carbonatic muds, microbial mats, storm layers and scattered evaporites forming the yellowish dolostones member of the Monte Maiore fm. (Costamagna et al., 2000). Afterwards, the sea level keeps rising, the carbonatic lagoon open up and is gradually covered by the deeper, outer shelf facies, formed initially by oolidal-oncoidal calcarenites representing an intermediate, bordering shallow bar dividing the inner from the outer shelf. The outer shelf is featured by alternations of fine calcarenites, bioturbated calcilutites and marly limestones

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forming the blue limestones member. Here storm layers intercalate. Over those marly-calcareous alternations, the renewing of the regressive trend is marked by the coming back of the blue limestones first, and later by pinkish dolostones with algae, evaporites and nodules of chert: this lithofacies forms the top of the succession.

The orientation of the shelf in respect to the eastern trade winds (Calvet & Tucker, 1988) makes storms a prevailing depositional mechanism. Besides, for the previously evidenced sedimentological features of the shelf (storm deposits abundance; lacking of lagoon-protecting bioconstructions; absence of slope and high-energy deposits), the morphology of this carbonate shelf can be referred to an homoclinal ramp (Figs 9, 10) (Costamagna & Barca, 2002).

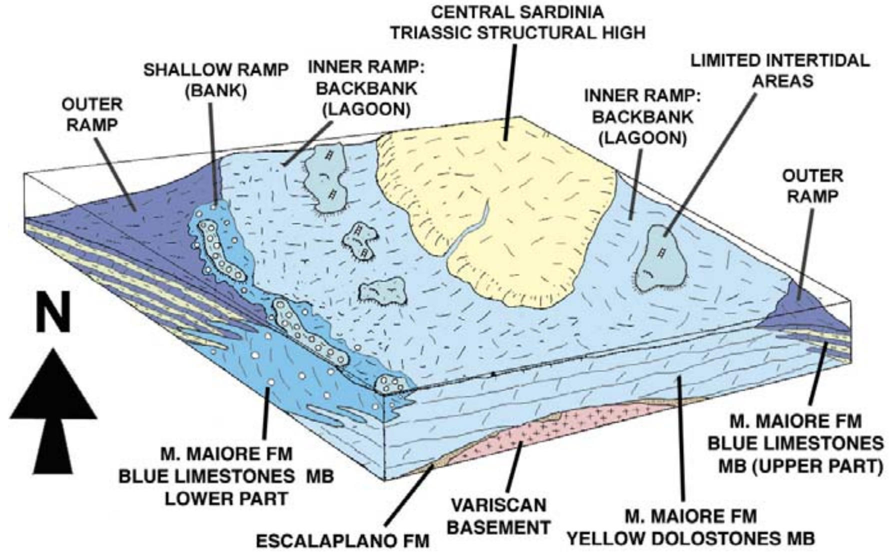

Fig. 9 – Paleogeography of the carbonate ramp of Central-Southern Sardinia during early Ladinian times. The structural high of Central Sardinia, entirely surrounded by the Triassic sea, will be gradually submerged during the maximum eustatic flooding of the late Ladinian. Note the progressive landward shift of the outer ramp facies. (mod. after Costamagna & Barca, 2002).

TRANSGRESSIVE EVOLUTION OF THE EARLY MIDDLE TRIASSIC CARBONATE RAMP				
OUTER RAMP	SHALLOW OUTER RAMP	SHALLOW INNER RAMP	INNER RAMP BACK RAMP	SABKHA
BELOW FAIR WEATHER WAVE BASE		WAVE AND STORM-DOMINATED	PROTECTED/SUBAERIAL	
marls, bioturbated limestones	bedded mudstones, bioturbated wacke- and mudstones, rare marls	sand (oolitic-bioclastic) belt and shoals, erosive surfaces, thick storm layers	lagoonal mudstones and marls, tidal flat (microbialites), supratidal carb. + evaporites, rare fine storm layers, erosive surfaces	

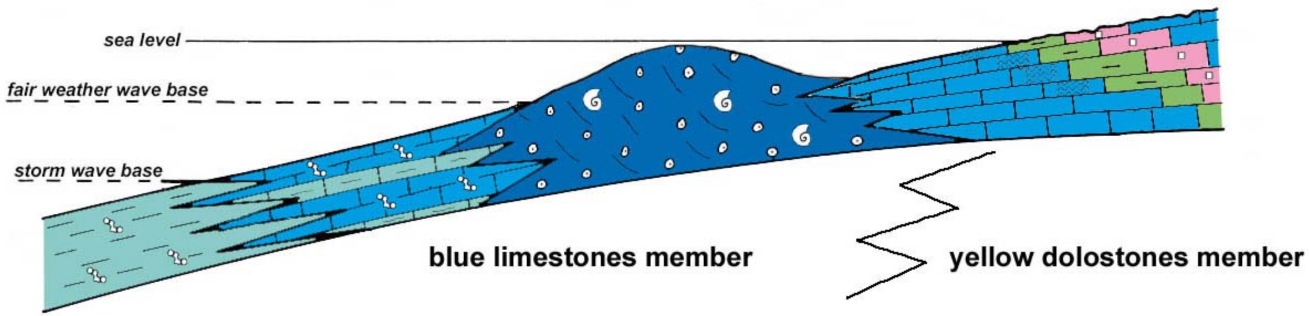

Fig. 10 – Transgressive evolution of the carbonate ramp of Central Sardinia during late Anisian to early Ladinian times. The outer ramp facies of the blue limestone member move gradually over the inner ramp-lagoon facies – tidal flat facies of the yellow dolostones mb.

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2.3 First Mesozoic sedimentary cycle in Central Sardinia: some remarks

As mentioned above, the Escalaplano Fm. and the Monte Maiore fm. are partially coeval (Figs 6, 7): in fact, the rising branch of the marine Triassic transgression over the peneplaned Variscan basement of Central Sardinia progresses gradually to N towards the last Variscan highs and so covering the gradually thinning continental-transitional deposits of the Escalaplano Fm. So, this first sedimentary cycle is initially formed by continental to transitional sediments, and then by marine carbonate deposits. The late Anisian sedimentary transgression (*sensu* Busson, 1982) is marked in the Escalaplano area by a microfloristic assemblages found in the lower part of the lithofacies 2 of the Escalaplano Fm.

The transgression completed during the early late Ladinian, when the Monte Maiore area, where the carbonates cover direcly the Variscan basement, was flooded (Costamagna et al., 2000). Here calcareous dolostones and dolomitic limestones containing quartz angular pebbles represent the basal deposit of this first sedimentary cycle. These deposits are rapidly followed by limestones containing *Costatoria goldfussi*: this bivalve is an index specimen of the late Ladinian in Catalonia (Sephardic Province of the Germanic Triassic Domain: Hirsch et al., 1987; Hirsch, 1991), that at those times was very close to the Sardinian area.
In part of the the Monte Maiore area, the lacking of prevalently terrigenous deposits at the base of this first depositional Mesozoic cycle, together with localized, thin lateritic deposits covering the metamorphic Variscan basement (Damiani & Gandin, 1973b; Costamagna, 1998) suggest the complete flooding of central Sardinia by the carbonate Triassic sea at late Ladinian times. At those times, perhaps, only the northeasternmost part of the Island (Gallura area) emerged from the sea (Figs 11, 12).

On the whole, the lower part of the succession, comprised between the continental lower part of the Escalaplano Fm. and the middle part of the upper member of the Monte Maiore fm. figuring out an outer ramp environment, represents the transgressive event of the sedimentary Triassic megacycle, debuting in Sardinia at late Anisian times and expressing during late Ladinian its maximum flooding surface (Costamagna & Barca, 2002). In Central Sardinia, the regressive part of this megacycle is represented only by the topmost part of the blue limestones member of the Monte Maiore fm. (Fig. 7).

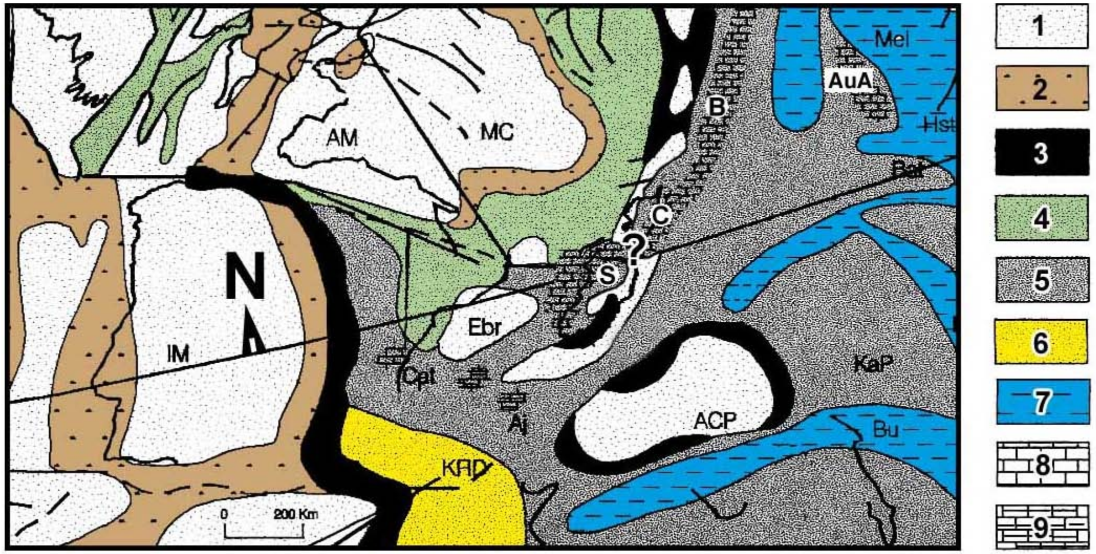

Fig. 11 – Late Anisian paleogeographic setting of the Western Tethys and Sardinia. Legend: **1)** Exposed land; **2)** Fluvio-lacustrine environments; **3)** Margino-litoral to lacustrine environments; **4)** Carbonate(?)-Evaporitic shelves; **5)** Shallow shelves; **6)** Terrigenous shallow shelves and basins; **7)** Slopes and deep basins; **8)** Shallow carbonates; **9)** Marls and clayey carbonates. **Aj** = Alpujarride; **ACP** = Apennine Carbonate Platform; **AM** = Armorican Massif; **Aua** = Australpine; **B** = Brianconnais; **Bat** = Balaton; **Bu** = Budva Through; **C** = Corsica; **Cpt** = Calabria-Peloritain Massif; **Ebr** = Ebro Massif; **Hst** = Hallstatt; **KaP** = Karst Platform; **KRD** = Kabila-Riff Ridge; **IM** = Iberian Meseta; **MC** = Central Massif; **Mel** = Meliata; **S** = Sardinia.

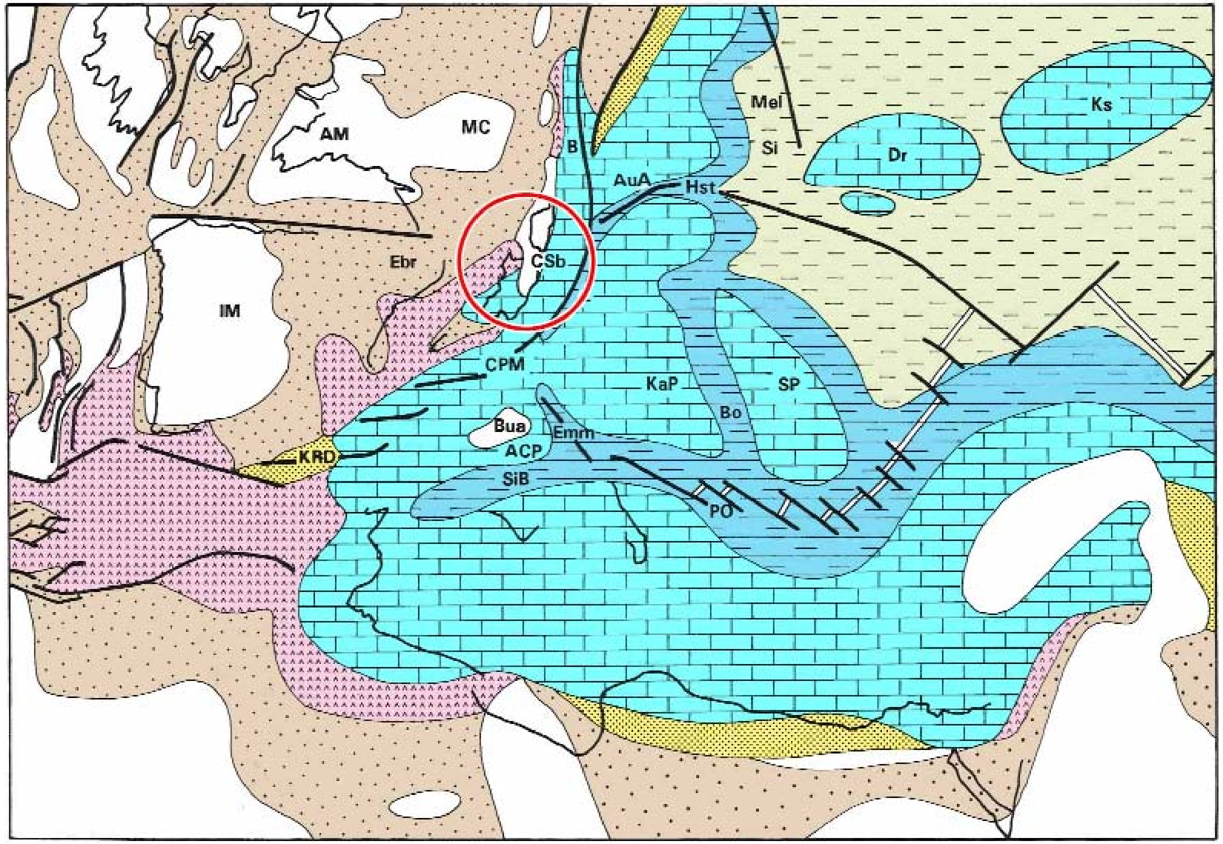

Fig. 12 – Late Norian paleogeography of Western Tethys and Sardinia (mod. after Costamagna & Barca, 2002 and from Dercourt et al., 2000): **ACP** = Apennine Carbonate Platform; **AM** = Armorican Massif; **AuA** = Australpine; **B** = Brianconnais; **Bo** = Bosnia; **BuA** = Burano; **CPM** = Calabria-Peloritain Massif; **CSb** = Sardinia-Corsica Massif; **Dr** = Drama; **Ebr** = Ebro Massif; **Emm** = Emma; **Hst** = Hallstatt Zone; **KaP** = Karst platform; **KRD** = Kabilia-Riff ridge; **Ks** = Kirsheir; **IM** = Iberian Meseta; **L** = Lombardy; **MC** = Central Massif; **Mel** = Meliata Zone; **PO** = Pindos-Olonos Zone; **Si** = Sicilicum; **SiB** = Sicanian Basin; **SP** = Serbo-Pelagonian Massif.

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Basing on several indirect leads found even at regional scale we suggest the first sedimentary Mesozoic cycle in Central Sardinia comprised even Late Triassic to Early Jurassic deposits, despite the fact they actually are nowhere to be found: the well-dated Middle Jurassic continental deposits cover unconformably terrains not younger than the Ladinian carbonates. So, the erosion of the Late Triassic – Early Jurassic deposits for the Tethyan extensional tectonics prevents to settle the environments developing in Central Sardinia during these times. Anyway, similarly to the close Western Sardinian areas (Nurra, NW Sardinia: Cherchi & Schroeder, 1986; Sulcis, SW Sardinia: Costamagna, 2000; Costamagna & Barca, 2002), and by means of the reworked pebbles sampled from the Eocene Chiappa conglomerates in Southern Corsica (Durand-Delga & Peybernés, 1986), a more or less restricted shallow carbonate shelf is hypotesizable at those times even in almost all the eastern part of Sardinia.

3. Post-variscan geological evolution: Jurassic

3.1. Jurassic successions: regional frame and stratigraphy

In Central, Eastern and Northeastern Sardinia the Middle-Late Jurassic successions (Fig. 13) lay down unconformably over the Variscan metamorphics, or, more rarely, on the first cycle Triassic deposits, or the older Permo-Carboniferous molassic deposits.

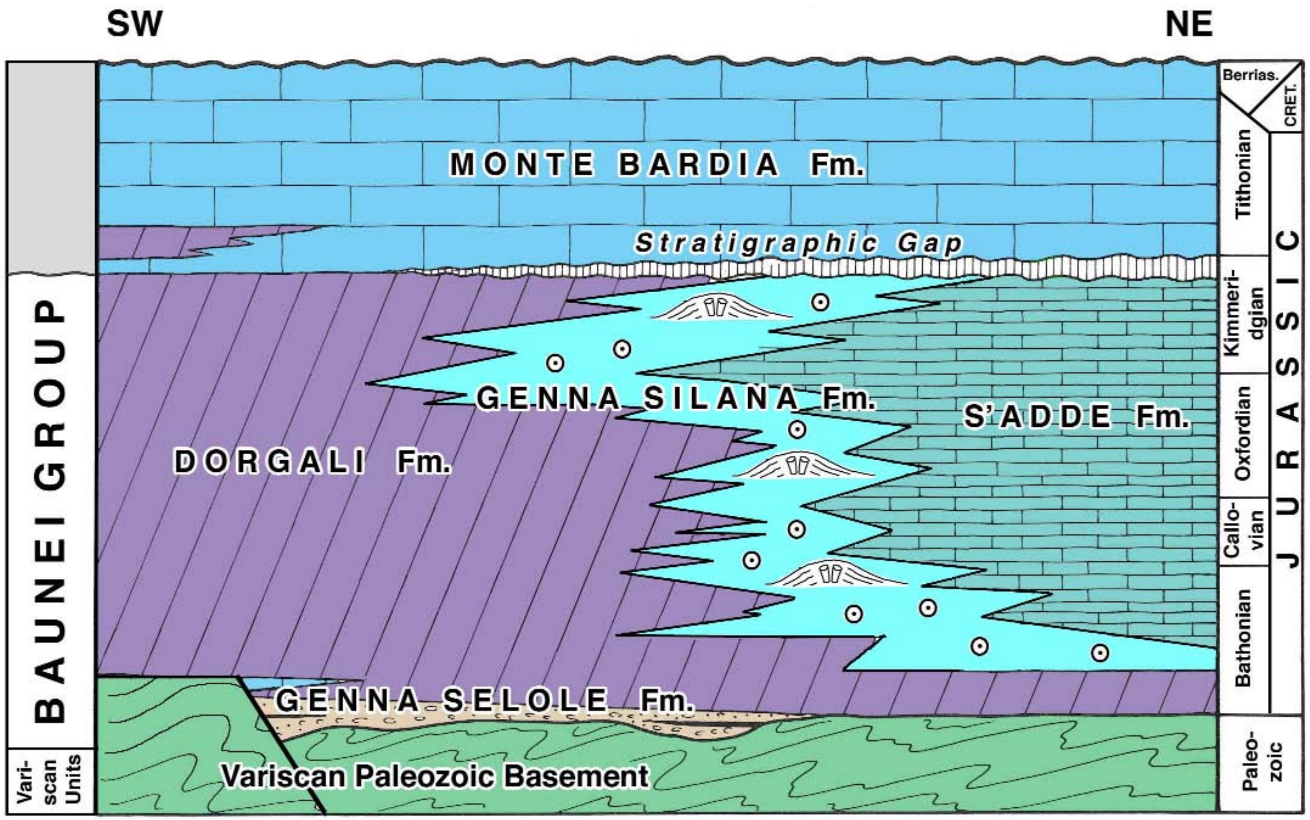

Fig. 13 - Stratigraphy and general framework of the Central-Eastern-Northeastern Sardinia Jurassic (after Costamagna et al., 2007).

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Thus, these sediments cover usually a variously eroded, older substratum. In the Tacchi area the depth reached by the erosion in different sectors is related to their location in respect to the paleorelief (tectonic Barbagia paleohigh) rised in Central Sardinia (Figs 14, 15) (Costamagna & Barca, 2004; Costamagna et al., 2007). This articulated landscape was created by extensional tectonics connected with the opening of the Alpine Tethys (Early-Middle Jurassic, Bernoulli & Jenkyns, 1974; Abbate et al., 1986). The more the areas were uplifted, the deeper dug up the erosion: so, in the central part of the paleohigh (Perdasdefogu, Esterzili, Ussassai, Seui) the Lower Jurassic and Triassic successions, most of the remaining part of the Permian and Carboniferous covers left by the former coeval erosional cyles (Cassinis et al., 2000), and often also sectors of the Variscan basement itself were dismantled. Otherwise, in the SW marginal, sloping parts of the paleohigh still the Middle Triassic remained (Laconi, Nurallao, Nurri, Escalaplano). Those mentioned localities are posed along a NW/SE belt possibly corresponding to a main extensional discontinuity reviving a former Variscan main thrust. The erosion and the pedogenesis developed over the surface of the discovered Variscan basement in the central part of the Barbagia paleohigh are evidenced

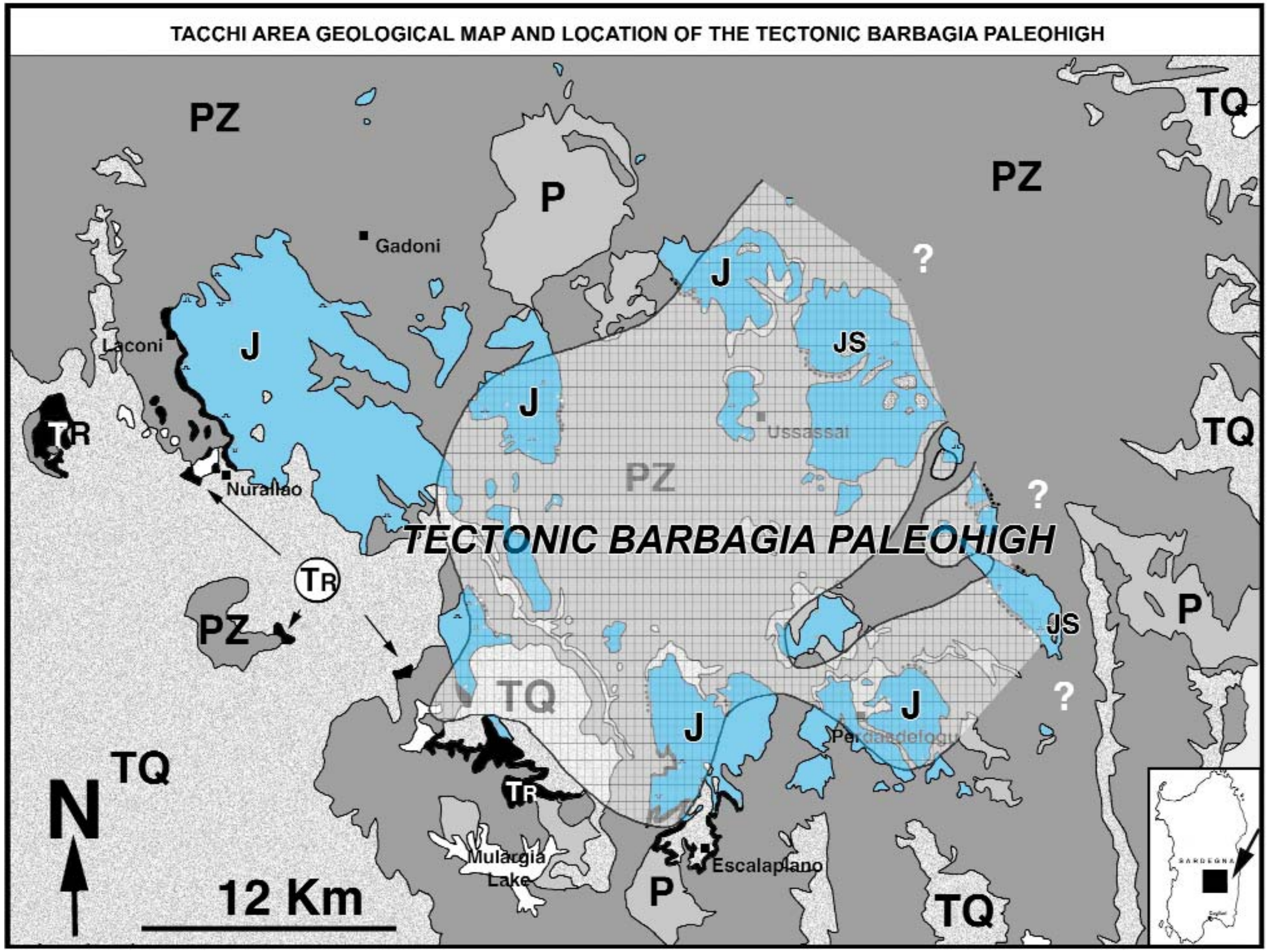

Fig. 14 – Location of the tectonic Barbagia paleohigh in Central Sardinia. **PZ** = Variscan basement; **P** = Permian; **TR** = Middle Triassic; **J** = Middle Jurassic; **Js** = Late Jurassic; **TQ** = Tertiary and Quaternary

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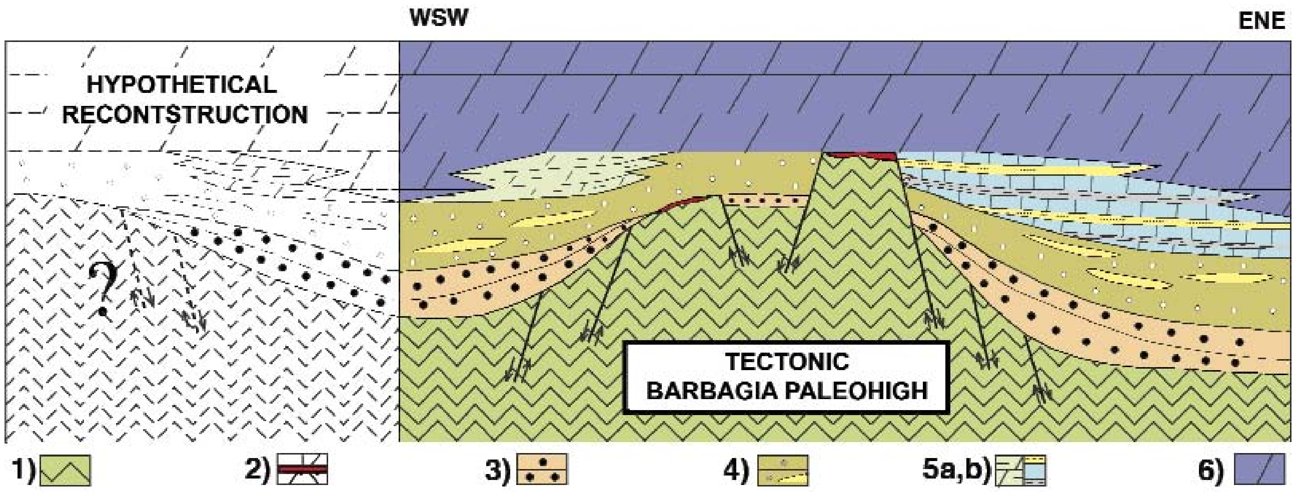

Fig. 15 - Sketch of the setting of the Jurassic deposits in the Tacchi area. **1)** Variscan basement; **2)** "Lateritic paleosoils"; **3)** Genna Selole fm.: Laconi-Gadoni lithofacies; **4)** Genna Selole fm.: Nurri-Escalaplano lithofacies; **5)** Genna Selole fm.: Ussassai-Perdasdefogu lithofacies (a: NW facies: b: NE facies); **6)** Dorgali fm. (mod. after Costamagna & Barca, 2004).

by lateritic deposits (accumulated as small lenses and vein fillings: "Ferro dei Tacchi", Marini, 1984) located along the angular unconformity between the Middle Jurassic sediments and the Variscan basement. Those Fe deposits are the most significant marker of the short-lasting Aalenian-Bajocian (Middle Jurassic) stabilized peneplain developed on the paleohigh.

So, generally during the early Middle Jurassic the Central, Eastern and Northeastern Sardinia area initially rises as an archipelago formed by the exposed juts of the paleohigh: the erosion wiped off almost entirely the Permian to Lower Jurassic deposits and discovered the Variscan basement. Still this archipelago was rapidly drowned by the extensional tectonics movements. The slopes of the larger islands (located prevalently in Central Sardinia) were first covered by at most some tens of metres of siliclastic deposits (Genna Selole fm.) deriving from the erosion of the exposed parts of the paleohigh itself. Afterwards, following the gradual flooding of the paleohigh and the vanishing of the terrigenous input, the lagoonal to marginal carbonate sedimentation progressed (Dorgali and Genna Silana fms), covering at the end the last emerged spots. In this latter case the carbonate deposits rest directly over the Variscan basement, or, rarely, over remains of Permo-Carboniferous sediments.
Analogies with the Triassic-Jurassic paleogeographic evolution of Central-Eastern Sardinia are described in Corsica (Beauvais & Rieuf, 1981), in the Brianconnais Domain s.s. (Bourbon et al., 1973; Costamagna, 2013) and the Ligurian-Brianconnais Domain (Lualdi, 1994; 2005). Those areas show interesting similarities: in the Western Tethys they formed a paleogeographic belt interested by the same tectonic evolution and directed WSW-ENE along the North-Tethyan edge (Fig. 16), so forming a well-defined regional domain.

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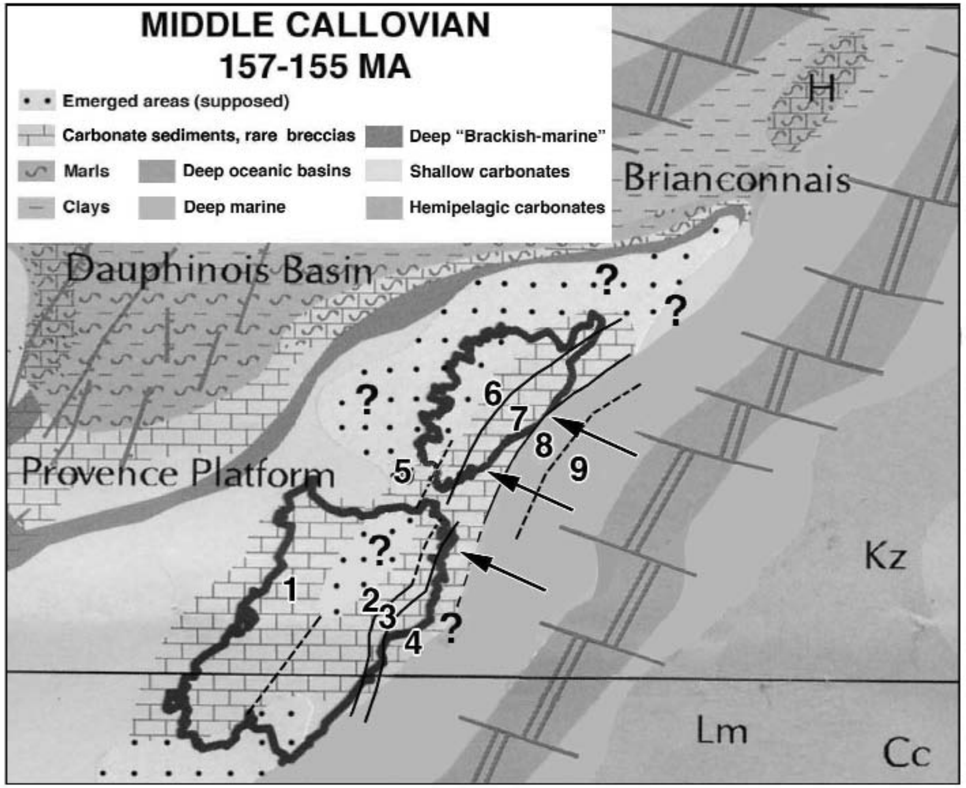

Fig. 16 - Paleogeographic reconstruction of the Sardinia-Corsica Tethyan margin during Callovian (Middle Jurassic) (mod. after Costamagna et al., 2007). Legend: Sardinia: **1)** Nurra, Sardinia-Provence Domain; **2)** Dorgali fm. area, extra-Alpine Domain (according to Durand Delga & Peybernés); **3)** Genna Silana fm. Area, extra-Alpine Domain; **4)** S'Adde fm. Area, extra-Alpine Domain. Corsica: **5)** Possible feeding area of the carbonate pebbles contained in the Eocene Chiappa Conglomerates, Sardinia-Provence Domain; **6)** Autochton: peritidal dolostones area, extra-Alpine Domain; **7)** Hypothesized Margin – Outer Shelf area, not outcropping, extra-Alpine Domain; **8)** "Prepiemontese" Zone: Francardo breccias, nodular limestones and limestones area, extra-Alpine Domain; **9)** Balagne thrust: radiolarites area, extra-Alpine Domain (according to Durand Delga & Peybernés). **H** = Hochstegen; **Kz** = Krizna thrust; **Lm** = Licicum; **Cc** = Choc thrust. The arrow shows the hypothesized shift of the coastline.

3.1.1. Genna Selole fm. (Middle Jurassic: Bajocian - Bathonian)

In the Tacchi area the Genna Selole fm. (Dieni et al., 1983) ranges between 0 to 78 m. (Fig. 17). The thickest stratigraphic section has been measured at Perda Liana, in the northwestern sector. The Genna Selole fm. is thicker along a circular belt surrounding the tectonic Barbagia paleohigh. The Genna Selole fm. has been subdivided into three lithofacies (Costamagna & Barca, 2004; Costamagna, 2015) (Fig.18), from the bottom:

1) Laconi-Gadoni conglomeratic-arenaceous lithofacies;
2) Nurri-Escalaplano siltitic-arenaceous-clayey-lignitiferous lithofacies;
3) Ussassai – Perdasdefogu mixed siliciclastic-carbonatic lithofacies.

Sometimes the described lithofacies do not crop out together in the diverse investigated stratigraphic sections for paleogeographic reasons. Besides, they show extremely variable thickness, are frequently heteropical and they may not simultaneously be present in every locality. Besides, in some localities alternations of the Laconi-Gadoni and Nurri-Escalaplano lithofacies have been noticed.

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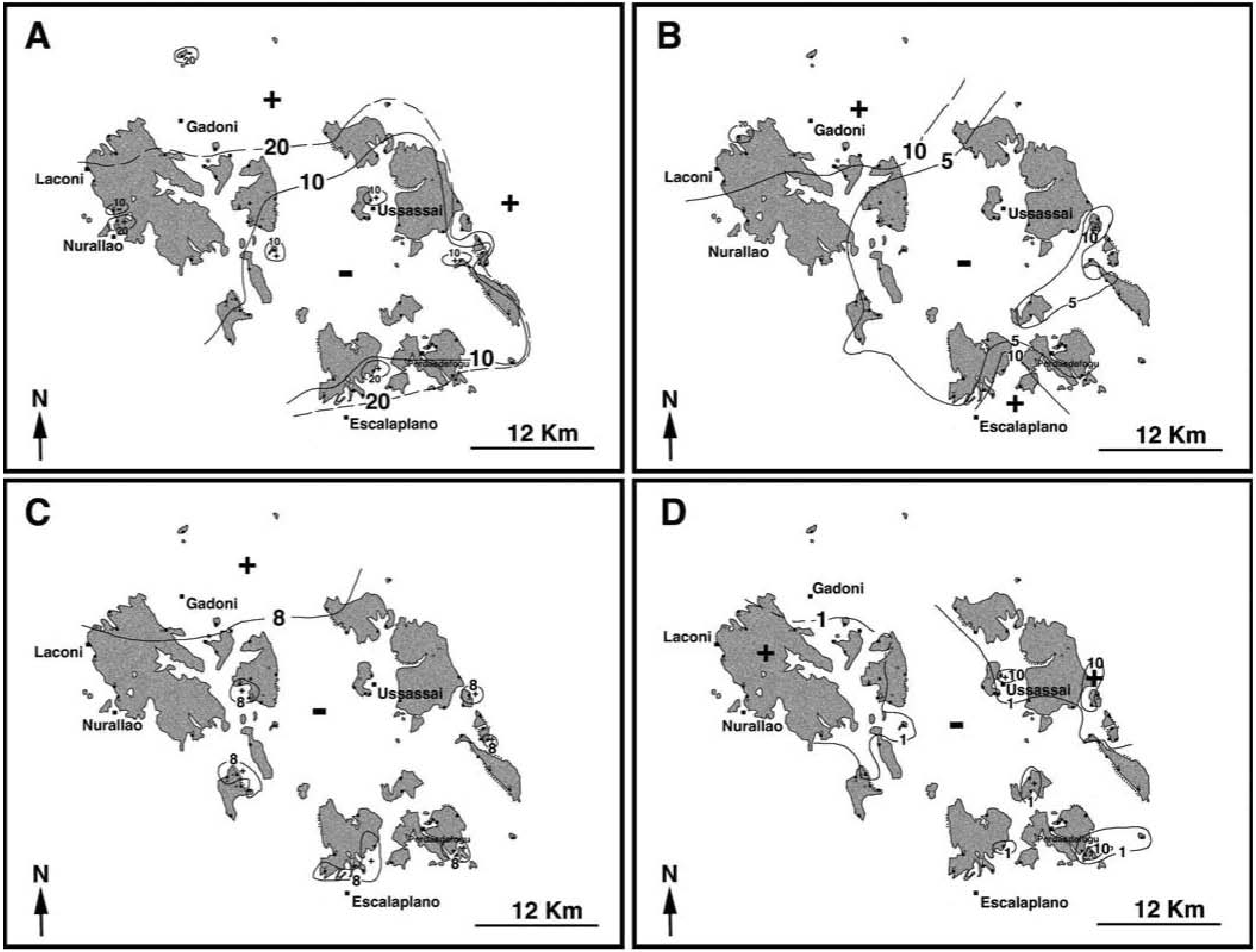

Fig. 17 - Genna Selole fm. isopachs **A)** total thickness; **B**) Laconi-Gadoni lithofacies; **C)** Nurri-Escalaplano lithofacies; **D)** Ussassai-Perdasdefogu lithofacies (after Costamagna & Barca, 2004).

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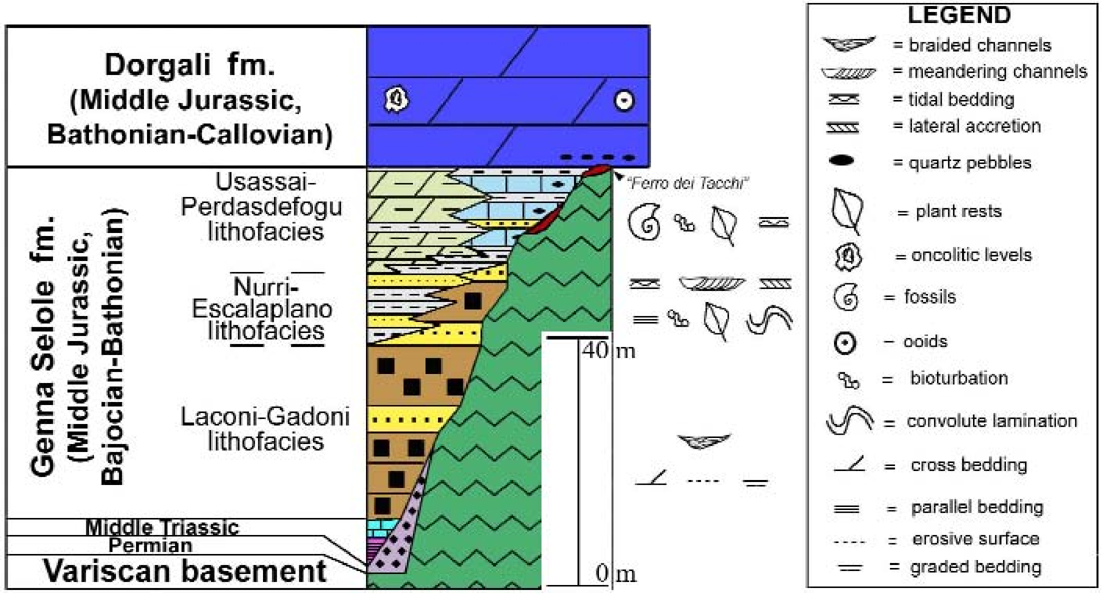

Fig. 18 – Stratigraphy of the Genna Selole fm. in the Tacchi area and relationships with the Permian and Triassic deposits (mod. after Costamagna & Barca, 2004).

The transgressed Variscan basement can be strongly altered and weathered for the subaerial processes occurred during the early Middle Jurassic (Fig. 19). In fact, the alternations of erosion, biostasy and resistasy processes triggered the development of more or less complete lateritic paleosoils or calicitized surfaces.

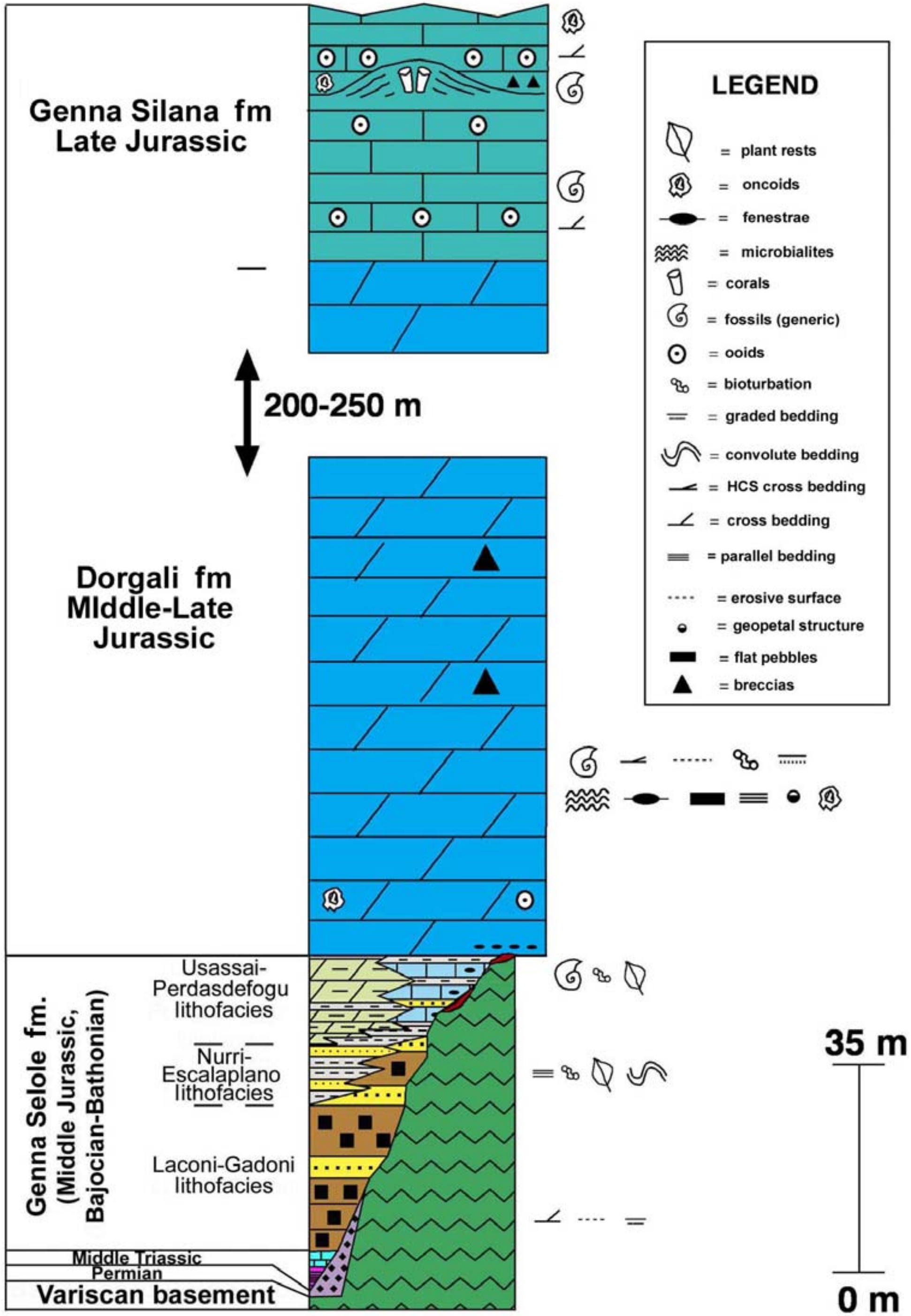

Fig. 19 – Jurassic stratigraphy of the Tacchi area (modified after Costamagna & Barca, 2004).

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Laconi-Gadoni lithofacies

The Laconi-Gadoni lithofacies, from 0 to 35 m thick, is built of usually mature, clast-supported, moderately to well-sorted, monomictic to oligomictic conglomerates containing lenses of quartzose to quartzose-feldspatic medium-grained to fine sandstones. This lithofacies tends to fine upwards, thus passing in the end to sandstones with rare conglomeratic lenses. The pebbles, angular to subrounded in shape, have a maximum size of 15-20 cm. Still, scattered pockets and sheets of siltites, clayey siltites and lignitiferous siltites dark in colour with occasional wood fragments may be intercalated between coarser deposits or alternatively be disposed along limited shallow scours and lows along the lower Variscan basement surface. The pebbles of the conglomerates are usually formed by quartz, but in limited areas the presence of metamorphics and late-Variscan porphyds clasts may be even dominant. Locally pebbles of Permian and Triassic deposits may be also present. The matrix of the conglomerates is usually sandy. Crude, parallel and tabular or through cross-bedding are diffuse, as well as convolute laminations, graded bedding and erosive surfaces. Imbrications are scattered. Sometimes the top of the conglomeratic episodes is marked by a reddish lateritic crust. In some fine-sized, whitish sandstone beds rare macroflora well-preserved specimens (es. *Williamsonia*) can be found. Upwards, this lithofacies passes gradually either to the other Genna Selole lithofacies, or directly, with the increase of the carbonate matrix, to the dolostones of the Dorgali fm.

Nurri-Escalaplano lithofacies

The Nurri-Escalaplano lithofacies is from 0 to 12 m thick. In the central part of the Tacchi investigated area this lithofacies may rest unconformably directly over the Variscan basement without any coarser intercalation in-between. This lithofacies is built of alternations of siltites, clayey siltites, lignitiferous siltites, clays and medium-grained to fine sandstones, from well-stratified to thinly laminated, blackish to whitish in colour. The sandstones may be lens-shaped and cross-bedded, with evident epsilon-cross bedding. In the finer lithologies, convolute lamination can be observed. Load casts are present. Bioturbation is scattered. Besides, fossil wood can be found in the lignitiferous clays, as plants rests, formed by leaves and branch casts. In the blackish lithologies the pyrite is often present, as well as scatterd gypsum crystals. The macro- and microfloristic assemblages found in this lithofacies suggest a Bajocian to Bajocian-Bathonian (Middle Jurassic) age (Del Rio, 1976; 1984; Dieni et al., 1983). In the central part of the Tacchi area this lithofacies may pass directly upwards to the carbonate Dorgali fm.

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Ussassai-Perdasdefogu lithofacies

This lithofacies ranges from 1 to about 35 m, and develops mainly in the northern sector of the Tacchi area: instead, in the other sectors it may be very thin (Fig.18). This lithofacies shows significant changes depending from its location. In the NW area it is thinner (6 m at the most) and is formed by marly dolostones containing scattered cm-thick siltitic and fine sandy terrigenous beds. Otherwise, in the NE sector, the lithofacies is higly variable and thick (until 20 m): it is formed by alternations of limestones, dolomitic limestones, marls and plant-rich, fine to medium-sized siliciclastics sometimes lens-shaped. Close to the passage to the Dorgali fm., cm-sized beds of black siltites with scattered plants rests are diffuse. The passage to the Dorgali fm. occurred with the complete vanishing of the terrigenous inputs in the carbonate sediments. The carbonates of this lithofacies are frequently fossiliferous (gastropods, bivalves, brachiopods, ostracods, characean algae oogons; in the upper part crinoids, foraminifers, and sponge spicules still appear) and cross-bedded: the fossiliferous beds may form dm-thick coquinas due to the winnowing. Lenticular, wavy, and flaser bedding has been observed, as well as fine intercalations of siliciclastic sediment between the carbonatic small-scale lens-shaped bodies. According to Dieni *et al*. (1983), the paleontological content allows the attribution of this lithofacies to the Bathonian. Close to the upper boundary, scattered little microbialitic mounds have been found. Besides, at this stratigraphic level, often firm- and hard ground surfaces partially bioturbated and/or bioeroded, thin oxidized crusts and early karstic phenomena develops at several levels over the carbonates, presently covered first by siltitic-clay blackish sediments, and later sharply by carbonate deposit again. These data evidence limited and short-lasting regressive events during the evolving Middle Jurassic trasgression (Costamagna et al., 2007).
Dieni et al. (2013) question the pertinence of the Ussassai – Perdasdefogu lithofacies to the Genna Selole fm.: for the lithological prevalence of carbonate deposits, they consider it a lower member of the Dorgali fm. and called it Perda Liana mb. We disagree with this attribution made on a lithological basis. We think that, according to the stratigraphic-depositional criteria expressed by Bosellini et al. (1989), in the grouping of the stratigraphic units the paleoenvironmental meaning of the lithofacies is significant as the lithological features, as it will be explained better below.

In addition to the Dispensa Selole type section (Baunei, Ogliastra: Dieni et al., 1983; Dieni & Massari, 1986), now almost totally buried by landslides and canceled by road works, two further supporting parastratotypes located in the Tacchi area have been proposed (Costamagna & Barca, 2004): one of them (Perdasdefogu) will be showed during the field trip (Stop 7).

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Synsedimentary tectonics in the Genna Selole fm.

Evidences of synsedimentary tectonics can be observed all in the Genna Selole fm.: they are neptunian dykes, synsedimentary faults, slumps. Diffuse, thin convolute laminations in the varved sediments and rare brecciated carbonate layers could be related to seismic shocks. Field observations suggest that early deformations occurred before the lithification of the sediment: they may be due to a sudden dump of the coarse bedload during the rapid slowing down of intense floods. The described features are related to the extensional tectonics connected with the Alpine Tethys opening.

3.1.2. Dorgali fm. (Middle – Late Jurassic: Bathonian-Kimmeridgian)

The carbonatic Dorgali fm. (Amadesi et al., 1960; Dieni & Massari, 1986; Costamagna & Barca, 2004; Costamagna et al., 2007) (Fig. 19) is the thickest Jurassic unit of the Tacchi area, reaching 250 m in its NE sector. Here it passes upwards sharply to the calcareous deposits of the Genna Silana fm. (Costamagna et al., 2007). The base of the Dorgali fm. is marked by the complete vanishing of all the terrigenous input: this indicate clearly the disappearance of any continental influence and of any emersion, regressive event. The start of the Dorgali fm. is referred to the Bathonian (Middle Jurassic) (Dieni et al., 1983). From that time on, the environment became entirely marine with no turning back.

In the Tacchi area the Dorgali fm. is formed by massive to well-stratified dolostones. Several fossils are present (bivalves, brachiopods, corals, echinoderms). Usually the strong dolomitization processes erased totally the original textures of the carbonate deposits: only few outcrops whose structures were valuable for sedimentological investigations have been found. So, in the Tacchi area a type section of the Dorgali fm. has not established yet. When the Dorgali fm. rests directly over the Variscan basement, quartzose and lyditic angular to subangular pebbles and quartz grains are scattered in the lower carbonate beds.

In the Dorgali fm. several lithofacies have been evidenced. The main lithofacies association is represented by irregular alternations of parallel- to cross-laminated dolomitized calcarenites and bioturbated dolomitized calcilutites. The laminated calcarenites, locally resting over an erosive coarse lag formed by bioclasts, have been related to storm layers. Here and there microbial mats locally containing fenestral structure occur. In the carbonate mud several structures can be observed: rip–up clasts, bioturbations, winnowed beds. In several outcrops, metric horizons of polygenic carbonate breccias posed at different stratigraphic levels of the Dorgali fm. have been found.

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3.1.3. Genna Silana fm. (Middle-Late Jurassic)

In the Tacchi area the calcareous Genna Silana fm. (Costamagna et al., 2007) (Fig. 19) occurs only on the top of the highest relieves of the easternmost carbonate outcrops: it corresponds to the top of the Jurassic Tacchi area succession. It covers abruptly the Dorgali fm. Nonetheless, it reaches its maximum thickness (150 m) northward, in the Baunei Supramonte area of Eastern Sardinia: here is located its type section. In the NE sector of the Tacchi area the Genna Silana fm. succession never exceeds 30 m and is arranged in a narrow, discontinuous belt running NW/SE (Fig. 14). The unit is here formed by cross-laminated oolitic to oolitic-bioclastic calcarenites, containing bioclasts of corals, bivalves, spongiomorph hydrozoans and green algae. Subordinately, the unit includes bioclasts of crinoids, gastropods, foraminifers and echinoid spines, together with rare specimens of *Ellipsactinia*: these latter allow to refer the age of the Genna Silana fm. in the Tacchi area to the Late Jurassic (Oxfordian).

Here and there, scattered carbonate layers with erosive base and formed by polygenic angular intraclasts embedded in a muddy matrix have been found.

The top of the unit and of the Tacchi Jurassic succession is formed by oncoidal floatstone beds made of cm-sized oncoids embedded into a muddy-sandy matrix. The oncoids start to develop around bioclastic nuclei.

3.1.4. Definition of the Baunei group (Middle - Upper Jurassic: Bajocian – Kimmeridgian)

The Jurassic stratigraphic units of the Tacchi area pertain to a carbonate shelf related to the wider Central-Eastern-Northeastern Sardinia Jurassic carbonate environment. Only in Eastern-Northeastern Sardinia (Supramonte and Baronie area: Fig. 3), those units partially are capped by and partially are coeval to the S'Adde fm. (Dieni & Massari, 1986), figuring out an outer shelf – slope environment that is the natural evolution of the transgressive Middle – Upper Jurassic sequence. All these formational units pertaining to this sequence have been united to form the Baunei group (Costamagna et al., 2007). The Baunei group (Fig. 13), Bathonian to Kimmeridgian (Middle - Upper Jurassic) in age, is terminated at the top by the Tithonian – Berriasian unconformity (Jurassic-Cretaceous boundary), related to a sharp fall of the relative sea level and to a retrogradation of the marine facies. The Baunei group represents the subsiding evolution of the Sardinian sector of the Alpine Northern Tethys margin. The Genna Selole fm., for its features, paleogeographic meaning and strict connection with the Bajocian – Kimmeridgian sedimentary cycle, can be included as base of the Baunei group.

Jadoul et al. (2010) propose to separate the Genna Selole fm. depositional cycle from the upper carbonate units, suggesting these latter pertain to an independent sedimentary cycle: the authors infer this from the presence of diffuse emersion evidences in the Ussassai-Perdasdefogu lithofacies. According to them, those

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emersions could encompass significant stratigraphic gaps during Callovian times, so representing minor depositional cycles. Conversely, we consider these upper, irregular small regressive cycles simply as consequence of a diffuse microtectonic activity during the marine transgression due to the drowning of the tectonic Barbagia paleohigh, and not really related to the Middle – Upper Jurassic sedimentary main cycle.

3.2 Depositional environment of the Jurassic units

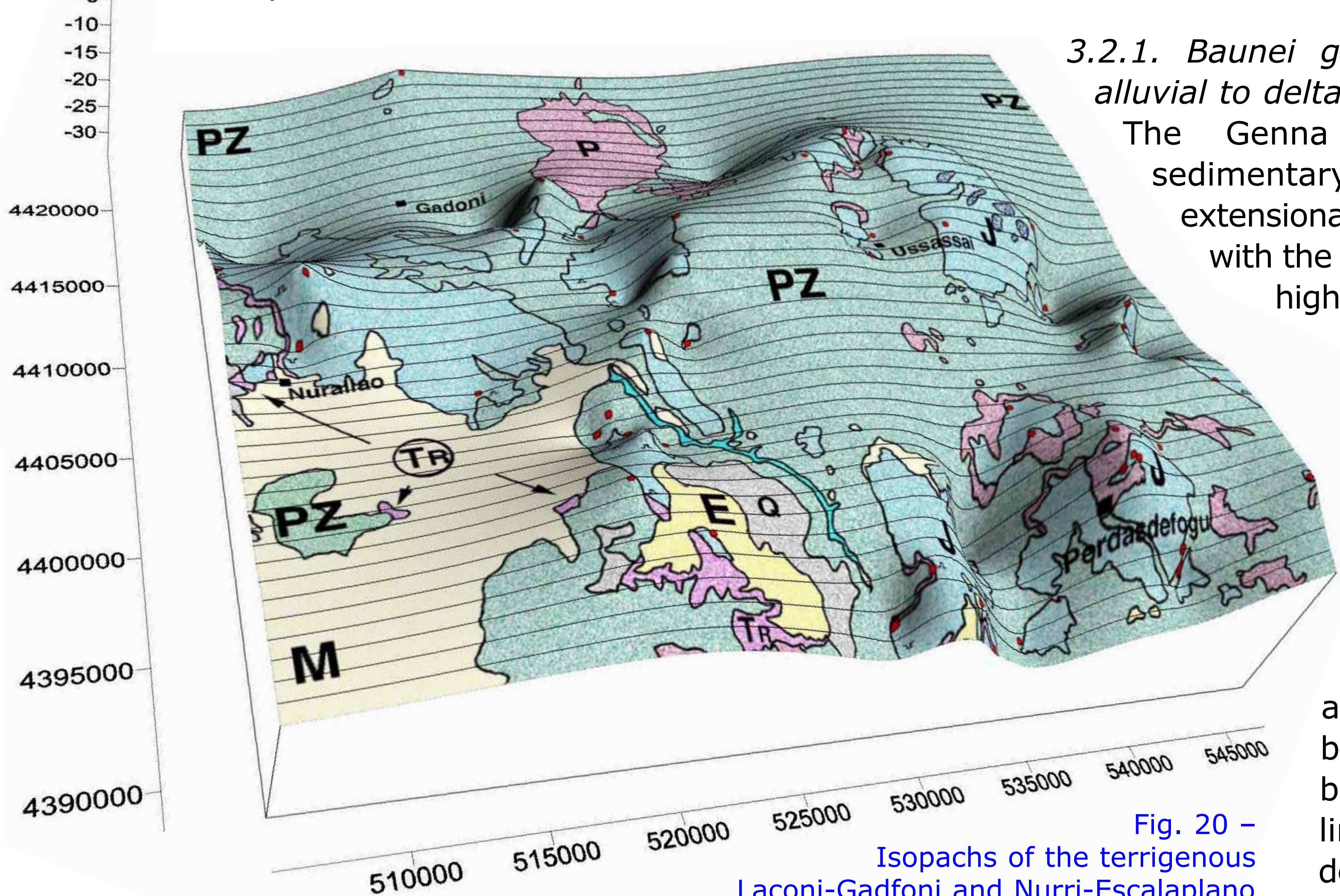

Fig. 20 – Isopachs of the terrigenous Laconi-Gadfoni and Nurri-Escalaplano lithofacies of the Genna Selole fm. in the Tacchi area: they evidence the relief of the tectonic Barbagia paleohigh.

3.2.1. Baunei group, Genna Selole fm.: alluvial to deltaic (?) system

The Genna Selole fm. was the sedimentary response to an active extensional tectonics context, starting with the rise of the Barbagia tectonic high and ending with its final drowning. Thus the unit represents a narrow continental depositional system placed along the slopes of the tectonic high: here, side by side, alluvial fan and braided stream environments passing rapidly to an alluvial-palustrine-littoral belt containing isolated brackish ponds, and perhaps limited delta bodies are developed (Figs. 20, 21). The fans were placed at the outlet of the valleys, while the

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alluvial-palustrine-littoral belt was posed along all the coastline: its width was limited in respect to the alluvial fans. Sometimes the coarse fan / braided stream deposits passed quite sharply to marine carbonate deposits: that suggest the localized presence of little fan deltas, or, possibly, the development of braid deltas (McPherson et al., 1987). So, the depositional mechanisms, the environments and the thicknesses of the Genna Selole fm. are constrained by the local paleogeography and by the arrangement of the Variscan basement, at that time tectonically reactivated by the Alpine extensional movements leading to the opening of the Alpine-Tethys.

Thus, in detail, the Laconi-Gadoni lithofacies was deposited in humid alluvial fan crossed by braided channels with relieves at their back and close to the coast: probably sometimes fan deltas passed to braid deltas. The conglomeratic events are longitudinal bars separated from each other by erosive surfaces due to diverse flood episodes. The discontinuous, lens-shaped sandstone intercalations located at the top of the conglomeratic sequences are related to sandy deposition in minor channels crossing the bar surface during the waning floods. The limited scattered dark clayey and clayey-silty accumulations is linked to the settling of fine sediment and the piling of vegetable organic matter in little, protected side areas of abandoned channels: perhaps those areas were comparable to oxbow lakes.

The Nurri-Escalaplano lithofacies was deposited into a low energy alluvial-palustrine-lacustrine environment (Fig. 21). This alluvial plain, often waterlogged, was crossed by migrating, meandering sandy channels sometimes overtopped by sandy crevasse splays, and colonized by hot-humid, tropical climate vegetation (Del Rio, 1976; 1984). With the smoothing of the relieves and the rise of the sea level, this lithofacies started to be deposited over the Laconi-Gadoni litofacies, following the transgressive trend over the structural high. A limited tidal influence is supposed at the outer rim of this lithofacies.

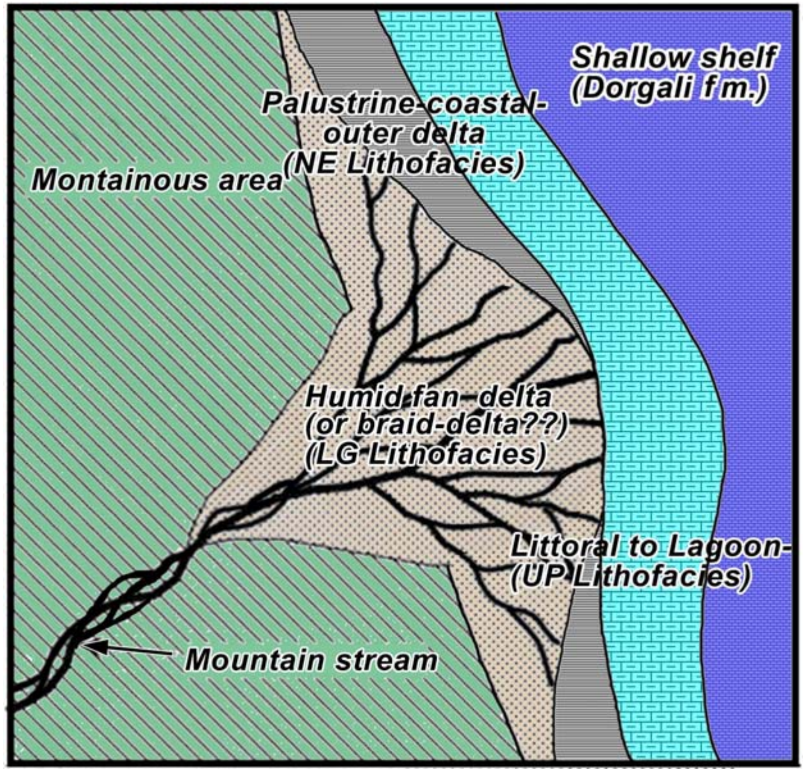

Fig. 21 – Paleogeographic sketch of the alluvial to transitional environments of the Genna Selole fm. (mod. after Costamagna, 2013).

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The Ussassai – Perdasdefogu lithofacies represents the passage to the Dorgali fm. This facies is well developed mainly in the northern sectors of the Tacchi area. In the NW sector it figures out a littoral-interdeltaic-environment: moving away from the coast, the carbonate sediments grew up until they dominated. Otherwise, in the NE sector, the closeness of fluvial outlets, and consequently deltaic-lagoonal environments with limited saline marshes can be supposed. In this environment, figured by protected lagoons and interdistributary bays, carbonate muds settled. Tidal influence is clearly evident, as well as sinsedimentary tectonics.
As sketched before, Dieni et al. (2013) refer the Genna Selole fm. upper lithofacies as a lower member of the Dorgali fm. instead, claiming the member depositional environment pertains to an already well-established marine environment, and so more similar to the Dorgali fm. We disagree on this assumption because the Ussassai-Perdasdefogu lithofacies contain diffuse regressive microsequences driving to karst development and deposition of dark, pyrite- and organich-rich intercalations with plant remains suggesting the persisting ephemeral onset of palustrine environments: this make the unit more similar to the continental - transitional Genna Selole fm. than to the marine Dorgali fm.

3.2.2 Baunei group, Dorgali fm.: tidal flat and inner ramp lagoon

The Dorgali fm. is a monotonous unit (Fig. 22) that posed in a shallow, variable energy inner shelf lagoon and is featured mainly by alternations of bioturbated muds and storm layers locally showing the typical three-folded sequence. Brecciated layers may represent sectors of synsedimentary tectonic activity. Still are scatteredly present tidal flat areas with fenestral bindstones containing mud cracks and tepee structures, as well as oncoidal restricted ponds and little oolitic bars.

3.2.3 Baunei group, Genna Silana fm.: oolitic margin with patch-reefs

The lithologies of the Genna Silana fm. represent the carbonate shelf margin, featured by high-energy conditions and built of oolitic bars (oolitic grainstones) embedding scattered little coral patch reefs (Fig. 22). The upper, episodical oncoidal facies embedded into an abundant micritic matrix (oncoidal floatstones) suggests the beginning of a slightly deeper sedimentation, probably just over the optimum depth of the patch reefs development.

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3.2.4. Paleogeographic and geodynamic meaning of the Baunei group

The Central-Eastern-Northeastern Sardinia Baunei group is formed by an alluvial system of variable thickness and width according to the blanketed morphology, and by a transgressive to regressive homoclinal carbonate ramp (Fig. 22): both are related to the opening and the gradual drowning of the Northern Tethyan margin. The Baunei group

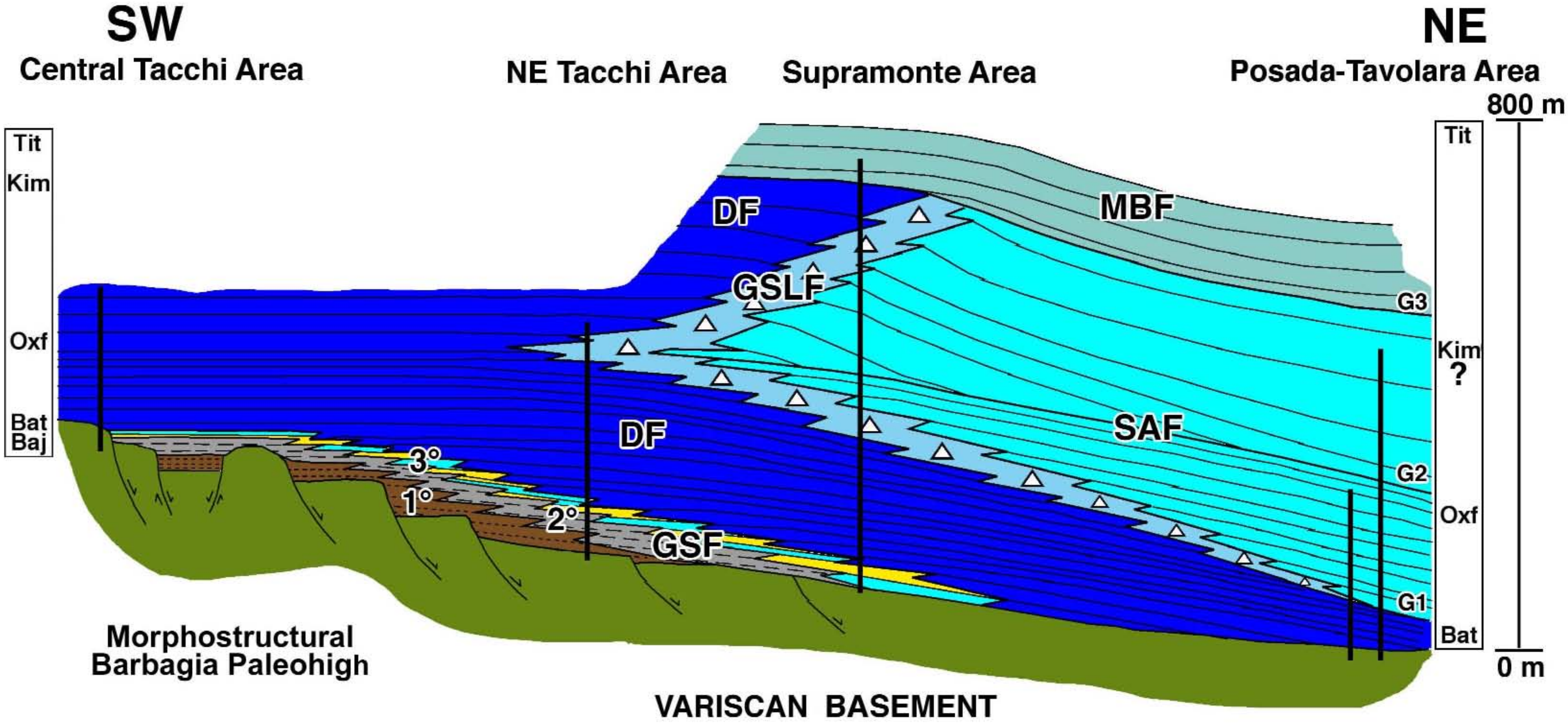

Fig. 22 – Schematic stratigraphic-sequential evolution of the Jurassic ramp of Central-Eastern-Northeastern Sardinia (after Costamagna et al., 2007 - scale and distance only indicative). Legend: **GSF**: Genna Selole fm. (**1°**: Laconi-Gadoni lithofacies; **2°**: Nurri-Escalaplano lithofacies; **3°**: Ussassai-Perdasdefogu lithofacies); **DF**: Dorgali fm.; **GSLF**: Genna Silana fm.; **SAF**: S'Adde fm.; **MBF**: Monte Bardia fm.. **G1**: lower stratigraphic gap (shelf drowning); **G2:** intermediate stratigraphic gap (inversion point of the depositional system); **G3**: upper stratigraphic gap (eustatic fall: type 2 discontinuity after Bosellini, 1991); **Baj**: Bajocian; **Bat**: Bathonian; **Oxf**: Oxfordian; **Kim**: Kimmeridgian; **Tit**: Tithonian.

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represents a Bajocian-Kimmeridgian transgressive-regressive cycle. Only the lower, transgressive part (LST and TST) of this cycle is visible in the Tacchi area (Costamagna et al., 2007): the upper regressive part (HST) can be seen just in Eastern and Northeastern Sardinia (Fig. 23). In the Tacchi area the Baunei group is formed by the Genna Selole fm. (from alluvial fan/braided stream to deltaic system/tidal flat?) (LST/TST), the Dorgali fm. (tidal flat and open shelf lagoon: inner ramp environments) (TST), and the Genna Silana fm. (shelf margin) (TST). The carbonate Jurassic shelf of Central-Eastern-Northeastern Sardinia had a ramp configuration: this is suggested by the significant amount of storm deposits into the lagoon, the scarce continuity, thickness and extent of the bioconstructions, the lacking of well-developed slope facies suggesting the absence of a strongly inclined slope.

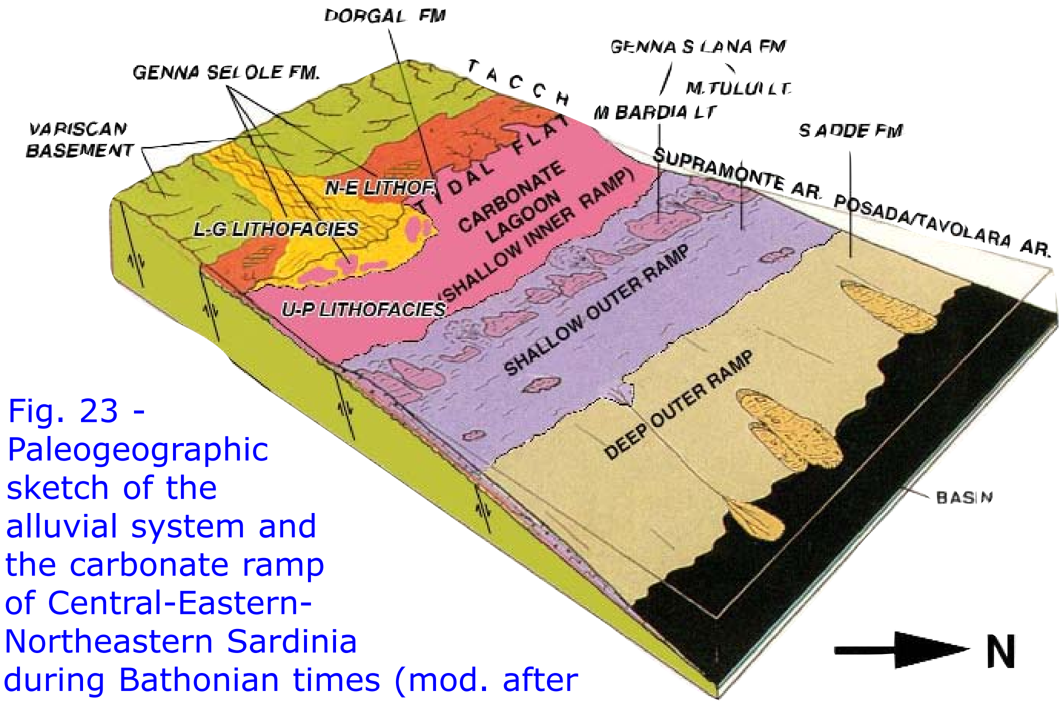

Fig. 23 - Paleogeographic sketch of the alluvial system and the carbonate ramp of Central-Eastern-Northeastern Sardinia during Bathonian times (mod. after Costamagna et al., 2007): **LT** = lithofacies; **L-G** = Laconi-Gadoni; **N-E** = Nurri–Escalaplano; **U-P** = Ussassai – Perdasdefogu; **AR** = area.

3.3. The Jurassic succession: second Mesozoic sedimentary cycle, conclusions

Due to the strong extensional tectonics leading to the opening of the Alpine Tethys (Fig. 24), possibly during Aalenian-Early Bathonian (?) the whole Central-Eastern-Northeastern Sardinia area emerges: in particular, Central Sardinia area turned to be the wider emerged part of the horst (tectonic Barbagia paleohigh) of all. The entire Central-Eastern-Northeastern Sardinia area perhaps resembled an archipelago disposed along the Northern margin of the Tethys (Fig. 25). Here the Triassic-lowermost Jurassic deposits are completely eroded, as well as part of the Post-Variscan Permo-Carboniferous molassic sediments and the Variscan metamorphic basement too.
Still the emerged horst is short-lasting: it starts to be buried just during the Bajocian-Bathonian, when the Baunei group deposits begins to accumulate (Middle-Late Jurassic, Costamagna et al., 2007). First, on the horst sides, the continental to transitional siliciclastic deposits (Genna Selole fm.) taken place: they are feeded by the erosion of the

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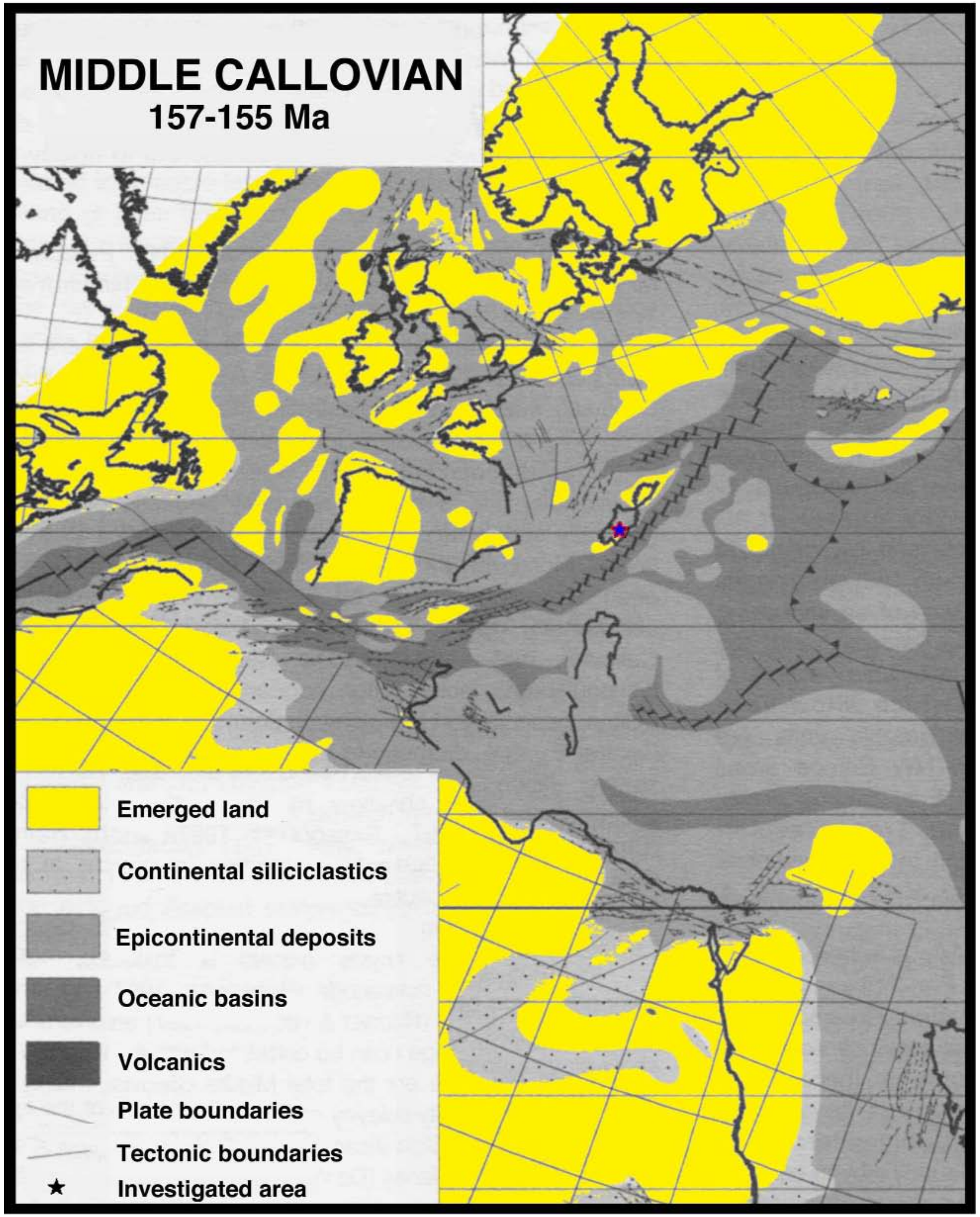

horst itself. Due to the gradual subsidence of the horst, correlated to the spreading Tethyan margin collapse and the eustatic rise, the continental-transitional deposits are covered by marine carbonate shelf sediments (tidal flat, lagoon and margin: Dorgali and Genna Silana fms). In the Tacchi area those formational units form the trasgressive system tract (Fig. 23) and the lower part of the Bajocian-Kimmeridgian tectono-sedimentary cycle. The complete marine development of this cycle crops out in the Eastern-Northeastern Sardinia (NE Ogliastra, Supramonte, Baronie): here the marginal Genna Silana fm. is covered by the S'Adde fm., figuring out mild slopes and possibly shallow basin environments.

In this paleogeographic setting, the Central Sardinia area represents the inner, more protected sector of the continental shelf and an important part of the SW margin of the Alpine Tethys.

Fig. 24 – Regional and paleogeographic framing of Sardinia during the Middle Callovian: the star marks the field trip area. (modified after Dercourt et al., 2000).

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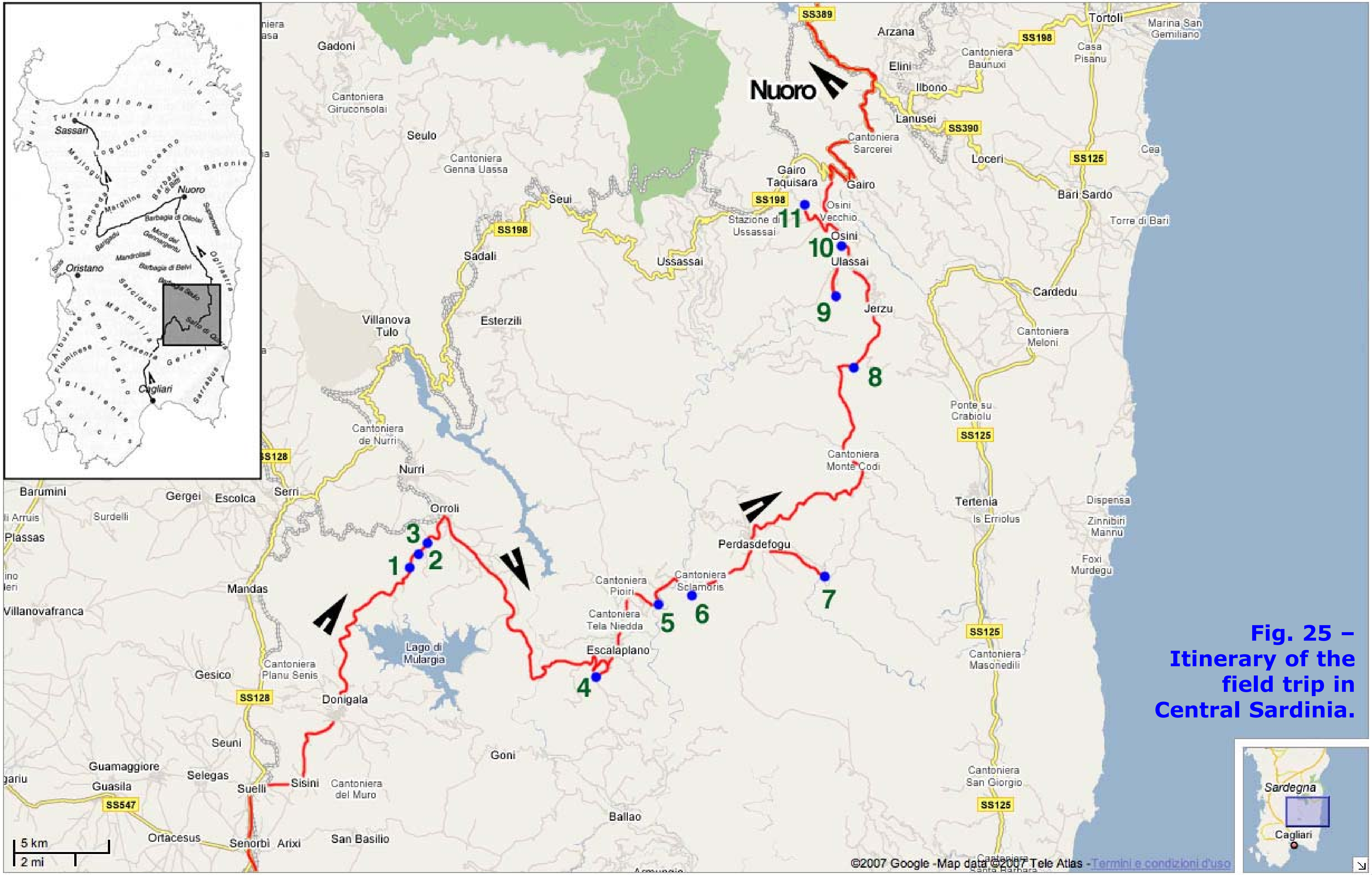

Fig. 25 – Itinerary of the field trip in Central Sardinia.

Day 1 - From Cagliari to Jerzu (OG).

Luca G. Costamagna

Just leaving the calcareous Late miocenic hills of Cagliari, the itinerary proceeds along the National Road 131 Carlo Felice headed to NNW and following the eastern rim of the Plio-Quaternary Campidano graben (Fig. 25).

Up to the km 20 of the Cagliari-Sassari SS131 motorway, first Early-Middle Miocene carbonate-terrigenous deposits are crossed, and later, andesites pertaining to the calc-alkaline Oligo-Miocene volcanic cycle and sandstones/siltstones of the Eocene-Oligocene Cixerri fm. On our left is the Plio-Quaternary NW/SE trending Campidano graben plain, resulting from the recent extensional tectonics leading to the Southern Tyrrhenian sea opening and filled by the Pliocene Samassi fm. and the Quaternary alluvial deposits. Conversely, the Oligo-Miocene sediments and volcanics (Pecorini & Pomesano Cherchi, 1969) fill the main, older N-S Sardinian rift crossing all the island. This former rift is related with the opening of the Algero-Provençal basin representing the back-arc basin of the Apennine Orogeny.
At the km 20 of the 131 motorway, we leave the Cagliari-Sassari motorway and we take the SS 128 road "Centrale sarda" leading to the Central Sardinia area, crossing the towns of Senorbi and Suelli: here along the road still Tertiary siliciclastic to carbonate deposits crop out. From Suelli, a secondary road to the northeast take us to the Siurgus Donigala town. After we pass this last town we leave behind the Tertiary sedimentary deposits of the Sardinian Rift and we enter in the Variscan basement outcrop area. This area is here featured by low-grade metamorphics as phyllites, schists and rare marbles: the inferred age of their protolith is Cambrian to Carboniferous. The Variscan metamorphic rocks are here and there covered by Permian molassic, limic to red bed deposits of the Rio Su Luda Fm. The Formation is validated by the Italian Commission on Stratigraphy (Delfrati, 2006b).

After overtaking the Mulargia Lake artificial basin, about 4 km SW to Orroli, the Mesozoic succession crops out along some road cuts at Bruncu Su Para (Stop 1), Bruncu Geroni (Stop 2) and Piccheri (Stop 3). Along a short distance (about 1.5 km), from Stop 1 to Stop 3 (Figs 26, 27), the post-Variscan stratigraphic succession varies significantly and shows several stratigraphic gaps located differently according to the location (Fig. 28). This is a plain indication of a repeatedly tectonically disturbed zone in several times. This assumption is further confirmed by the Variscan metamorphic rocks outcropping in rare erosional windows

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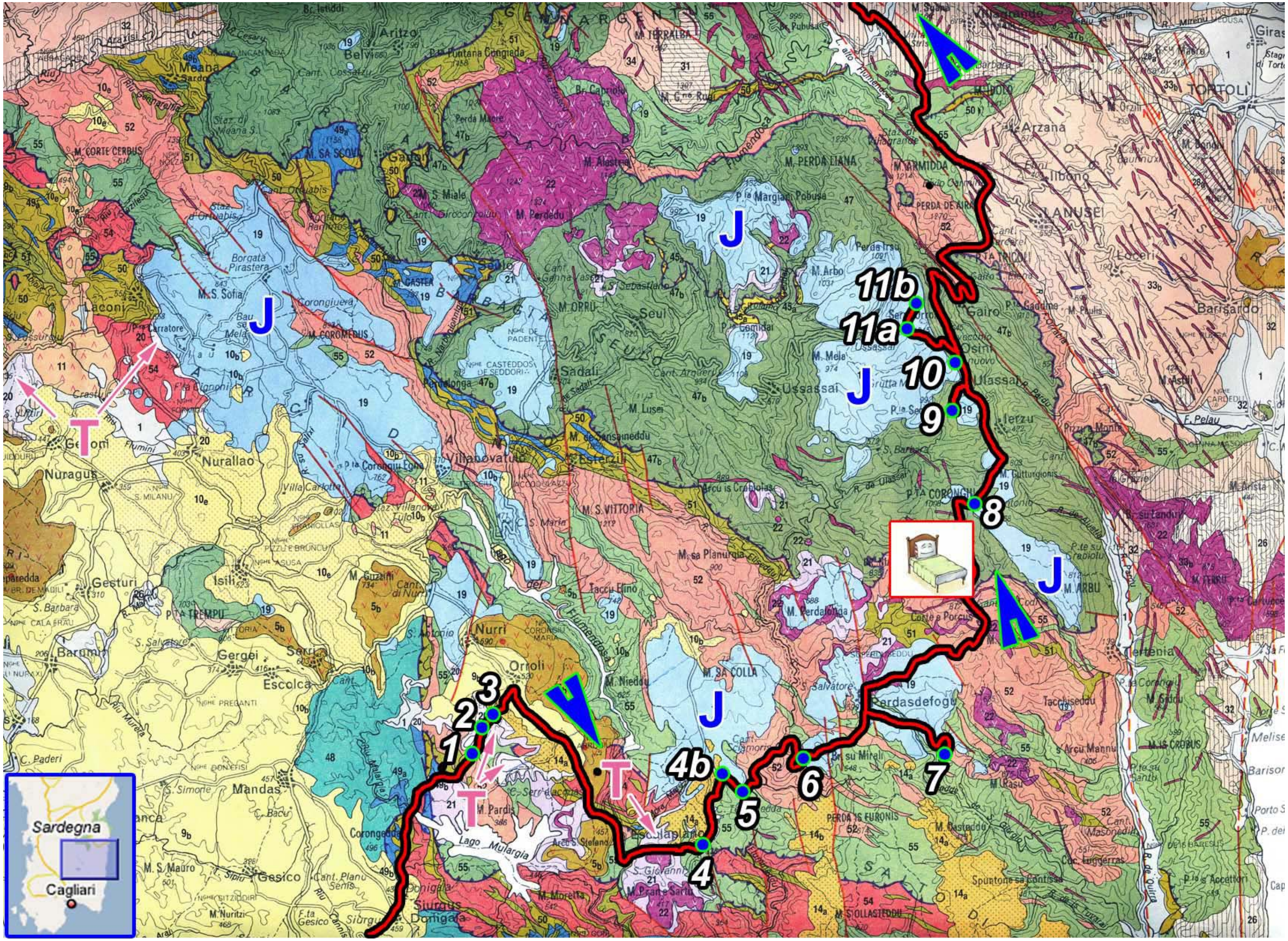

Fig. 26 – Geological Map of the Tacchi area, itinerary of the field trip and location of the Stops; **TR** = Triassic; **J** = Jurassic; **Bed** = stay overnight.

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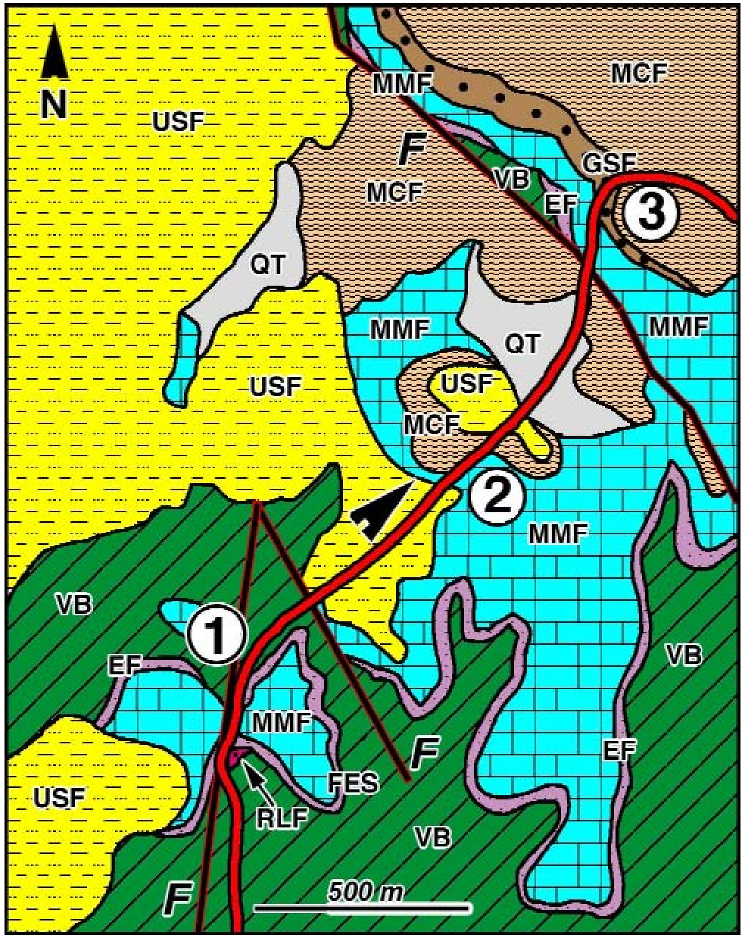

Fig. 27 - Stop 1, 2, 3: Geological sketch of the Bruncu Su Para **(1)**, Bruncu Geroni **(2)** and Piccheri **(3)** areas. Legend; **VB**: Variscan Basement (Cambrian-Carboniferous); **RLF**: Rio Su Luda Fm. (Permian); **EF**: Escalaplano Fm. (Middle Triassic); **MMF**: Monte Maiore fm. (Middle Triassic); **GSF**: Genna Selole fm. (Middle Jurassic); **MCF**: Monte Cardiga fm. (Early-Middle Eocene); **USF**: Ussana fm. (Late Oligocene – Early Miocene); **QT**: debris (Quaternary); **F** = Fault.

underneath the post-Variscan cover. In fact they belong to several superimposed tectonic units and pertain to the western part of the "Flumendosa antiform" (Carmignani et al., 1992, 1994), a strongly deformed Variscan structure.

The Triassic outcrops located between the Sarcidano and the Northern Gerrei in Central Sardinia (Fig. 25) (Costamagna et al., 2000; Costamagna & Barca, 2002) form a short siliciclastic to carbonate (with rare evaporites) succession whose thickness grows up from NW to SE, being comprised between 2 and 35 – 40 m. They crop out along a narrow belt 40 Km long, oriented NW/SE and posed between the Laconi and Escalaplano villages.

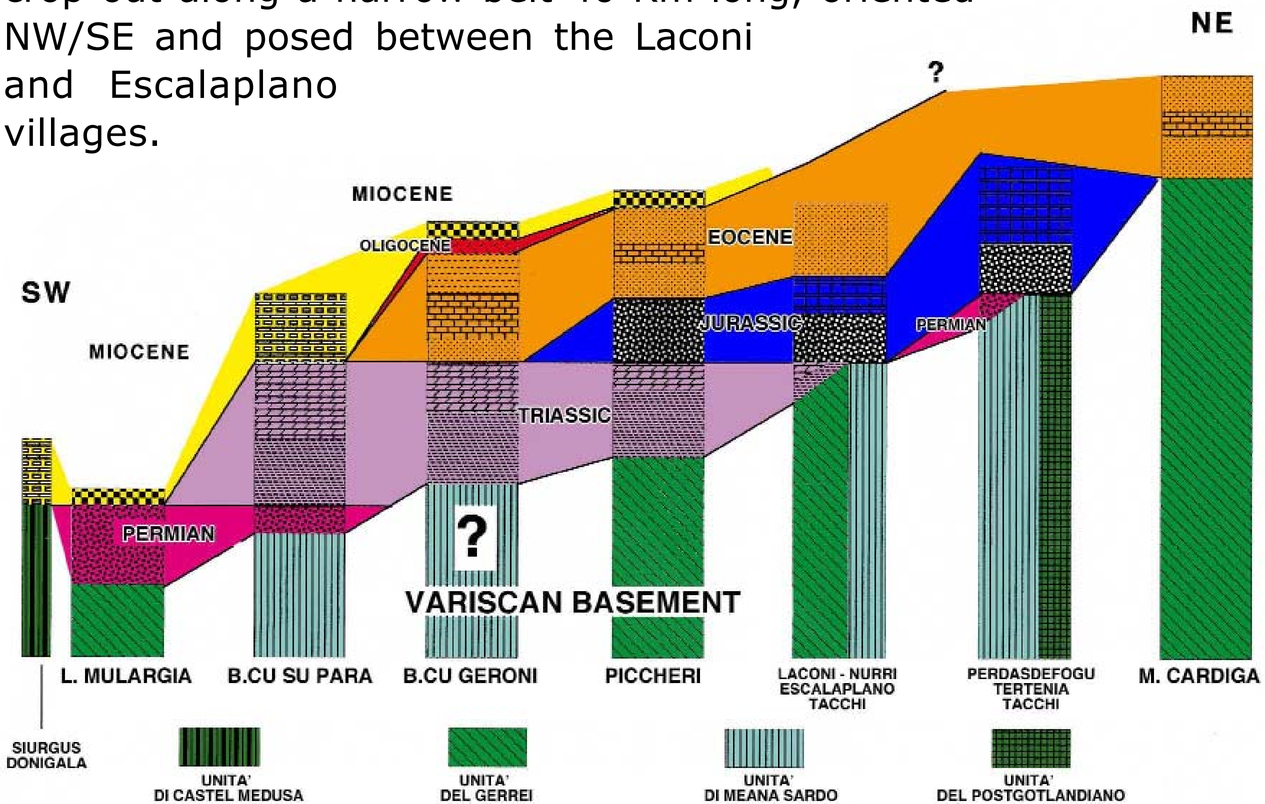

Fig. 28 - Permian, Mesozoic and Tertiary sedimentary cycles in the Gerrei – Ogliastra area and their relationships with the Variscan basement.

The Triassic succession rests unconformably over the Variscan metamorphics, and in its turn is covered by younger deposits of Jurassic, Eocene or Miocene age. The complex relationships between all those sedimentary cycles suggest several superposed erosional cycles of variable age (Barca & Costamagna, 1999). The main effects of these cycles are the intense pedogenetic alteration over the Triassic carbonates that probably came to be frequently exposed surfaces. Even some of the dolomitization processes of the Triassic carbonates may be related with the same events.

STOP 1 - Bruncu su Para (Orroli): general features of the Escalaplano Fm. and Monte Maiore fm. (Middle Triassic)

In this road-cut the Gerrei Middle Triassic succession shows an almost horizontal attitude and rests unconformably over the metavolcanics of the Meana Sardo Variscan tectonic unit (Monte S. Vittoria fm., Ordovician: Carmignani et al., 1992, 1994) and, locally, over a thin Permian red bed remain (Rio Su Luda Fm., Carmignani et al., 2001). Here the Escalaplano Fm. (late Anisian–early Ladinian) siliciclastics of the Sardinian Buntsandstein group passes sharply upwards to the well-bedded carbonates of the yellow dolostones member of the Monte Maiore fm. (Ladinian), referable to the Sardinian Muschelkalk group (Fig. 29 A).

Bruncu su Para succession

The Middle Triassic Bruncu Su Para succession (Fig. 30) is exposed along two road cuts: on the right, it rests unconformably over red to dark brownish metavolcanic schists pertaning to the Variscan cycle (Fig. 29 B), and, locally, over Permian thickly stratified red arenaceous siltites and siltites containing yellowish calcrete nodules and layers, in their turn laid down over the Variscan basement.

The Middle Triassic Escalaplano Fm. starts with a thin 20 cm thick bed of polygenic (quartz, metamorphics) clast-supported conglomeratic breccias, followed by massive to poorly stratified reddish to greenish argillaceous siltites and siltites containing scattered cm-sized thin, irregular beds of yellowish marly sandstones / sandy marls previously containing former evaporites, now calcitized. The argillaceous siltites may contain mud cracks. Often the lower surface of the marly/sandy beds shows halite casts (Fig. 29 C) due to the early dissolution of evaporitic crystals. The Escalaplano Fm. is here 8.5 m thick. On the left road cut the Escalaplano Fm. passes gradually but sharply with the sudden growth of the carbonate content (Fig. 29 A) to the dolostones of the yellow dolostones member of the Monte Maiore fm. This unit begins with yellowish marly

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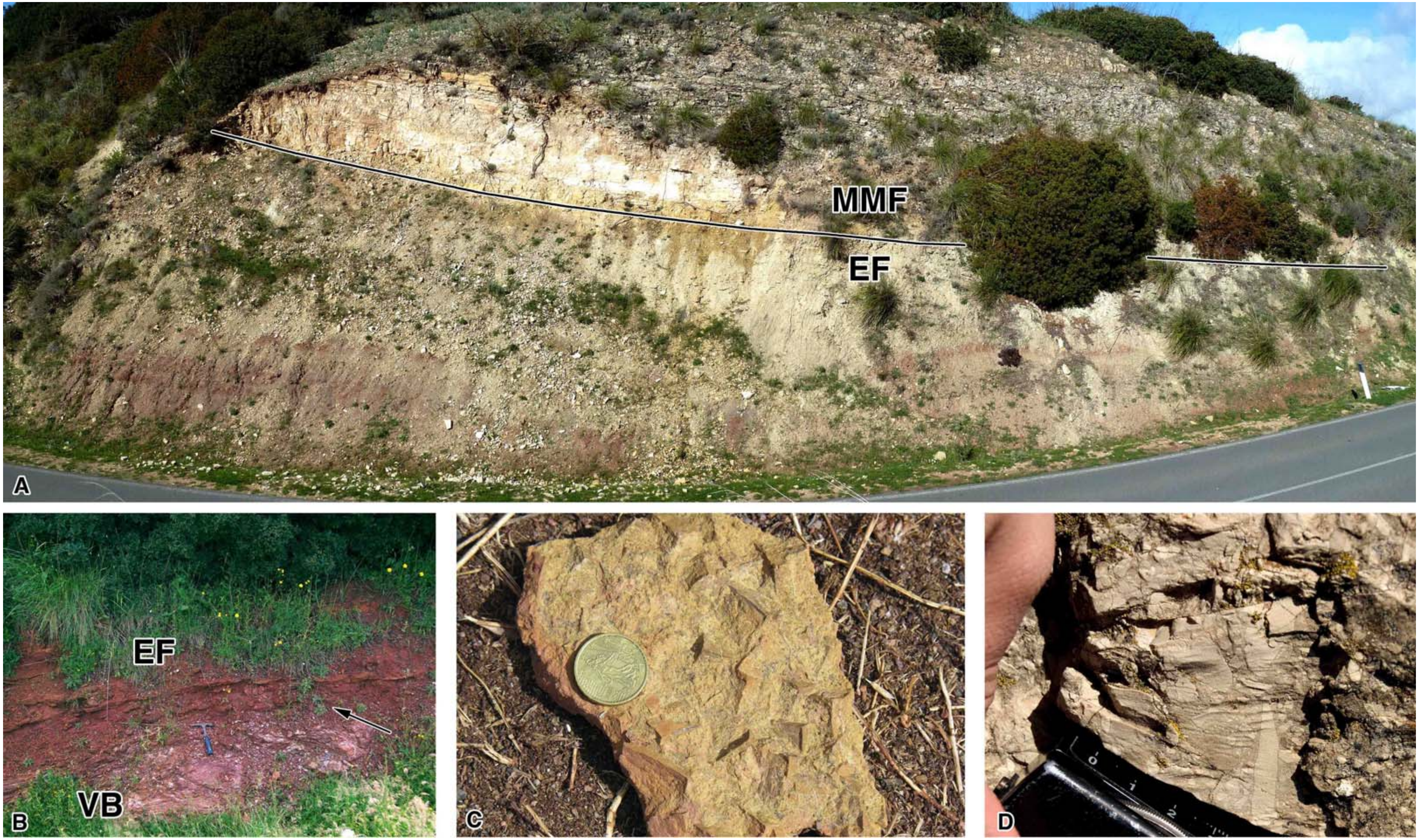

Fig. 29 - **A**) Overview of the intermediate part of the Bruncu Su Para section. **EF** = Escalaplano Fm.; **MMF**: Monte Maiore fm. **B**) Unconformity of the Escalaplano Fm. (EF) over the Variscan basement (VB). **C**) halite cast at the bottom of a sandy bed in the lithofacies 2 of the Escalaplano Fm.; **D**) Collapse breccias in the yellow dolostones mb of the Monte Maiore fm.

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dolostones and dolomitic marls passing quickly upwards to grey to grey-yellowish dolostones showing a laminated to thinly stratified bedding. Thin intercalation of yellowish marls are also present. The dolostone beds may be massive or alternatively may show several sedimentary structures, as cross bedding (HCS), ondulate bedding, ripple marks, tepees, evaporitic molds (gypsum and halite), collapse breccias (Fig. 29 D). The supposed thickness of the unit here is less than 25 m.

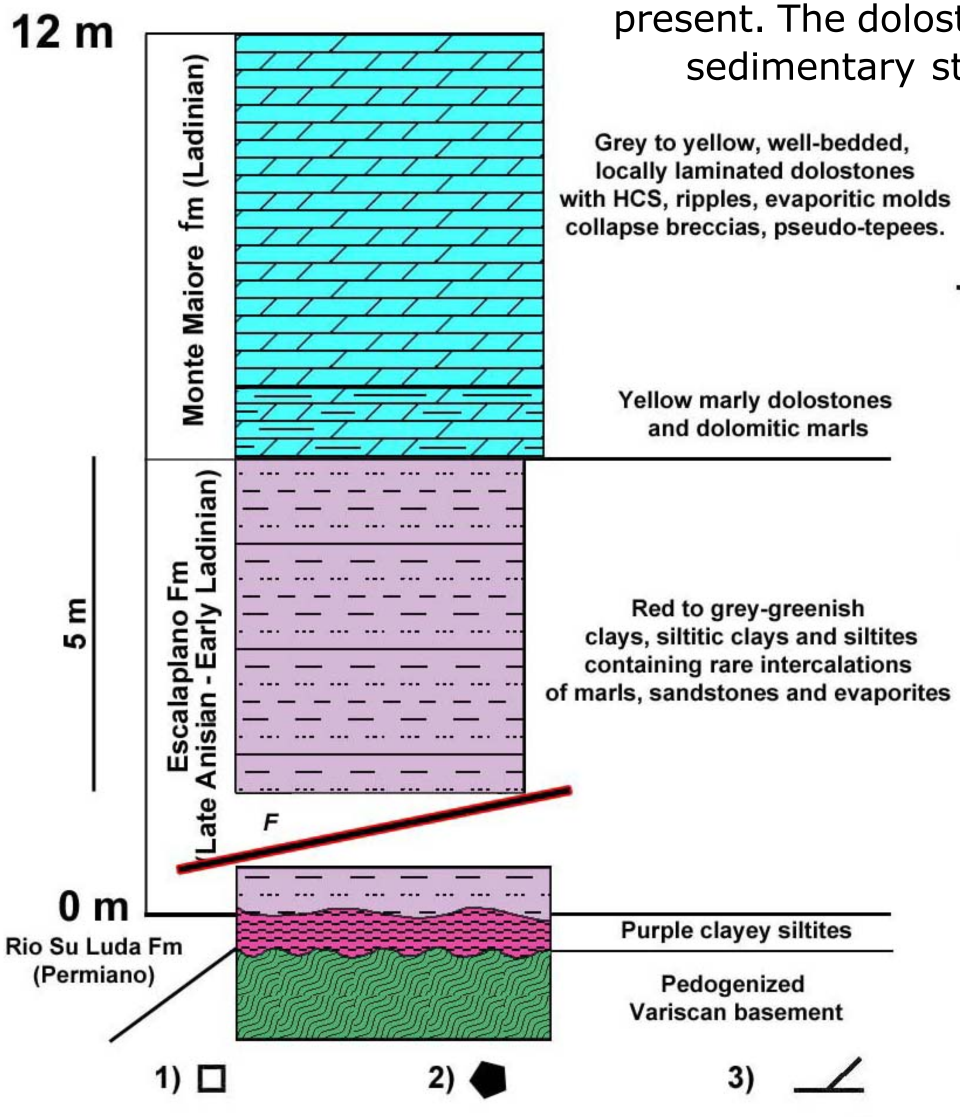

Fig. 30 – Bruncu su Para (Orroli) lower to intermediate part of the Middle Triassic Bruncu Su Para stratigraphic section. Legend: **1)** Evaportic molds: **2)** Collapse breccias; **3)** Cross bedding.

<u>Summary</u>: here the continental to transitional mudflat deposits of the Middle Triassic Escalaplano Fm. sharply pass upwards to the restricted carbonate shelf ouctrops of the Middle Triassic Monte Maiore fm.

Keeping going on along the Siurgus-Donigala – Orroli road, the next stop is about 500 m ahead.

STOP 2 - Bruncu Geroni (Orroli): algae in the yellow dolostones member of the Monte Maiore fm. and passage to the Tertiary deposits

This outcrop shows better on the left road cut. It is costituted by 2 to 3 m of Middle Triassic poorly stratified yellowish to grey dolostones bearing an almost horizontal attitude (Fig. 31 A). They contain abundant remains of Dasycladacean algae (Fig. 31 B). These remains are better identifiable in small isolated areas left untouched by the late dolomitization process (Fig. 31 C).

The upper part of this outcrop is deeply altered by later pedogenization processes. The dolostones are irregularly changed to Tertiary carbonatic calicitized "Pseudobreccias"

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with *Paronipora* (ex-*Microcodium:* Smit, 1979; Cherchi & Schröeder, 1988), described by Murru (1990) (Fig. 31 A). These "Pseudobreccias" mark locally the upward passage to the fluvial sandstones of the Monte Cardiga fm. (Early Eocene) (Carmignani et al., 2001). Otherwise, this passage may be evidenced sharply by thin quartzose microconglomerates, or by subtle levels rich of mm-sized hematite pebbles. In the sandstones, locally channel structures cut directly over the Triassic dolostones may even be observed. The Monte Cardiga fm. is followed upwards by the reddish deposits of the Upper Oligocene - Lower Miocene Ussana fm. (Pecorini & Pomesano Cherchi, 1969).
The classification of the Dasycladacean algae contained in the Middle Triassic dolostones is complicated: they could be referred to *Diplopora annulata* PIA, *Diplopora annulata debilis* and *Macroporella spectabilis*, that are Middle Triassic species described at Monte Maiore by Damiani & Gandin (1973a).
Despite the complication of the sedimentogical analysis of this outcrop due to its deep dolomitization and the plant cover, nonetheless the chaotic arrangement of the algae specimens and their fragmented nature suggest a storm transport and a reworking of the bioclastic debris on the shelf.

<u>Summary:</u> the algae-rich dolostones of the Monte Maiore fm. pass upward to the Paleogene pedogenetic carbonate "Pseudobreccias", and later to the fluvial Eocene deposits.

The next stop is located about 500 m northward.

Fig. 31 - Bruncu Geroni: **A)** Monte Maiore fm. dolostones (MMF) passing upwards to the "Pseudobreccias" of the Monte Cardiga fm. (MCF); **B, C)** Dasycladacean algae in the dolostones of the Middle Triassic Monte Maiore fm.

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STOP 3 - Piccheri (Orroli): Middle Triassic/ Middle Jurassic unconformity and general features of the Genna Selole fm.

Here, on the right road cut, the conglomeratic-sandy alternations of the Middle Jurassic (Bajocian-Bathonian in Dieni et al., 1983) Genna Selole fm. rest unconformably with a low angle over an irregular karstified surface with evident relief (Fig. 32 A) cut on the yellowish-grey dolostones of the Middle Triassic Monte Maiore fm. Frequently, coarse debris of the upper Genna Selole fm. fills the karstic fractures in the Monte Maiore fm. Both the units show a northward attitude of few degrees.

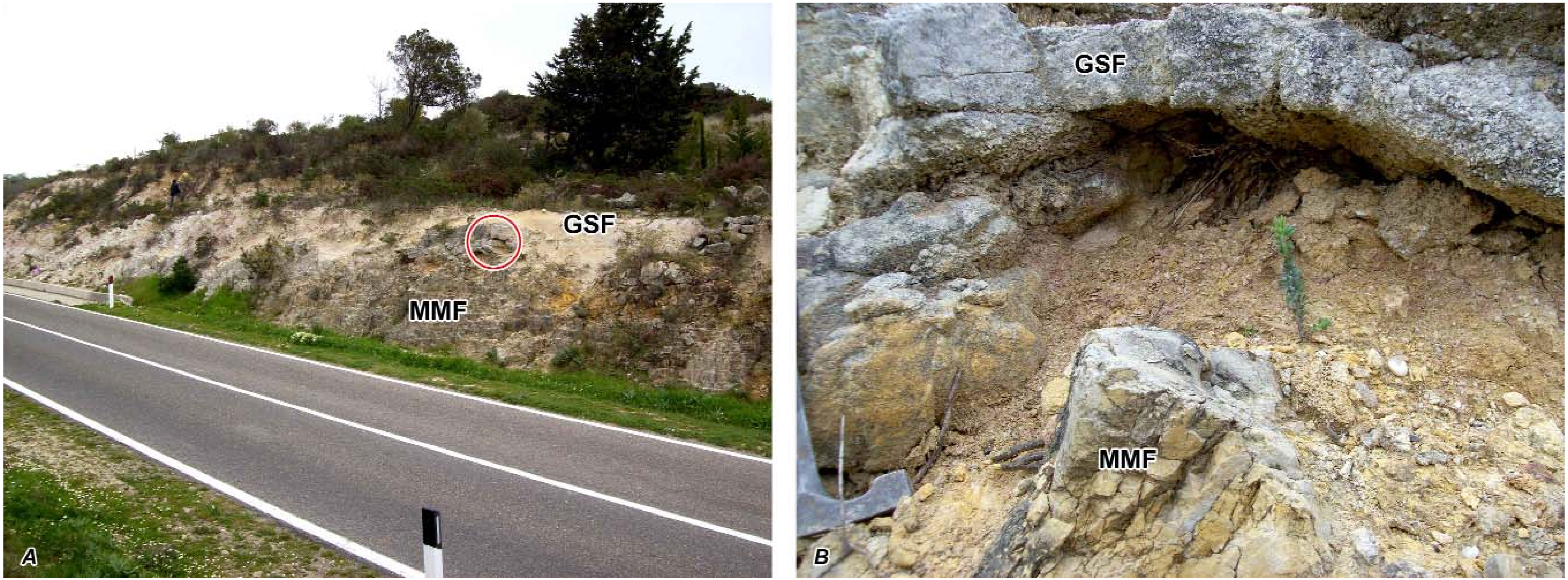

Fig. 32 – Piccheri: **A)** Unconformity between the dolostones of the Middle Triassic Monte Maiore fm. (MMF) and the terrigenous deposits of the Middle Jurassic Genna Selole fm. (GSF): the circle marks the location of the close-up B; **B)** Pocket filled by pedogenetic material between the Middle Jurassic Genna Selole fm. (GSF) and the Middle Triassic Monte Maiore fm. (MMF).

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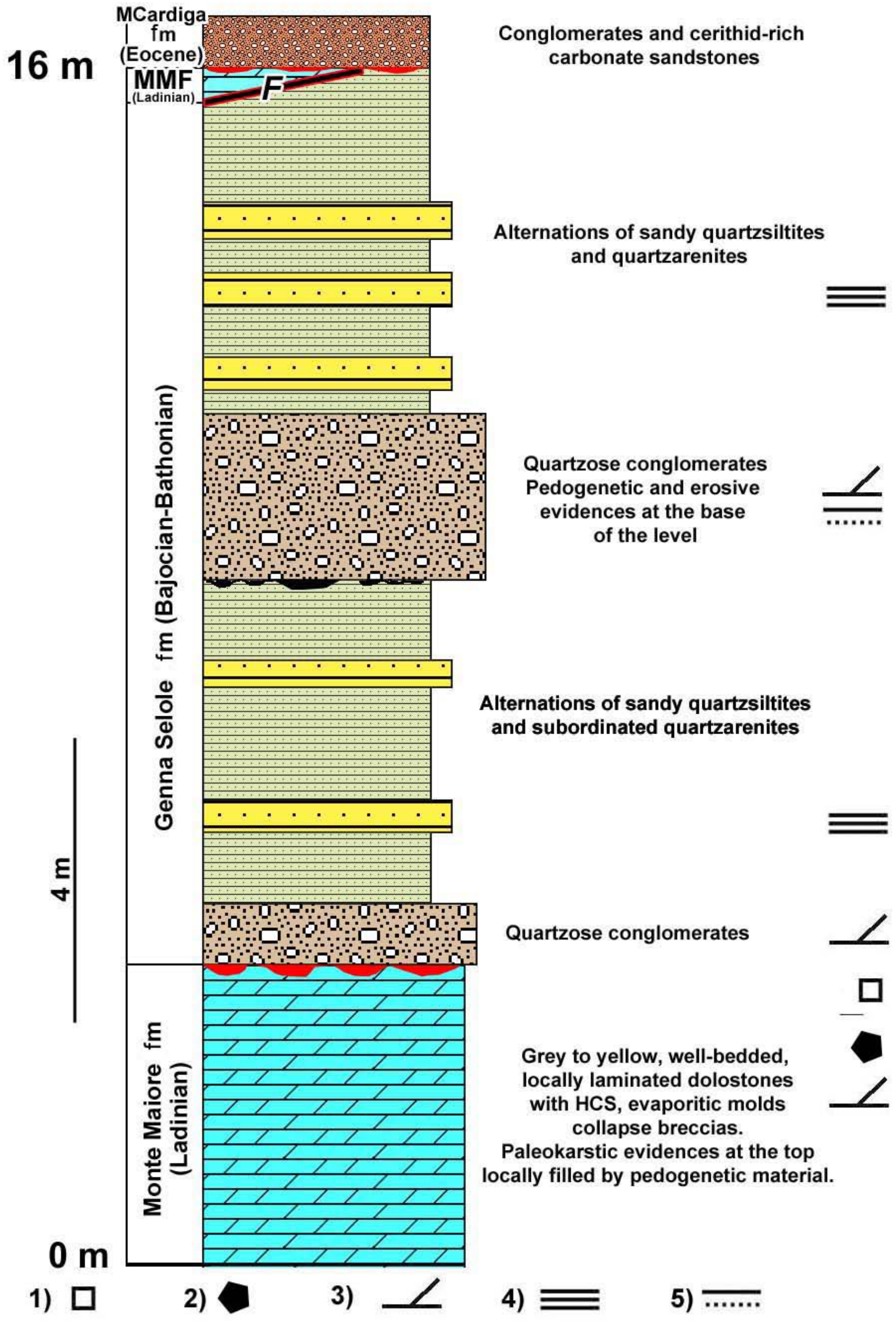

The Monte Maiore fm. (Fig. 33) has a short thickness of no more than 5 m and is here constituted by thick-bedded yellowish dolostones locally showing evaporitic mold-rich levels and collapse-breccias horizons. The Genna Selole fm. is nearly 15 m thick and it is made up by two fining upward (FU) cycles, every one of them formed by the lower Laconi - Gadoni lithofacies passing upward to the intermediate Nurri-Escalaplano lithofacies: whitish and well-sorted quartzose cross- to plane-parallel bedded conglomerates (made of subangular to subrounded pebbles of quartz and rare lydites) gradually fine up passing in the end to grey-brown quartzsiltites. The upper FU cycle is posed sharply over the lower one, whose topmost deposits are probably weakly pedogenized. Localized rubefied oxidized surfaces with faint and discontinuous hematitic beds and thin purple to violet layers, usually made of pebbly sandstone deposits and possibly deriving from starvation periods, are scattered along the lower part of the cycles: in fact, the covering whitish quartzose layer above is always coarser. Rare hematitic pebbles are present too. In their turn these two siliciclastic FU sequences are formed by several minor scale, pebbly to sandy FU depositional events representing building events of fluvial bars. Rare CU sequences are visibile too, probably due to the progressive superposition of the bar head over the bar tail during normal flood events.

Fig. 33 – Piccheri stratigraphic section. **MMF** = Monte Maiore fm. Legend: **F** = Fault. **1)** Evaporitic molds; **2)** Collapse breccias; **3)** Cross bedding; **4)** Parallel laminations; **5)** Graded bedding.

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Along the unconformity between the Triassic and the Jurassic rocks a fine siliciclastic brown fissile (pedogenetic?) deposit may lay down. It is confined in small pockets over the oxidized and karstified Triassic dolomitic irregular surface (Fig. 32 B).
In its turn, the Genna Selole fm. is covered unconformably by sandy cerithides-rich sandy limestones pertaining to the Monte Cardiga fm. (Early Eocene).

The Genna Selole fm. is laterally cut by a reverse fault. This fault poses the unit in contact with the Monte Maiore fm. dolostones acting as a hanging wall. This fault is sealed by the Lower Eocene deposits of the Monte Cardiga fm., so suggesting a pre-Eocene age of the fault itself: thus this discontinuity may be related to the Laramic tectonic phase (Cherchi & Tremolières, 1984; Barca & Costamagna, 1997; 1999; 2000), up to now signaled only in the Western part of the Island.

<u>Summary</u>: in this location the restricted carbonate shelf ouctrops of the Middle Triassic Monte Maiore fm. are unconformably covered by the fluvial deposits of variable energy (channel and interchannel areas) of the Middle Jurassic Genna Selole fm.

Still running along the road to Orroli, the Eocene deposits of the Monte Cardiga fm. pass abruptly to the fluvial conglomerates of the Ussana fm., located at the base of the Upper Oligocene-Miocene depositional cycle. Nonetheless, the boundary is not directly visibile.

The road reaches the Orroli village, and turn towards SE. Close to Orroli are the noteworthy Nuraghe Arrubiu and another important archeological site: the "Domus de Janas" of Parco Su Motti.
The itinerary goes surrounded by a landscape of highplains and smooth hills. While the slopes of the hills are formed by Variscan metamorphics, conversely their flat top may be covered unconformably by sedimentary deposits of Mesozoic to Tertiary age or by Pliocene basaltic flows. Finally, passing through the Santo Stefano Gate, you reach the edge of the deep gorge of the Flumendosa river. During Quaternary times the river escavated a valley, so cutting entirely the basaltic flows and the Variscan metavolcanics of the Santa Vittoria fm. (Ordovician).

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Now the itinerary proceeds down the western slopes of the Flumendosa valley, while to South on the background stands the volcano-sedimentary Escalaplano Permian succession. In the bottom of the valley the road turns sharply to East, crossing the Flumendosa river and climbing the opposite slope. Along the road cuts may be observed the whole Permian red bed succession of the post-Variscan molassic Escalaplano basin. At the end of the rise, on the top of the ridge the Permian deposits are unconformably capped by the terrigenous Early Eocene lower M. Cardiga fm. deposits. Then, you move down to the Escalaplano village (Fig. 34).

The itinerary now runs again over the Variscan metamorphics, before to cross scattered Triassic outcrops resting unconformably above them. The Stop 8 is located close to the southern outskirts of the Escalaplano village.

STOP 4 – Escalaplano (Escalaplano Tacco): type section and sedimentological features of the Escalaplano Fm. (Middle Triassic)

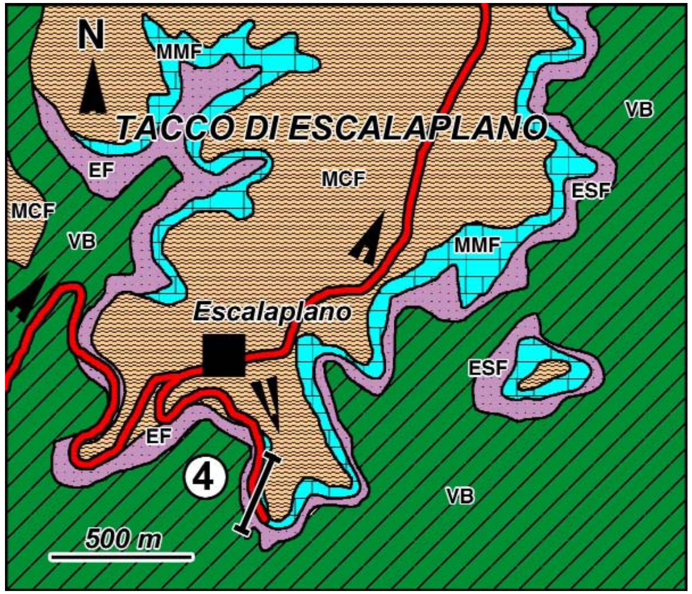

Fig. 34 - Geological sketch of the Escalaplano Stop (8) (Escalaplano Fm. type section). Legend; VB: Variscan basement; ESF: Escalaplano Fm. (Middle Triassic); MMF: Monte Maiore fm. (Middle Triassic); MCF: Monte Cardiga fm. (Early Eocene). The trace of the type section is marked.

Here, on the road cuts of the southern periphery of the Escalaplano village, the base of the first Mesozoic sedimentary cycle unconformably overlies the Variscan basement. The Escalaplano Fm. (late Anisian/early Ladinian) (Fig. 5), here 16 m thick, is formed by 4 lithofacies: it rests above Variscan metasandstones and metasiltites (San Vito sandstones fm., Late Cambrian - Early Ordovician: Meana Sardo tectonic unit) showing in their upper part alterations and carbonate pedogenesis. Over the reworked basement surface and going uphill along the road cuts, follow: the lithofacies 1, formed by 1 m of alternations of reddish polygenic (quartz, Variscan metamorphics, Permian volcanics and sandstones) conglomerates, breccias and sandstones (Fig. 35 A). It is sharply covered by the lithofacies 2 built of 7.20 m of cyclical alternations of siltites, clayey siltites and silty clays from fissile to thinly stratified, reddish-purplish to grey-greenish and decimetric beds of dolomitic marls and sandy dolomitic marls orange-yellowish in colour. Localized load casts and calcrete layers are also present

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(Fig. 35 B). Upwards, the lithofacies 3 gradually appears. It is built of 3 m of thin, regular alternations of clayey siltites, siltitic clays and subordinated siltites from greysh-blackish to reddish in colour, in their turn alternated with thin pink crystalline gypsum veins (satin spar), probably precipitated from sulphate solutions inside the bedding surfaces during late diagenesis. The same gypsum is present also in veins crossing the rock (Fig. 35 C). Finally, with the disappearance of the gypsum beds and veins, and the turning of the colour to a grey-greenish tone, the 4 m thick lithofacies 4 takes place. Especially in its upper part, scattered beds of carbonate sandstones and marly sandstones foretell the passage to the dolostones of the Monte Maiore fm. (Fig. 35 D).

The Monte Maiore fm. is represented by the yellow dolostones member: here it is formed by 1.2 m of yellowish dolostones built of faintly wavy, thin microbialitic laminae intercalated by thicker micritic levels. (Fig. 36 A).

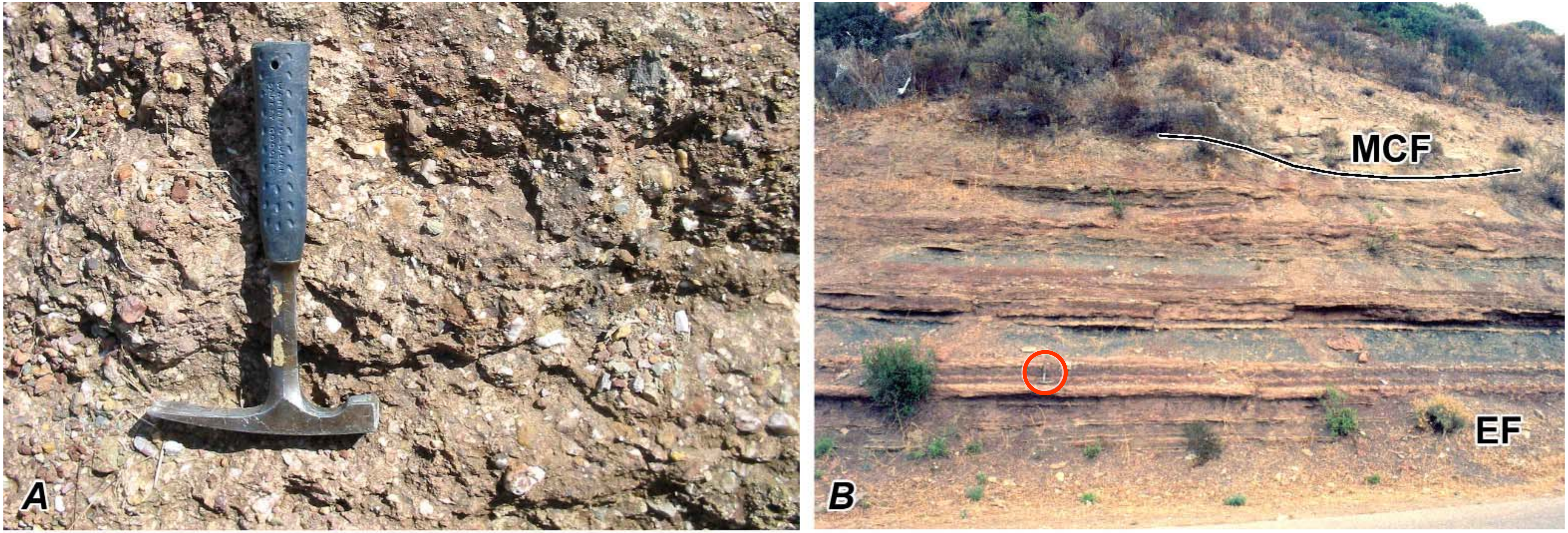

Fig. 35 (p.1) – Escalaplano: the Escalaplano Fm. lithofacies (**A**: lithofacies 1; **B**: lithofacies 2; **EF** = Escalaplano Fm.; **MCF** = Monte Cardiga fm. In the picture B the circle marks the hammer for scale.

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Fig. 35 (p.2) – Escalaplano: the Escalaplano Fm. lithofacies (**C**: lithofacies 3; **D**: lithofacies 4).

The Triassic units are unconformably followed by the polygenic, chaotic conglomerates of the Monte Cardiga fm. (Early Eocene): these conglomerates contain also rounded pebbles and cobbles of the Triassic carbonates (Fig. 36 B) posed underneath.

Summary: during Middle Triassic over the smoothed Variscan basement mild alluvial slopes representing the base of the Escalaplano Fm. took place: they were followed by an alternatively emerged and flooded, sometimes restricted mudflat of the upper Escalaplano Fm., finally covered, with the stop of the terrigenous inputs, by the carbonate sediments of the Middle Triassic restricted ramp of the Monte Maiore fm.

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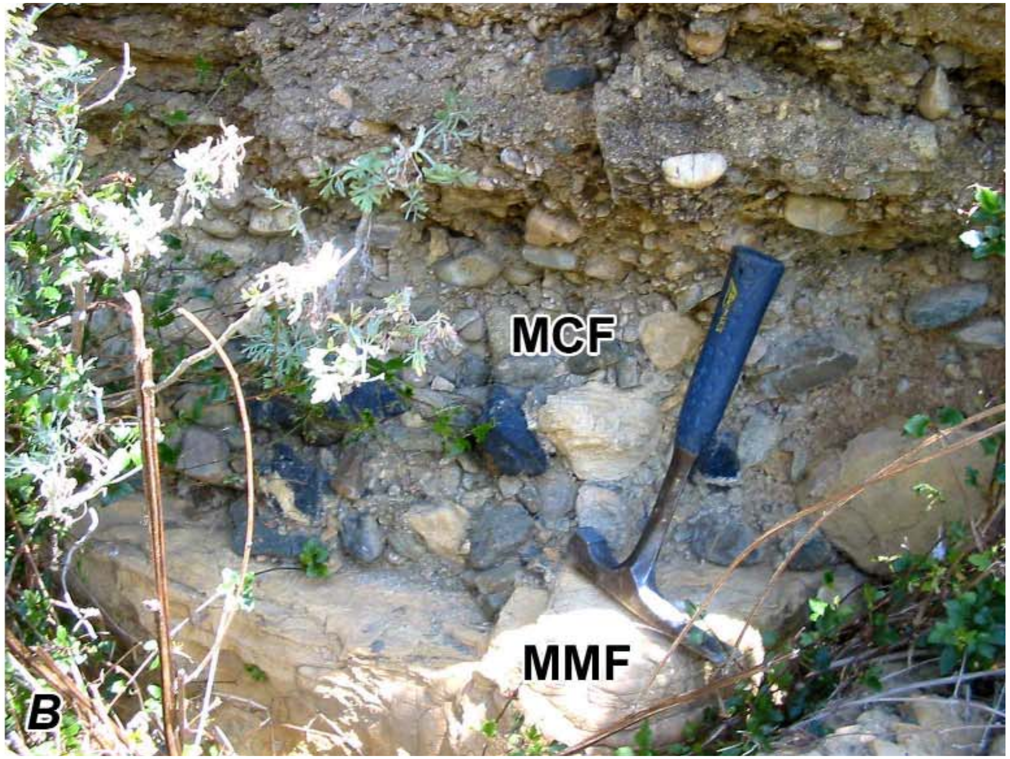
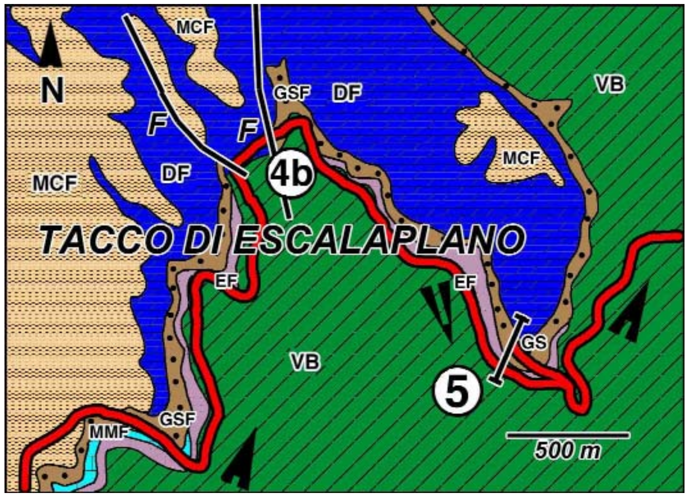


Fig. 36 – **A)** Microbialitic dolostones of the Monte Maiore fm.; **B)** Basal conglomerate of the Monte Cardiga fm. (Early Eocene) unconformably posed over the carbonate Monte Maiore fm.: light Triassic carbonate pebbes are clearly visible.



The road moves northward, turning back and crossing the Escalaplano village again. A secondary road to Perdasdefogu is picked: 1 km past, a right turn is chosen on the old road (a dirt track) to Perdasdefogu (Fig. 37)*. This road runs bordering the edge of the Escalaplano Tacco,*

Fig. 37 - Geological sketch of the Arcu de Is Fronestas Stop (9) and surrounding areas. Legend: **VB**: Variscan basement; **EF**: Escalaplano Fm. (Middle Triassic); **MMF**: Monte Maiore fm. (Middle Triassic); **GSF**: Genna Selole fm. (Middle Jurassic); **DF**: Dorgali fm. (Middle Jurassic); **MCF**: Monte Cardiga fm. (Early Eocene); **F**: Fault. The trace of the stratigraphic section is marked.

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moving up and down along its edges, so allowing observation of the several stratigraphic unconformities among the Variscan basement and the Triassic, Jurassic and Eocene covers. Some interesting outcrops of the Escalaplano, Monte Maiore, Genna Selole and Dorgali fms can be noticed.

Stop 4b - Ponte Tradala - Features of the transition from the Genna Selole fm. to the Dorgali fm.

In particular, at Ponte Tradala (Stop 4b) the passage from the upper Ussassai-Perdasdefogu lithofacies of the Genna Selole fm. to the Dorgali fm. is exposed. Well-stratified brownish marly dolostones with lenticular to wavy bedding, bioturbation and bioclasts (bivalves) and intercalated thin beds of dark siltites with plant remains are visible (Fig. 38 B, C, D). The last, upper dark siltite bed mark the passage to the grey, thin-bedded dolostones of the Dorgali fm.: here the upwards decrease of the terrigenous content passing from the brownish upper lithofacies of the Genna Selole fm. to the grey Dorgali fm. carbonate deposits is clearly visible.

Looking northward across the Rio Tradala valley a panoramic overview (Fig. 38 A) of the lansdscape is visible, showing as ledges the quartzose conglomeratic lower lithofacies of the Genna Selole fm. and the dolostones of the Dorgali fm. overlaying Triassic and Paleozoic deposits.

STOP 5 - Arcu de Is Fronestas (Escalaplano Tacco): unconformity between the Escalaplano Fm. (Middle Triassic) and the Genna Selole fm. (Middle Jurassic)

On the road cut at the Km 10 of the secondary road connecting the villages of Escalaplano and Perdasdefogu (Fig. 38), at Arcu de Is Fronestas (Fazzini et al., 1974; Costamagna et al., 2000), a well-exposed stratigraphic section about 25 m thick crops out (Fig. 39). This section is exposed partially (Paleozoic to Triassic deposits) on the dirt track followed thus far, and partially on the paved secondary road located nearly 10 m above (Triassic to Jurassic deposits). It is formed, from the bottom, by Variscan metamorphics (San Vito Sandstones fm., Late Cambrian - Early Ordovician: Meana Sardo tectonic unit) followed unconformably by stratified reddish conglomerates (Fig. 40 A), sandstones and purple to blackish siltites and clayey siltites of the Escalaplano Fm. (Middle Triassic), here 7-8 m thick: cross laminations in the sandstone beds and halite-casts at their bottom are visible. Upwards, in the road cut located along the paved road, the blackish pelites of the Escalaplano Fm. have rare dm-thick marly-dolomitic-sandy beds with scattered microbialitic mats. In the pelites a microfloristic assemblage of Pelsonian-Illyrian age (late Anisian, Middle Triassic: Pittau Demelia & Flaviani, 1983; Costamagna et al., 2000) has been found. Above, the Escalaplano Fm. is in its turn unconformably covered by the cross-bedded and locally graded quartzose

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Fig. 38 - Ponte Tradala **A)** Overview of the Rio Tradala left slope. Legend; **VB**: Variscan basement; **EF**: Escalaplano Fm. (Middle Triassic); **GSF**: Genna Selole fm. (Middle Jurassic); **DF**: Dorgali fm. (Middle Jurassic); **B, C, D)** Passage from the UP lithofacies of the Genna Selole fm. (**GSF**) to the Dorgali fm. (**DF**): the upmost dark clayey siltites level separating the units is evidenced by the arrow. The sudden upward change of colour and bedding from the lower to the upper unit is evident, as well as the wavy bedding in **(C)** and the bioturbation in **(D)**. Front height in (B) = 2.5 m.

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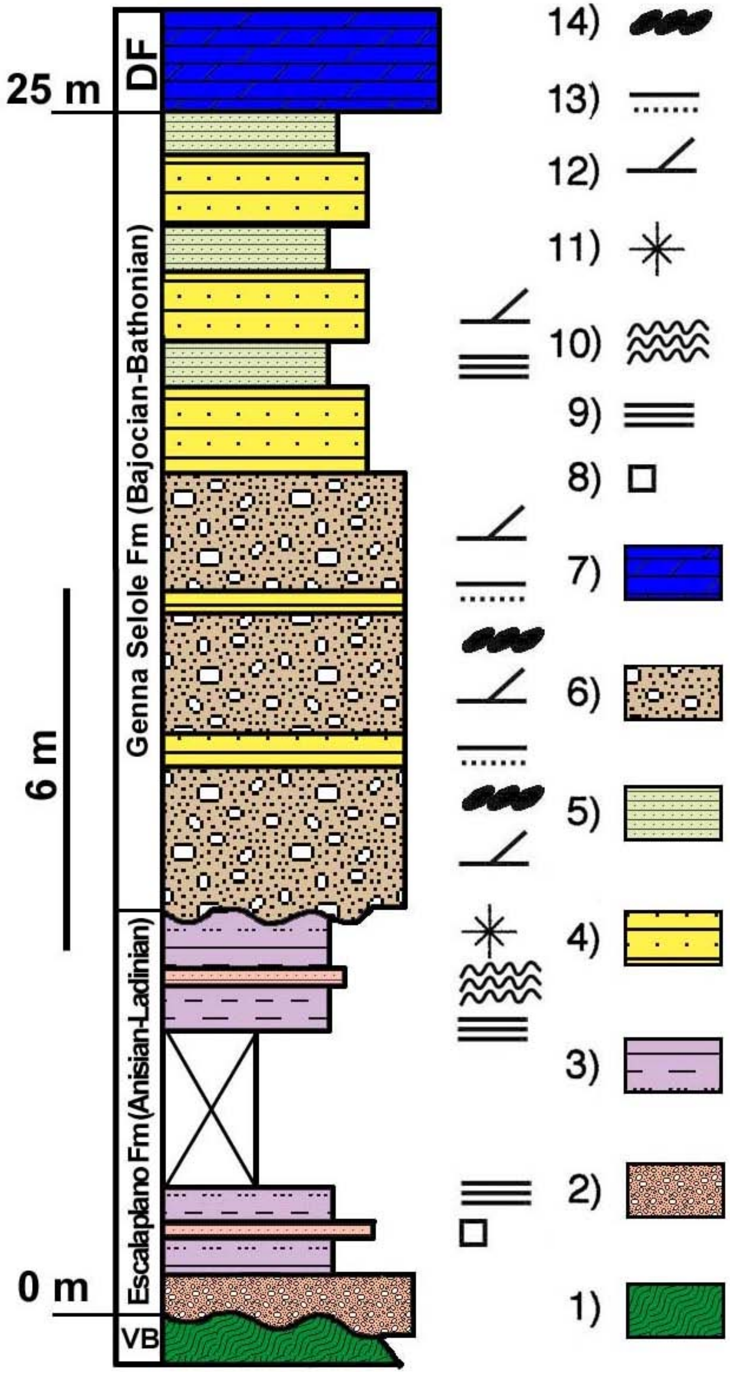

conglomerates of the lower Laconi-Gadoni litofacies of the Genna Selole fm. (Middle Jurassic) (Figs 40 B, C). The conglomerates are subdivided in meter-thick depositional FU sequences (Fig. 40 C) separated by erosional surfaces and containing rare coarsening-upward (CU) sequences. In the middle of the conglomerates rare and discontinuous thin intercalations of dark siltites and clays are present.

Imbricated pebbles are common. In the conglomerates, blackish pebbles from the dismantling of the silicized Permian limestones are scattered (Fig. 40 D). The conglomerates are suddenly covered by whitish quartzarenites with wavy to flaser bedding (Fig. 40 C). Over this coarse lithofacies, the finer Nurri-Escalaplano darker lithofacies sharply occur.

Summary: the restricted mudflat of the upper Escalaplano Fm. is unconformably covered by the fluvial braided bars of the lower Laconi-Gadoni lithofacies of the Genna Selole fm., in turn covered by sandstones.

The road descends from the northern slopes of the Escalaplano Tacco and then climbs the next slopes of the Perdasdefogu Tacco, once more on Variscan metamorphics the Jurassic succession follows.

Fig. 39 - Arcu de Is Fronestas (Escalaplano); stratigraphic section of the Escalaplano Fm. and Genna Selole fm. Legend – **1)** Variscan basement; **2)** Oligomictic conglomerates; **3)** Pelites; **4)** Sandstones; **5)** Marls, sandy marls, clayey marls; **6)** Coarse quartzose conglomerates containing sandstone lenses; **7)** Dolostones; **8)** Halite-casts; **9)** Parallel laminations; **10)** Microbialitic mats; **11)** Palynomorphs-bearing horizons; **12)** Cross laminations; **13)** Graded bedding; **14)** Imbrications; **VB:** Variscan basement; **DF:** Dorgali fm.

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Fig. 40 – Arcu de Is Fronestas: **A**) Conglomeratic base of the Escalaplano Fm. (EF) (Middle Triassic): a frontally-accreted pebbly bar prograding over the Variscan basement (VB); **B**) Unconformity between the Genna Selole fm. (GSF) (Middle Jurassic) and the Escalaplano Fm. (EF) (Middle Triassic); **C**) Cross bedding in the conglomerates of the Genna Selole fm.: the conglomerates are covered at the top by flaser–bedded sandstones; **D**) Close up of the Genna Selole fm. conglomerates: a black silicized Permian carbonate pebble 8 cm large (Middle Jurassic).

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STOP 6 - Sa Teria (Perdasdefogu Tacco): sedimentological features of the upper Genna Selole fm. and the lower Dorgali fm. (Middle Jurassic)

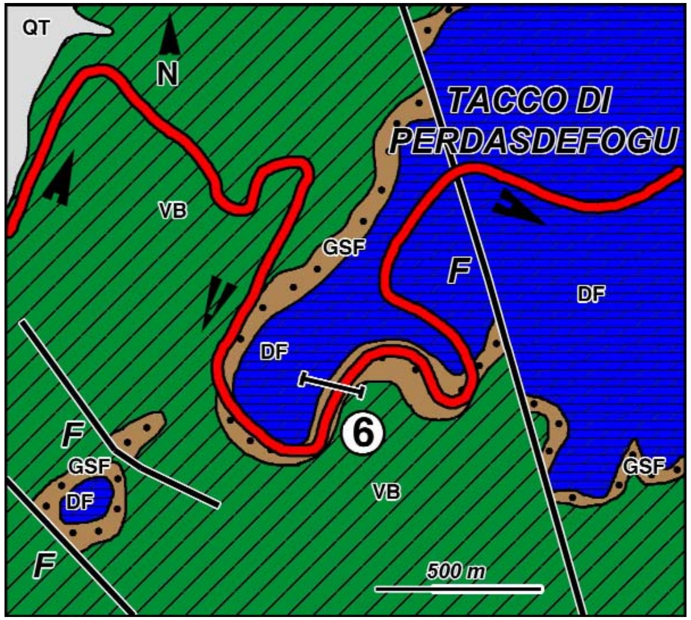

Fig. 41 – Geological sketch of the Sa Teria Stop (10) and surrounding areas. Legend; **VB:** Variscan basement; **GSF:** Genna Selole fm. (Middle Jurassic); **DF:** Dorgali fm. (Middle Jurassic); **QT:** Quaternary debris; **F:** Fault. The trace of the stratigraphic section is marked.

At Sa Teria, 4 Km SW to Perdasdefogu (Fig. 41), the Jurassic stratigraphic section is located below and above the secondary road Escalaplano-Perdasdefogu. The upper Genna Selole fm. and the lower Dorgali fm. crop out along the old dirt track still running about 5 metres above the new road.

The Middle Jurassic succession of the Perdasdefogu Tacco starts with the Genna Selole fm., about 30 m thick: it rests over Variscan metavolcanics (Monte Santa Vittoria fm., Ordovician: Meana Sardo tectonic unit). The lower part of this unit is reachable with difficulty below the secondary road Escalaplano-Perdasdefogu. The Genna Selole fm. is initially built of quartz conglomerates, passing quickly to whitish sandstones (Laconi-Gadoni lithofacies, about 15 m). The pebbles are imbricated towards S or SW. The intermediate lithofacies is formed by alternations of frequently cross-laminated quartzarenites, siltites, clayey siltites and silty clays grey-whitish to green in colour with load casts (Nurri-Escalaplano lithofacies, about 8 m). In the upper part (along the old dirty track), the carbonate sedimentation begins suddenly: over whitish quartzarenites, rare well-bedded dolomitic sandstone, grey-green sandstones and blackish lignitiferous siltitic clays intercalate (Ussassai-Perdasdefogu lithofacies, about 4 m). The Dorgali fm. rests over the last terrigenous, blackish silty bed.

Here the Dorgali fm., about 12 m thick, is built of well-bedded dolostones, white-grey to bluish in colour. There are rich in sedimentary structures and textures: bioturbations, load-casts, parallel and cross laminations, rip-up and flame structures, algal bindstones (Fig. 42), storm layers with coarse basal lags, erosive irregular surfaces often rubified (Fig. 43). Oncoids, flat pebbles, intraclasts and bioclasts are still evident. The most frequent lithofacies association is formed by alternations of storm layers and bioturbated muds.

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Summary: over a fluvial to palustrine sedimentation, following the progressive vanishing of the terrigenous input (Genna Selole fm.), a pure carbonate sedimentation took place: here a prevalently subtidal-lagoonal low energy environment frequently interested by reworking of the primary deposits and the deposition of storm layers (Dorgali fm.) dominated.

Fig. 42 – Sa Teria (Perdasdefogu): Stromatolitic bindstone with wrinkled mats (dark) and micritic beds (light) passing upward to bioclastic grainstones. Dorgali fm. dolostone.

Fig. 43 – Sa Teria (Perdasdefogu): sedimentary structures in the Dorgali fm. **A)** bioturbated muds; **B)** wave cross laminations; **C)** oncoidal basal lag of a storm layer covering laminated microbialites; **D)** bioclastic molds in a storm basal lag covering an erosive surface.

The road moves on to the Perdasdefogu village: here it turns right and take a secondary road towards Tertenia leading to the Serra Is Arangius stratigraphic section designated as parastratotype of the Genna Selole fm.

STOP 7 - Serra Is Arangius (Perdasdefogu Tacco): parastratotype and sedimentological features of the Genna Selole fm. (Middle Jurassic)

At Serra Is Arangius (Fig. 44) a splendid Genna Selole fm. section (Figs 45, 46 A), chosen as parastratotype of the unit crops out. At the base, Variscan metamorphics (San Vito sandstones fm. and Santa Vittoria fm., Late Cambrian to Middle Ordovician: Meana Sardo tectonic unit) crop out. They are unconformably covered first by the whitish monomictic conglomeratic-sandy Laconi-Gadoni FU lithofacies: at its very base, scattered pockets of black silty-clayey materials may be present. Cross-bedding is diffuse (Fig. 46 B), as well as lens-shaped horizons representing minor fluvial channels, and rubified and oxidized surfaces suggesting breaks in sedimentation. This lithofacies is 9.4 m thick and it is sharply followed by the blackish siltites - clayey siltites with rare thin whitish sandstone beds of the Nurri-Escalaplano lithofacies. Here rootlets (Fig. 46 C), plant remains, black clay pockets, convolute laminations and load casts are visible. Thickness is about 6 m. In its turn this lithofacies is suddenly covered by the well-stratified carbonate-sandy-silty alternations of the Ussassai-Perdasdefogu lithofacies, 11 m thick through a weak angular unconformity (?) perhaps related to a ravinement surface. Rarely, cross bedding, lenticular and flaser bedding are present. Frequently, in the carbonate lithofacies brachiopods and gastropods-rich horizons, erosive surfaces and bioturbation are visible. The vanishing of the terrigenous inputs marks the passage to the Dorgali fm.
The total thickness of the Genna Selole fm. is here 26.4 meters.

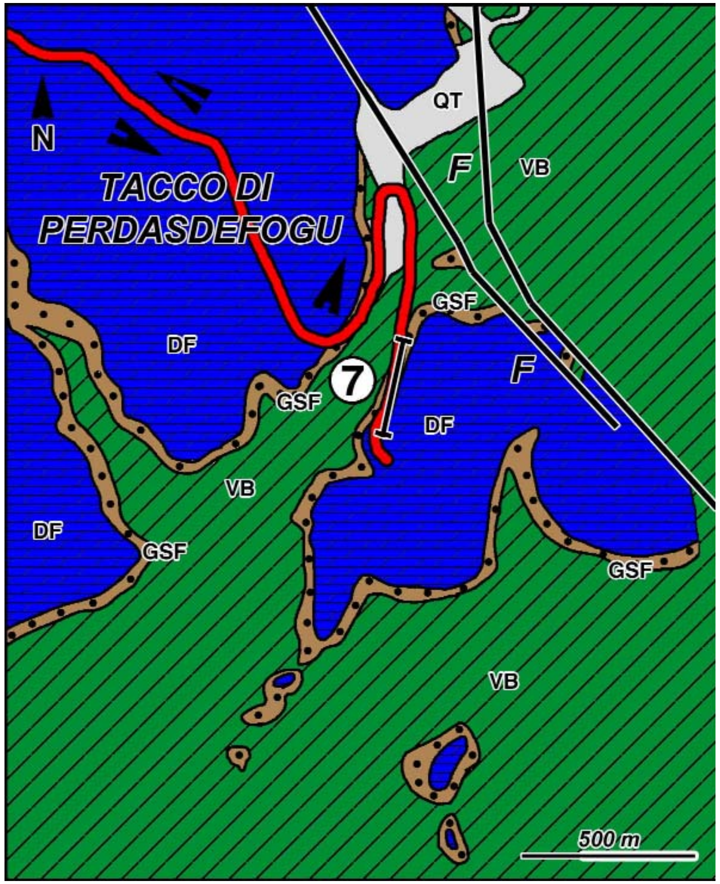

Fig. 44 - Geological sketch of the Serra Is Arangius Stop (11) and surrounding areas. Legend; **BPZ**: Variscan basement; **FGS**: Genna Selole fm. (Middle Jurassic); **FDO**: Dorgali fm. (Middle Jurassic); **QT**: Quaternary debris; **F**: Fault. The trace of the stratigraphic section is marked.

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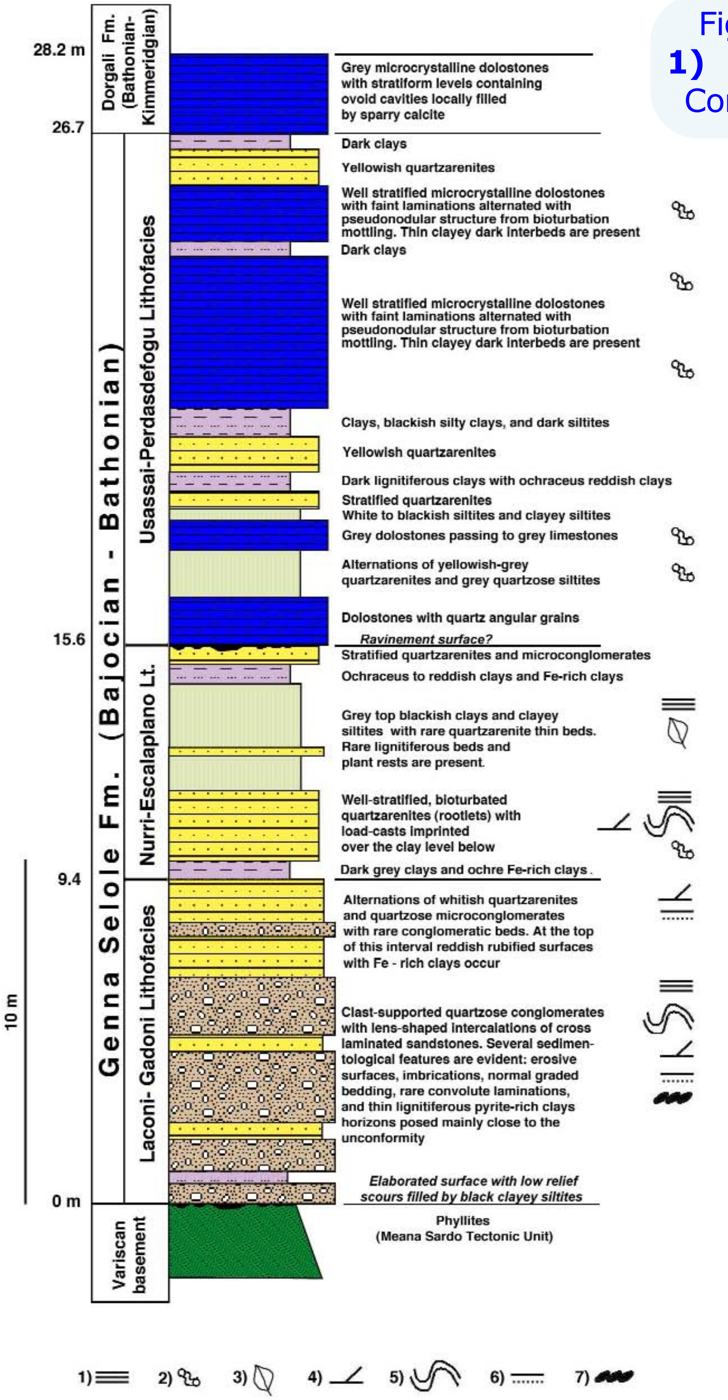

Fig. 45 – Serra Is Arangius (Perdasdefogu): Genna Selole fm. parastratotype. Legend: **1)** Parallel laminations; **2)** Bioturbation; **3)** Plant rests; **4)** Cross laminations; **5)** Convolute laminations and load-casts; **6)** Normal graded bedding; **7)** Imbrications.

Fig. 46 – Serra Is Arangius. **A)** Stratigraphic section overview: Legend; **VB**: Variscan basement; **GSF**: Genna Selole fm. (Middle Jurassic); **DF**: Dorgali fm. (Middle Jurassic); **B)** Variscan basement / Genna Selole fm. unconformity: close up (**VB**: Variscan basement; **GSF**: Genna Selole fm.); **C)** Root-cast into a sandstone layer of the Nurri-Escalaplano lithofacies (Genna Selole fm.).

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Summary: the deposition of the Genna Selole fm. occurred first into a braided stream context passing rapidly to a palustrine-alluvial environment and later to a lagoonal, tide-influenced one with various (carbonate and terrigenous) sedimentary contributions: a fluvial outlet cyclically closed and moved away.
Here, in times the terrigenous inputs gradually disappeared, giving place to the Dorgali fm. carbonate shelf.

On the western side of the valley along an abandoned track, another good section of the Genna Selole fm. crops out. This is especially true for the upper Ussassai-Perdasdefogu lithofacies: here sedimentary structures suggesting tidal processes and fossils are abundant.

The road turns back to Perdasdefogu and moves North, towards the Jerzu village. Along the road just out Perdasdfefogu, for about a couple of km are visible on the left road cuts the Jurassic deposits unconformably overlapping the Permian late-Variscan volcanics.
Here the Genna Selole fm. thins out dramatically, reaching at the best not more than 3-4 m of thickness. It is formed only by fine terrigenous deposits and few carbonate beds. This stratigrapic arrangement is the result of the paleogeographic setting of the area at early Middle Jurassic times: here the watcher stands over the former Barbagia paleohigh, where the Jurassic deposits often may even start directly with the carbonate Dorgali fm. containing only scattered centimetric quartz pebbles close to its base.
Our itinerary heads to the overnight stay place at the "Rifugio di Ogliastra" and develops exclusively over low- to medium grade Variscan metamorphics.

Overnight stay at "Rifugio d'Ogliastra", 4 km SW to Jerzu.

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Day 2: from Jerzu to Osini

Luca G. Costamagna

The itinerary moves back to SW for nearly 1 Km, reaching the Pitzu S. Antonio Gate (Fig. 47). Here the Middle Jurassic transgressive deposits are strongly reduced in thickness. The features of the Pitzu S. Antonio stratigraphic section are connected to the peculiar Middle Jurassic paleogeographic and paleostructural configuration of the area. The tectonic Barbagia paleohigh for its raised topographic position was the last area of the Variscan basement reached by the Middle Jurassic transgression (Costamagna & Barca, 2004; Costamagna et al., 2007). So, weathering and alteration phenomena worked hardly over the exposed paleohigh, activating pedogenesis and preventing the deposition of the Genna Selole fm. but on its slopes. In some areas, those processes induced laterization processes over the Variscan basement and, consequently, the development of lateritic paleosoils along the unconformity between Variscan basement and Jurassic deposits ("Ferro dei Tacchi": Marini, 1984).

Fig. 47 - Geological sketch of the Pitzu S. Antonio Gate Stop (12) and surrounding areas. Legend; **VB**: Variscan basement; **GSF**: Genna Selole fm. (Middle Jurassic); **FD**: Dorgali fm. (Middle Jurassic); **QT**: Quaternary debris. **F?**: Fault.

STOP 8 – Pitzu S. Antonio (Tertenia Tacco): sedimentological features of the Middle Jurassic transgression over the Variscan basement

At the Pitzu S. Antonio Gate (Fig. 48), at the base of the road cut Variscan basement reddish schists crop out (Gennargentu grey phyllites fm., Late Cambrian – Early Ordovician: Barbagia tectonic unit); their alteration grow up towards the top, passing in only 1 meter and almost sharply, first to pedogenized reddish clays with quartz cobbles (weak laterization - Fig. 49 A) followed quickly by greyish silty clays with quartz cobbles and finally by sticky grey clays. In their turn these gray clays are covered by 20 cm of black, fissile clays that terminate upwards with a thin, locally shiny coal bed. Over the coal, the carbonate

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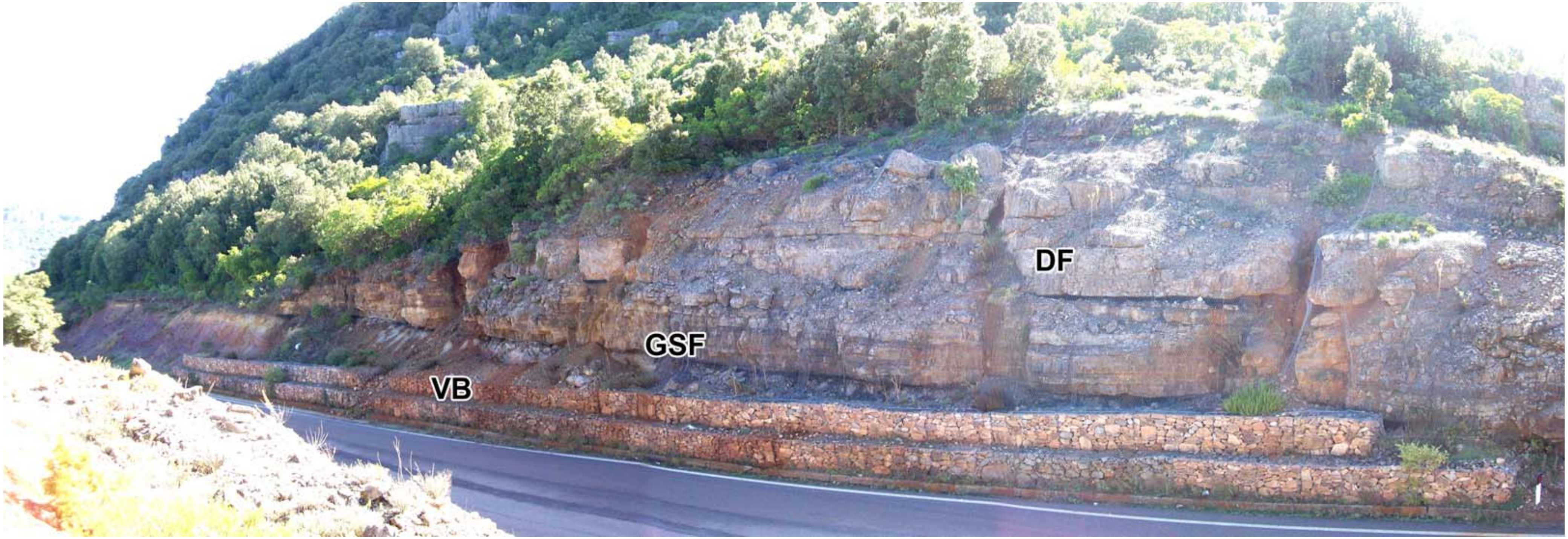

Fig. 48 – Overview of the Pitzu S. Antonio Gate stratigraphic section. The front is about 7 m high. Legend; **BPZ**: Variscan basement; **FGS**: Genna Selole fm. (Middle Jurassic); **FDO**: Dorgali fm. (Middle Jurassic).

sedimentation starts suddenly. It is formed by bedded dolostones (bioclastic-intraclastic grainstones) with a terrigenous content (quartz pebbles and clays) gradually fading upwards. Here bioturbation (Fig. 49 B), irregular and erosive surfaces with significant relief, plane-parallel and ripple cross laminations and cross bedding are abundant. Gastropods (*Nerinella bathonica*) are also present. Often, in the carbonates the erosional surfaces are covered by thin oxidized, reddish coatings or by an intraclastic breccia containing also angular quartz pebbles. In their turn these deposits are followed by cm-thick blackish siltitic clays that make sharp transition back to the carbonates. Sometimes a complete sequence made of oxidized coatings, conglomerates and siltitic clays develops: it represents the start again of the sedimentation following the emersion and before the recovery of the carbonates. The topmost blackish siltitic-clayey intercalation marks the transition from the Genna Selole fm. to the Dorgali fm. The thickness of the investigated section is about 8 meters.

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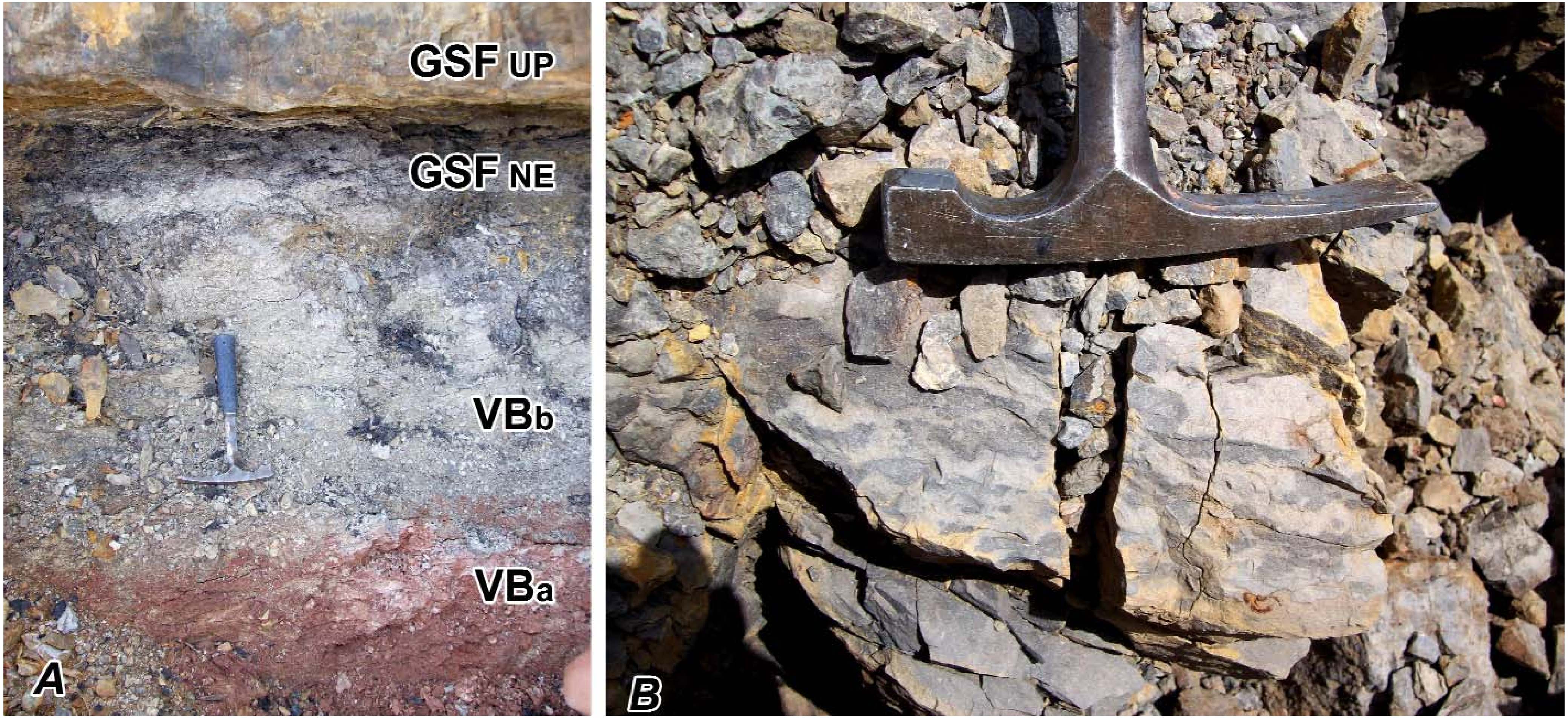

Fig. 49 **A)** – Close-up of the Pitzu S. Antonio Gate stratigraphic section. Legend; **VBa**: weakly altered Variscan basement; **VBb**: pedogenized Variscan basement; **FGSNE**: Genna Selole fm., lithofacies NE (Middle Jurassic); **FGSUP**: Genna Selole fm., lithofacies UP (Middle Jurassic); **B)** Bioturbations in the UP lithofacies of the Genna Selole fm.

Summary: this succession represents the development of an erosive-pedogenetic profile over the Variscan basement, rapidly followed by a brief palustrine-littoral episode immediately preceeding the setting of a lagoonal mixed carbonate-terrigenous sedimentation. Nevertheless, some ephemeral (tectonic? eustatic?) drops of the sea level determinate short-lived, mild regressions and several restarts of the continental-palustrine conditions before the ultimate setting of the carbonate open shelf sedimentation.

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Fig. 50 - Ungul'E'Ferru (Stop 8b): progradation clinoforms in the Dorgali fm. (Middle Jurassic).

Stop 8b - Ungul'e Ferru: accretion clinoforms in the Dorgali fm.

Now the road leads to Jerzu, and close to the Ungul'E Ferru locality turns right on a small track (Fig. 47): after some hundred of metres (Stop 8b), a wide overview of the whole hill is visible (Fig. 50). The stacking pattern of about 80 m of well-stratified dolostones belonging to the Dorgali fm. is evident: there are prograding clinoforms unconformably overlying a flat basal surface and directed towards N. Most likely they are related to the shift of a little, intra-lagoon sand bar.

The road moves back to the secondary road towards Jerzu (Fig. 51), and after 2 Km you take on the left a dirt track that go around Monte Limbarau (Jerzu Tacco): this hill is made up of Jurassic deposits unconformably posed over the Variscan metamorphics.

Fig. 51 - Geological sketch map of the M. Lumburau (Jerzu) (9), Buncu Matzeu (Ulassai) (10) and Grutta Orroli (Osini) (11a, 11b) Stops and surrounding areas. Legenda: **VB**) Variscan basement; **GSF**) Genna Selole fm. (Middle Jurassic); **DF**) Dorgali fm. (Middle Jurassic); **GSiIF**) Genna Silana fm. (Late Jurassic). The trace of the stratigraphic section is marked close to the edge of the Ulassai Tacco.

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STOP 9 - Monte Lumburau (Jerzu Tacco): laterites ("Ferro dei Tacchi") at the base of the Middle Jurassic transgression

The Su Lumburau iron mine (Jerzu) was exploited during the World War II (Fig. 52). In the trench leading to the main gallery, the front shows, from the top: A) dolostones from thick- to thin-bedded; B) thin, laterally discontinuous lenses of quartzose matrix-supported conglomerates and conglomeratic dolostones; C) massive to bedded dolostones; D) a thin interval of greyish to whitish silty-clayey material unconformably overlies E) whitish fissile, weathered basement ; F) sharp passage to violet fissile basement which colour passes gradually to reddish; G) massive, hard laterized basement with high concentrations of iron oxides in the fractures and cavities. H) sharp passage to unaltered blackish-bluish Variscan schists (Gennargentu grey phillytes fm., Late Cambrian – Early Ordovician: Barbagia tectonic unit).

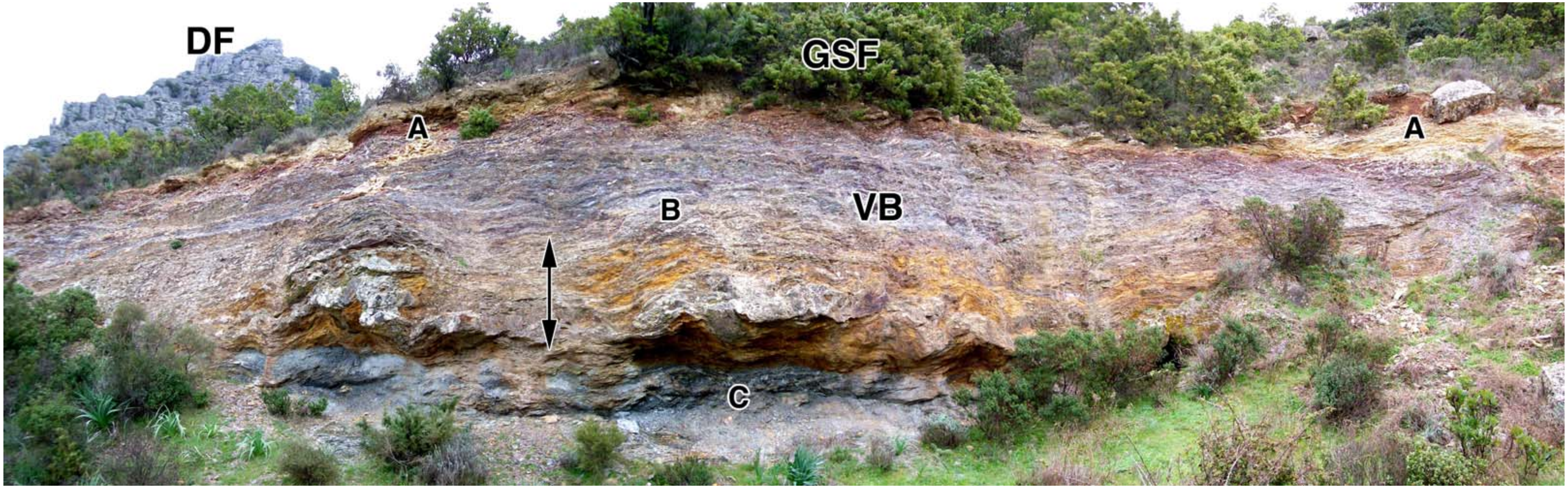

Fig. 52 – Monte Lumburau (Jerzu Tacco) abandoned Fe mine. Quarry front showing the main mineralized level. Legend: **VB**: Variscan basement, Gennargentu Grey Phyllites; **A)** Lisciviation zone; **B)** Fe precipitation zone; **C)** Unaltered zone; **GSF**: Genna Selole fm. (Middle Jurassic) **DF**: Dorgali fm. (Middle Jurassic). The double arrow marks the ore level, nearly 1.2 m thick.

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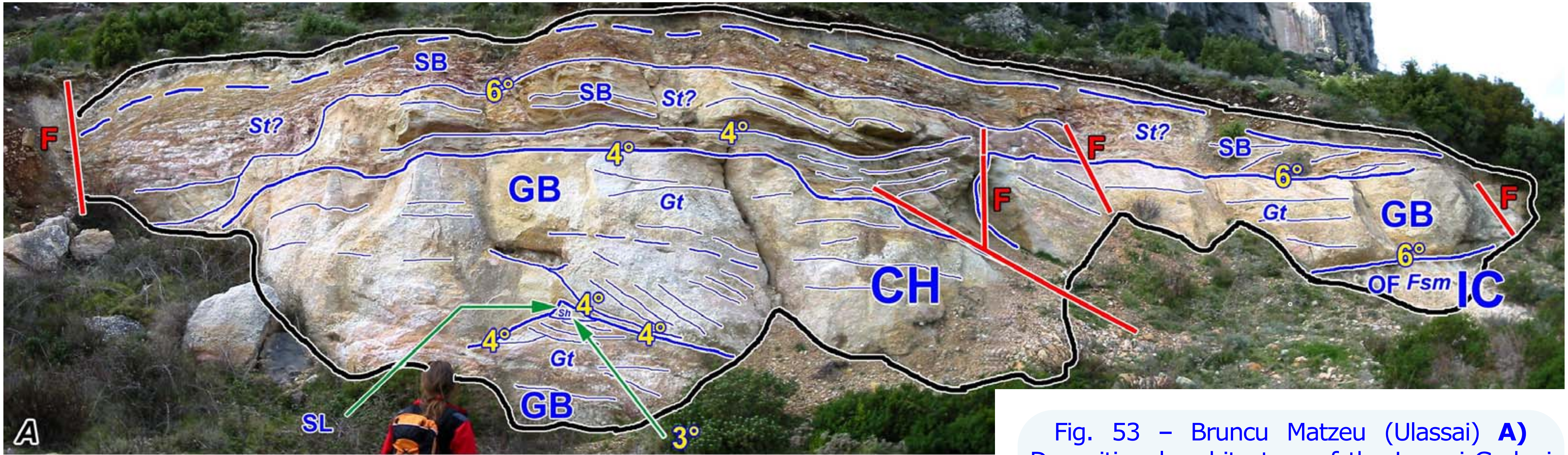
Summary: in this locality, a thin lower Genna Selole fm. less than 2 metres thick (considering only the Laconi Gadoni and Nurri Escalaplano lithofacies) and formed by fine terrigenous and rare thin conglomerate lenses covered the upper part of the Gennargentu grey phillytes fm. of the Gennargentu tectonic unit. During early Middle Jurassic, the Barbagia paleohigh emerged and the Early Mesozoic covers were removed, exposing the Variscan basement underneath. For the topographic position of the paleohigh, only a limited and upper siliciclastic part of the Genna Selole fm. cover was deposited here. So, under a hot-humid climate, the percolating waters first triggered a strong laterization of the metamorphics underneath, creating a thick Fe-rich paleosoil. The metamorphic rocks below the base of the groundwater were protected, remaining unaltered.

The secondary road to Jerzu leads towards Ulassai. Here you take a left road reaches the cliff of the Ulassai Tacco (Fig. 51). At its base the passage from the Genna Selole fm. to the Dorgali fm is visible. A brief and easy walk is necessary to reach the carbonate cliffs of Bruncu Matzeu.

STOP 10 - Bruncu Matzeu (Ulassai Tacco): synsedimentary extensional tectonics, transitional depositional environments and early karstic cycles at the Genna Selole fm. / Dorgali fm. transition (Middle Jurassic)

Rising to the cliff a conglomerate-sandstone outcrop pertaining to the Laconi-Gadoni lithofacies of the Genna Selole fm. is visible. The outcrop (Fig. 53 A) is built of clast-supported quartzose conglomerates and quartzarenites formed by several depositional events. In the lower conglomeratic part cross bedding as well as erosive surfaces are visible: upwards, the sandstones prevail together with the parallel bedding: erosional surfaces are also here. The occurring of several flood events building and eroding pebbly to sandy bars is clearly evident. Towards the top, the transport energy decreased and sandy bars with intercalation of possible reddish, rubified surfaces (suggesting periodic stops of the sedimentation) take place. Besides, a sinsedimentary tectonic discontinuity cutting the outcrop is clearly visible. Upwards, poorly outcropping alternations of gray to blackish siltites, clayey siltites and sandstones pertaining to the Nurri Escalaplano lithofacies and related to an alluvial-palustrine environment cover sharply the coarser lithologies of the lower lithofacies of the Genna Selole fm.



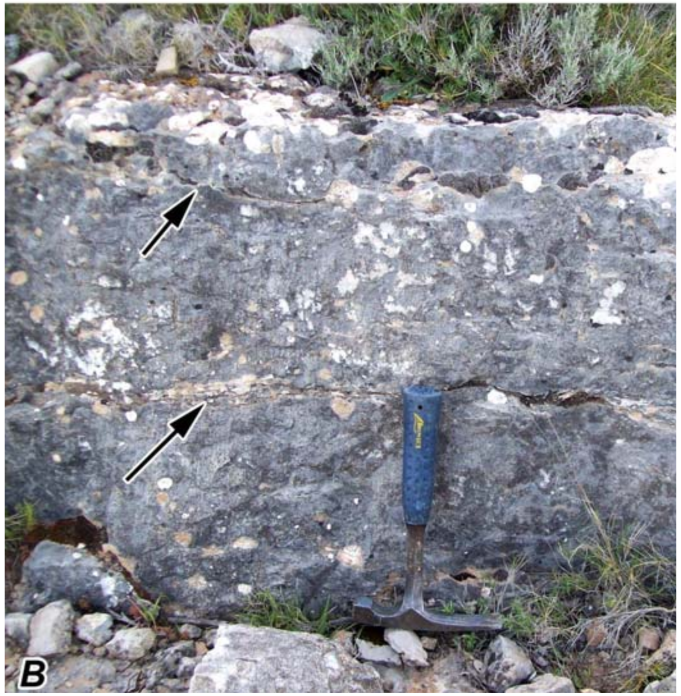


Fig. 53 – Bruncu Matzeu (Ulassai) **A)** Depositional architecture of the Laconi-Gadoni lithofacies: **A)** Braided multi-storey channel fill built of several overlapping pebbly bars (incomplete fluvial sequences) passing upwards to sandy tide-influenced bars. Synsedimentary tectonics features are clear. Legend; **CH**: Channelized architectural elements; **IC**: interchannel architectural elements; **GB**: pebbly bars; **SB**: sandy bars; **SL**: tabular bodies of laminated sand; **OF**: overbank fines; **Gt**: cross-bedded conglomerates; **St**: cross-bedded sandstones; **Sh**: plane-parallel laminated sandstones; **Fsm**: massive silt and mud. Numbers: Bounding surfaces rank; **F**: fault. **B)** Dolomitic limestones cut by rubified emersion surfaces; **C)** Vertically-restricted karstic events (arrow) evidencing ephemeral regressive episodes in the upper part of the Genna Selole fm. Little angular quartz pebbles at the restart of the carbonate sedimentation are visible.

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Still upwards, alternations of thick beds of grey to bluish limestones, dolostones and thinner layers of blackish lignitiferous pelites belonging to the Ussassai-Perdasdefogu lithofacies suddenly take place.
Here limestone layers rich of bioclastic debris and sometimes of quartz grains and little angular pebbles are also intercalated. Irregular, erosive and rubified surfaces with relief (Fig. 53 B), sometimes with karst evidences over the carbonates indicate ephemeral emersion episodes during the Middle Jurassic transgression and localized, limited terrigenous inputs (early karstic phenomena: Fig. 53 C).

Summary: in this Stop the complete evolution of the Genna Selole fm. continental to transitional system can be seen, up to the passage to the marine sedimentation, as well as early karst phenomena due to ephemeral regressions and the sinsedimentary tectonics influence on the unit.

The road moves back and proceed to Ulassai: here, 1 km to NW, is the beautiful karstic Su Murmuri cave 1 km long, a famous tourist attraction. In the Osini village a local road climb to the top of the Osini Tacco, passing all the way through the S. Giorgio Gorge, a splendid natural monument due to the karstic processes.

STOP 11 - Grutta Orroli and Punta su Scrau (Osini Tacco): oolitic grainstones, patch reefs and oncoids of the Genna Silana fm. (Late Jurassic)

Stop 11a - Osini Tacco: small patch reef in the Genna Silana fm.

A narrow paved road runs on the Osini Tacco top surface (Fig. 51): the Dorgali fm. dolostones crop out all around. Towards North, at Grutta Orroli the dolomitization fades sharply: thick-bedded oolitic and/or bioclastic calcareous grainstones cropout just along the sides of the dirt track. Here you follow on the right a narrow trail in the wood (Stop 11a). After nearly 100 m the grainstones are sharply intercalated by a little massive lens-shaped coral patch reef, about 20 m wide and 60-70 cm thick (Fig. 54 A, B, C). This patch reef is in its turn covered again by bioclastic/oolitic grainstones. These limestones pertain to the Late Jurassic Genna Silana fm. and represent the sharp passage to the shelf margin sedimentation.

Stop 11b - Punta Su Scrau: oncolitic floatstones in the Genna Silana fm.

Coming back to the bus and moving on along the dirt track to North, after 1 km close to another trail in the wood a 10 minutes walk allows to reach Punta Su Scrau (1000 m). Here (Stop 11b), over the patch reef there is the local

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upper level of the Late Jurassic Genna Silana fm., the topmost unit of the Tacchi succession: oncolitic floatstones (Fig. 54 D) where the oncoids have a diameter of 3 cm at most. The thin algal envelopes are evident as well as the subtle wrinkling between the different algal coatings. The nuclei are formed frequently by coral fragments or, rarely, little quartz grains. The matrix surrrounding the oncoids is formed by bioclastic grains, possible intraclasts and peloids.

Summary: over the lagoonal deposits of the Dorgali fm., the Genna Silana fm. marginal unit is here formed first by oolitic/bioclastic deposits embedding little patch reefs. These latter deposits are followed by mudstones and wackestones containing oncoids and coarse bioclastic fragments (floatstones). The patch reefs mark a discontinuous belt constituing the rim of the shallow carbonate domain and dividing the inner ramp from a gradually, smoothly deepening outer ramp. The superposition of the finer floatstones suggests the deepening of the environment and the passage to the outer ramp.

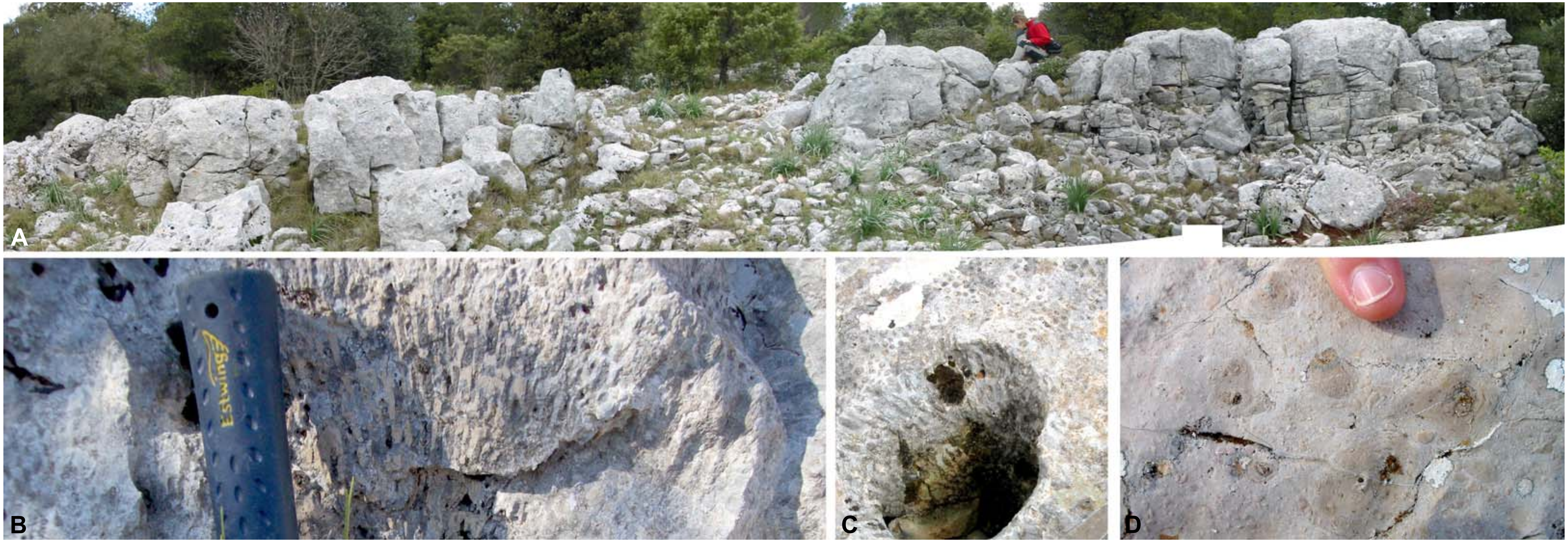

Fig. 54 – Grutta Orroli (Tacco di Osini): Genna Silana fm. **A)** Overview of the patch reef: the arrow points to the massive bed above the bioclastic/oolitic grainstones; **B, C)** Close-ups of the patch reef evidencing the coral specimens; **D)** Punta su Scrau: oncoids of the top of the Genna Silana fm.

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Tacco di Tertenia:
Punta Corongiu in the background

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memorandum

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