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Upper Triassic basinal carbonates between the Molise and Sannio Nappes near Frosolone (Duronia, Molise): geological implications

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Carbonati bacinali del Trias superiore tra le Falde Molisane e la Falda Sannitica presso Frosolone (Duronia, Molise): implicazioni geologiche a scala regionale

E' stata riconosciuta nell'area di Duronia (Molise) l'esistenza di dolomie e calcari dolomitici con selce del Trias superiore riferibili alla Formazione dei "Calcari con Selce" delle Unità Lagonegresi. Questi carbonati bacinali, presenti nella parte basale della Falda Sannitica in prossimità del contatto con le Falde Molisane (Unità di Frosolone), sono stati interpretati in passato come olistoliti all'interno delle Argille Varicolori, come depositi della successione sannitica o come depositi della successione sicilide e ad essi sono state attribuite età che vanno dal Cretaceo superiore al Miocene medio. L'esistenza di depositi bacinali triassici nella regione molisano-sannitica ha come implicazione paleogeografica la continuazione verso nord di un ramo del Bacino Lagonegrese e come implicazione tettonica un forte raccorciamento tra i massicci carbonatici riferibili alla Piattaforma Appenninica e quelli riferibili alla Piattaforma Simbruini-Matese.

KEY WORDS: *Molise Nappes, Sannio Nappe, Lagonegro Nappes, Upper Triassic Cherty Limestone.*

The Molise and Sannio Nappes were formally introduced in the geologic literature by SELLI (1962) in an important paper representing the first regional synthesis of the Southern Apennines after the pioneer works of DE LORENZO (1896, 1904).

Fifty years have passed from the work of SELLI and lots of papers specifically dealing with the Sannio and Molise Nappes have been published in this time (see, among many others, CROSTELLA & VEZZANI, 1964; PESCATORE, 1965; CRESCENTI, 1966, 1967; CROSTELLA, 1967; ORTOLANI *et alii*, 1975; CLERMONTÈ, 1977, 1982; SGROSSO *et alii*, 1988; AMORE *et alii*, 1988; AMORE, 1992; RENAUD *et alii*, 1990; PATACCA *et alii*, 1992 a, b; DI BUCCI, 1993, 1995; SCROCCA *et alii*, 1995; SCROCCA, 1996; DI BUCCI & SCROCCA, 1997; CORRADO *et alii*, 1996, and 1998 a, b, c; DI BUCCI *et alii*, 1999; DI LUZIO *et alii*, 1999; PAGLIARO, 1999; SCROCCA & TOZZI, 1999; ANTONUCCI *et alii*, 2000; PATACCA & SCANDONE, 2005).

The Molise Nappes are represented by at least three first-order thrust sheets known in the geological literature as the Frosolone-Agnone Unit (possibly composed of two units called the Frosolone Unit and the Agnone Unit), the Tufillo-Serra Palazzo Unit and the Daunia Unit. These units are represented by basinal sequences ranging in age from the Late Jurassic to

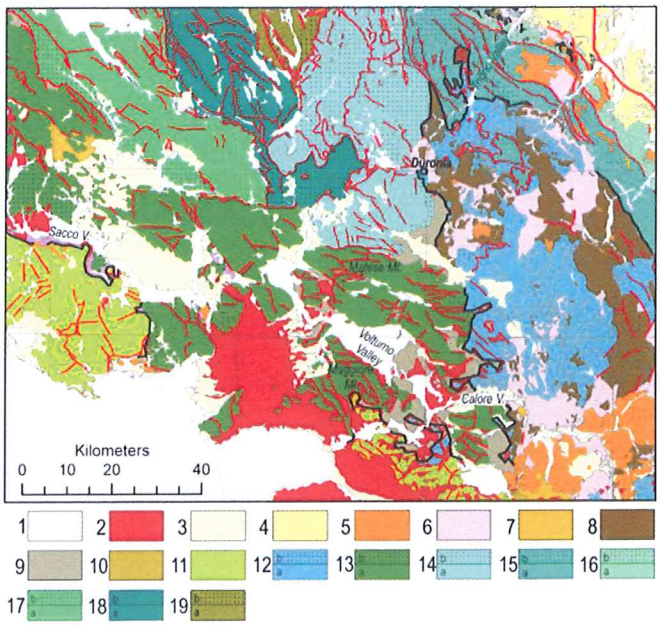

Fig 1 - Simplified geological-structural map of the south-eastern Latium-Abruzzi region and of the Sannio-Molise region. The heavy black line marks the base thrust of the Sannio Nappe where the latter has transported piggy back the Alburno-Cervati Unit, as well as the base thrust of the Alburno-Cervati Unit where the Sannio Nappe is missing The picture also evidences the lateral ramp of the Sannio Nappe which extends from the Low Volturno Valley to the Trigno Valley NNE of Duronia.
1 Upper Pleistocene p.p.-Holocene continental and subordinate coastal-marine deposits. 2 Middle Pleistocene-Holocene volcanites and volcaniclastic deposits. 3 Middle Pleistocene (and subordinate Villafranchian) continental deposits. 4 Lower Pleistocene p.p. marine and subordinate continental deposits. 5 Undifferentiated Plio-Pleistocene marine deposits of the Apennine Adriatic border. 6 Uppermost Messinian Calaggio Chaotic Complex. In black (upper right side of the picture), major slides of gypsum. 7 Undifferentiated Messinian deposits. 8 Lower Messinian (pre-salinity crisis) basinal thrust-top deposits unconformably overlying the Sannio Nappe (San Bartolomeo Fm). 9 Lower Messinian (pre-salinity crisis) deposits unconformably overlying the Simbruini-Matese Unit (San Massimo Fm) and conformably overlying the Frosolone Unit (Sant'Elena Sandstone). 10 Serravallian-Tortonian p.p. thrust-top deposits unconformably overlying the Alburno-Cervati Unit (Castelvetere Fm). 11 Alburno-Cervati Unit. 12 Sannio Nappe. 13 Simbruini-Matese Unit. 14 Frosolone and Agnone Units. 15 Tufillo-Serra Palazzo Unit. 16 Daunia Unit. 17 Western Marsica-Meta Unit. 18 Gran Sasso-Genzana Unit. 19 Morrone-Porrara Unit. In all tectonic units dotted areas indicate siliciclastic flysch deposits conformably overlying the carbonate sequences.

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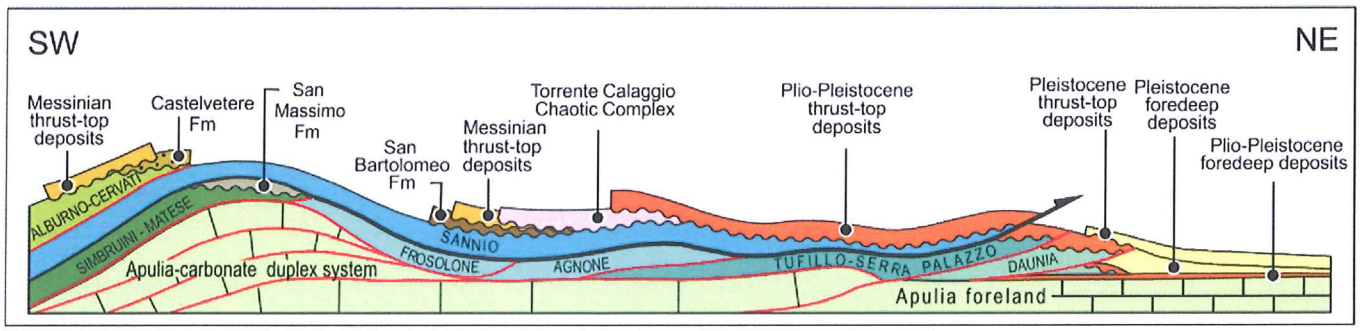

Fig. 2 – Simplified geometrical relationships between the Alburno-Cervati, Sannio, Simbruini-Matese and Molise Units in the Molise-Sannio region.

the Miocene and composed of hemipelagic limestones with intercalated platform-derived resediments conformably overlain by siliciclastic flysch deposits. The onset of the siliciclastics dates back to the latemost Tortonian close to the base of the Messinian.

The Frosolone carbonate deposits testify to the existence of a slope apron limited towards the south by a Jurassic-Cretaceous rimmed-platform which evolved in the Miocene into an open ramp. Geological evidences indicate that this platform was represented by the Matese domain (CLERMONTÉ & PIRONON, 1979; PIRONON, 1980) and that the amount of tectonic shortening between Matese and Frosolone was very modest (SCROCCA *et alii*, 1995; SCROCCA, 1996; DE CORSO *et alii*, 1998; SCROCCA & TOZZI, 1999). Shortening took place in early Messinian times (PATACCA *et alii*, 1990, 1992a), as it is testified by the age of siliciclastic basinal deposits cropping out in the area that in the south lie with an unconformable contact over the deformed Matese carbonates (San Massimo Sandstone) while in the north cover with a conformable contact the undeformed basinal deposits of Frosolone (Sant'Elena Sandstone).

The Sannio Nappe consists of Lower Cretaceous shales and siliceous radiolarites followed by Upper Cretaceous-Lower Miocene basinal limestones and marls locally rich in platform-derived resediments, punctuated by depositional and erosional hiatuses. The carbonates are followed by upper Burdigalian quartzarenites (Numidian Sandstone) and by Langhian foraminiferal limestones deposited in a deep-ramp setting. The sequence ends with flysch deposits represented by Serravallian feldspatolithic sandstones (see among many others PESCATORE, 1965; PATACCA *et alii*, 1992b; PAGLIARO, 1999 and references therein; SABATO *et alii*, 2007). According to the current literature the Sannio stratigraphic sequence is the Cretaceous p.p.-Miocene portion of the Lagonegro sequence detached from its sedimentary substrate during the tectonic superposition of the Alburno-Cervati Unit over the Lagonegro Basin. After this detachment, the Sannio Nappe was transported towards the Apulia foreland as a tectonic unit geometrically and kinematically independent from the Lagonegro Units.

The areal distribution of the Molise and Sannio Nappes, together with the Alburno-Cervati and the Simbruini-Matese Units in the south-eastern Latium-Abruzzi region and in the Sannio-Molise region is shown in figure 1. The geometrical relationships between these units are schematized in figure 2.

Near Duronia, a small village not far from Frosolone, prominent outcrops of basinal cherty dolomites and dolomitic limestones present at the base of the Sannio Nappe reveal the existence of a dismembered stratigraphic succession unusual for the Sannio and Molise Nappes. These dolomitic rocks characteristically protrude from the smooth morphology that in the region shapes the Sannio Nappe and the Miocene terrigenous deposits of the underlying Frosolone sequence (figure 3).

In the official geological map of Italy 1:100.000 Sheet 162-Campobasso (SERVIZIO GEOLOGICO D'ITALIA, 1970) the Duronia cherty dolomites have been considered olistoliths of Upper Cretaceous rudistid limestones included in an Oligocene chaotic complex made up of varicoloured shales and basinal limestones ("Argille Varicolori" *Auctt.)*.

In the new official geological map of Italy 1:50.000 Sheet 393-Trivento (ISPRA, 2012) the Duronia outcrops, described as recrystallized calcarenites and calcareous microbreccias associated with calcilutites and calcareous marls, have been mapped as a member of the Upper Oligocene?-Middle Miocene "Argille Varicolori Superiori", a lithostratigraphic unit considered to constitute the base of the Sannio Nappe in the

Fig. 3 – Panoramic view of the Duronia village and La Civita hill showing the sharp relief in correspondence to vertical beds of basinal cherty dolomites and dolomitic limestones, strongly contrasting with the surrounding smooth morphology corresponding to shaly lithologies.

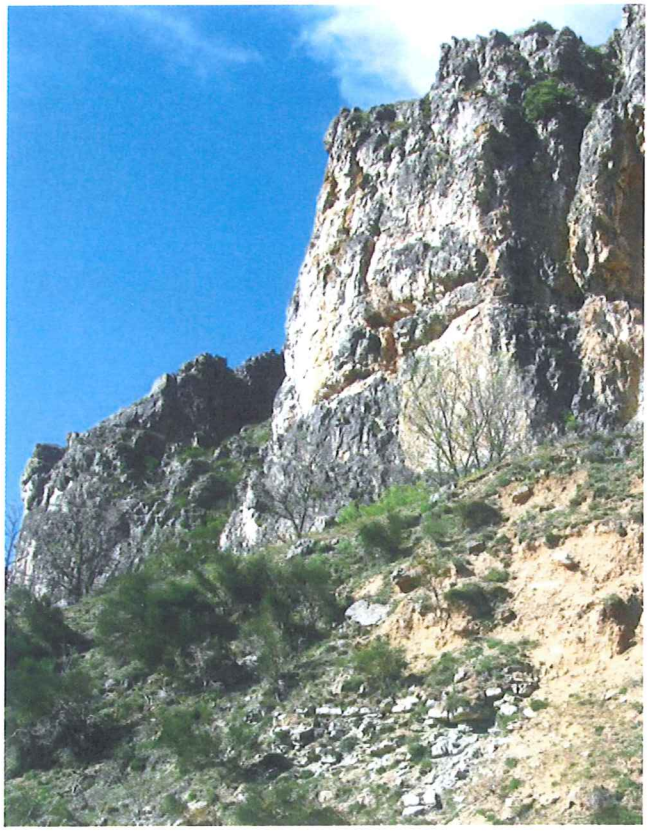

Fig. 4 – Southern slope of La Civita. Note the presence of well-bedded cherty limestones beneath vertically-dipping dolomites.

area.

In the geological map of Molise 1:100.000 edited by VEZZANI *et alii* (2004) the bulk of the Sannio Nappe cropping out in the region has been attributed to the Sicilide Unit and the Duronia dolomites, described as detrital limestones and micritic cherty limestones, have been attributed to the Upper Cretaceous-? Eocene "Calcari cristallini" Formation.

The lithologic descriptions of the quoted maps do not match at all the lithologic characteristics of the carbonates of Duronia. The bulk of these rocks, in fact, are represented by completely dolomitized basinal cherty limestones which only locally have preserved their primary composition and texture. Actually, a small portion of sequence that has escaped dolomitization has been recognized at the foot of the southern slope of the La Civita hill (figure 4). In this locality the preserved primary lithologies are represented by light-grey radiolarian-bearing cherty limestones and by greenish and pinkish lumachella beds with thin interlayers of green shales. The lumachella beds are rich in pelagic pelecypods referable to *Posidonomya* and *Halobia* (figure 5). These characteristic cherty limestones, widespread in all Upper Triassic Tethyan basinal domains of the Mediterranean region, have never been recognized in the Sannio stratigraphic sequence. On the contrary, they are common in the Lagonegro sequence ("Calcari con Selce" Formation in SCANDONE, 1967, 1972). Note that in the Upper

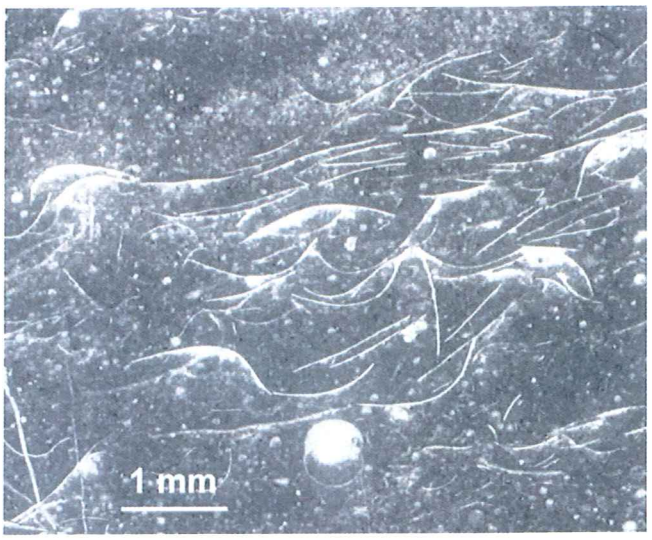

Fig. 5 – Characteristic microfacies of the lumachella beds exposed at the foot of La Civita (see fig. 4). The picture shows a bioclastic wackestone/packstone with thin-shelled pelagic pelecypods and large radiolarian tests filled by sparite. A coiled ammonite embryo is recognizable in the lower centre of the picture.

Lagonegro Unit (Lagonegro Unit II of the geological literature) and particularly in the Pignola-Abriola and San Fele facies the basinal cherty limestones have undergone the same pervasive dolomitization processes as the Duronia carbonates. In spite of the dolomitization, the Late Triassic age of the dolomitized cherty limestones of the Upper Lagonegro Unit is adequately documented in Basilicata and Campania by the systematic occurrence of key beds rich in well preserved *Halobia*. In the Duronia area, chances to recover the same beds with intact shells of *Halobia* are obviously little because of the quite generalized dolomitization of the exposed rocks.

Below the cherty limestones of La Civita (unfortunately the contact is hidden by detritus) other lithologies are present, though poorly exposed. They are represented by red and green shales associated with wavy cross-laminated siltites and siliciclastic ooidal calcarenites of Middle Triassic age. The lithologic association displays close similarities with the Monte Facito Formation of the Lagonegro sequence. Note that the Monte Facito Formation is present only in the Upper Lagonegro Unit, stratigraphically underlying the Cherty Limestone Formation. The Middle Triassic age of the Duronia deposits underlying the cherty limestones of La Civita is based on the occurrence of *Meandrospira pusilla* (figure 6), a microfossil that is quite common also in the siliciclastic calcarenites of the Monte Facito Formation (PATACCA, 2007).

In the Southern Apennines the basal portion of the Sannio sequence is everywhere represented by deep-water varicoloured shales associated with siliceous radiolarites and sporadic black-shale horizons reflecting the Aptian-Albian and uppermost Cenomanian-lowermost Turonian worldwide oceanic anoxic events. This lithostratigraphic unit is known in the geological literature as "Argilliti e Radiolariti di Campomaggiore"

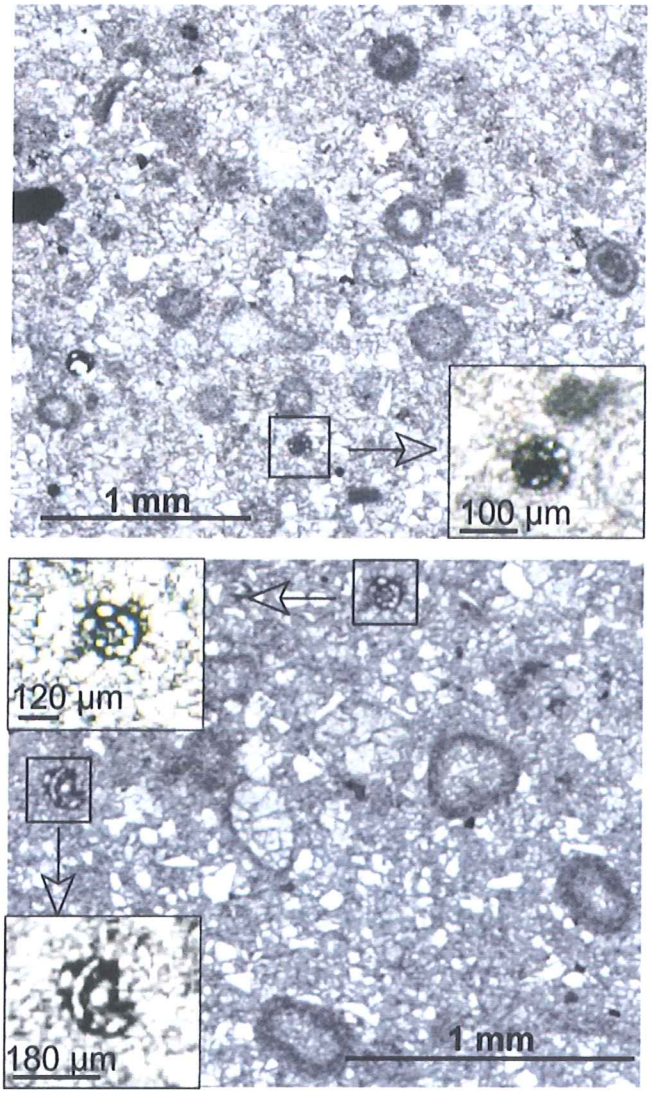

Fig. 6 – Recrystallized siliciclastic ooidal packstone with *Meandrospira pusilla*.

(SABATO *et alii*, 2007). The top of the Lagonegro Nappes is usually represented by the Lower Cretaceous Galestri Formation. However, siliceous deposits comparable with the "Argilliti e Radiolariti di Campomaggiore" of the Sannio Nappe locally overlie the Galestri Formation with a conformable contact (e.g. Brienza area in Basilicata). Conversely, lithologies referable to the Galestri Formation are sporadically present at the base of the Sannio Nappe (e.g. Riccia area in Molise, Taburno 1 well near Benevento). The occurrence of comparable lithostratigraphic units at the base of the Sannio Nappe and at the top of the Lagonegro Nappes strongly supports the reconstruction according to which the stratigraphic sequences of these tectonic units have derived from the same basinal domain and represent different portions of an originally continuous stratigraphic succession.

The presence of terms as old as the Late Triassic at the base of the Sannio Nappe may be explained by decapitation processes leading to the incorporation of lower portions of the sequence in the hangingwall block. This incorporation was possible if the detachment of the Sannio Nappe from its sedimentary substrate took place with an out-of-sequence kinematics. In any case, the Duronia cherty dolomites testify to the northward continuation of the Triassic Lagonegro Basin in front of the Apenninic Carbonate Platform as far as the present-day Sannio-Molise region. As a consequence of this, a wide basinal area representing the northern branch of the Lagonegro Basin is required at the rear of the Simbruini-Matese Platform (figure 7).

Presently, there is no trace of Triassic-Jurassic basinal deposits referable to the Lagonegro Units between the shallow-platform carbonates of the Alburno-Cervati Unit and those of the Simbruini-Matese Unit. However, surface and subsurface data suggest a tectonic shortening south of Monte Maggiore (PESCATORE & SGROSSO, 1973) and in correspondence to the Sacco Valley. The discovery at Duronia of Upper Triassic basinal carbonates referable to the Lagonegro Cherty Limestone Formation emphasizes the importance of this shortening and supports a kinematic reconstruction according to which east of the present-day confluence between the Calore and Volturno

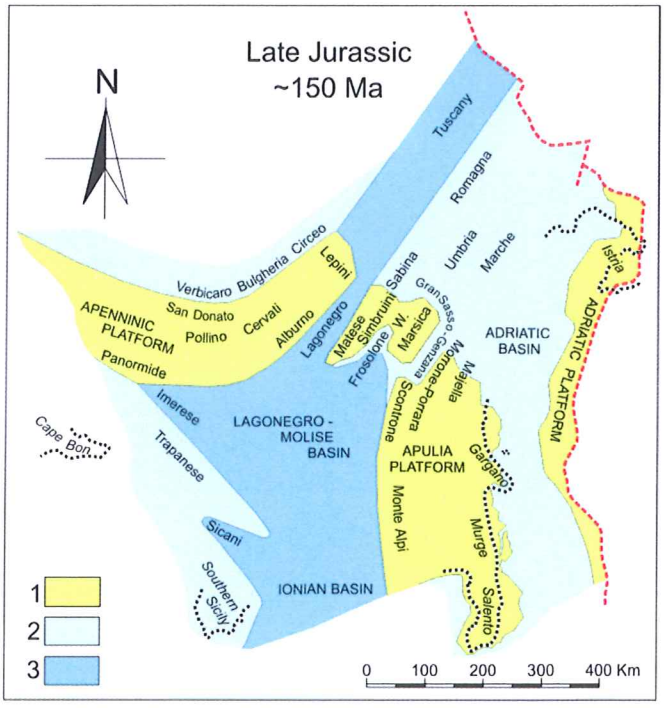

Fig. 7 – Palinspastic restoration of the Apenninic realms and surrounding areas referred to the Late Jurassic, when all paleogeographic Apenninic domains were well defined. Boundary conditions in the foreland areas have been established by the relative position of Africa with respect to Europe deduced from the opening of the Atlantic Ocean. In the areas affected by Alpine shortening the relocation of the paleogeographic realms has been obtained using classical criteria of retrodeformation and structural balancing. The fronts of the Southern Alps and External Dinarides (dashed red line) are mere geographic reference lines.
1 Rimmed carbonate platforms. 2 Deep-marine domains above the CCD. 3 Deep-marine domains below the CCD.

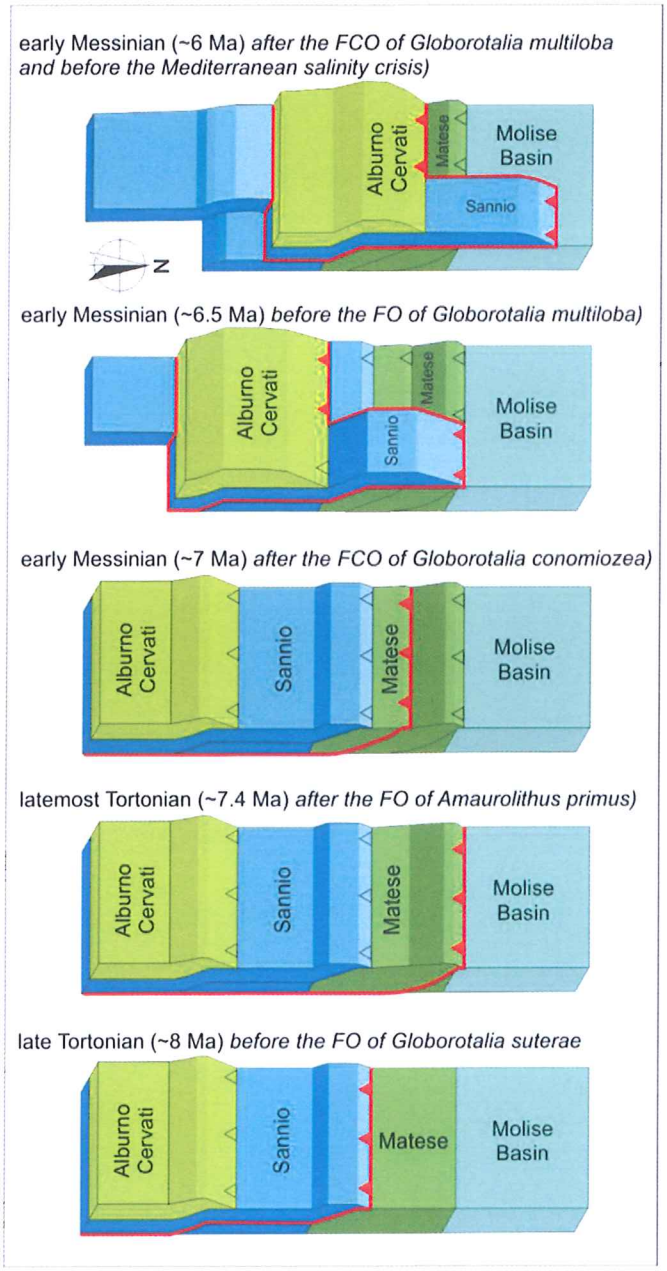

Fig. 8 – Sequence of drawings depicting the development of the lateral ramp that limits towards the west the Sannio Nappe

rivers the Sannio Nappe moved on top of a long thrust flat over the Simbruini-Matese and Molise Units carrying piggyback the carbonates of the Apenninic Platform. In the same reconstruction, west of the confluence between the Calore and Volturno rivers the Sannio sequence remained in the footwall of the thrust, buried beneath the Alburno-Cervati Unit.

Figure 8 depicts in five steps the development of the lateral ramp that limits towards the west the Sannio Nappe. Most of the analytical data justifying this reconstruction are available in PATACCA *et alii* (1991). In the first step (late Tortonian), the front of the Sannio Nappe coincided with the front of the mountain chain. This structural configuration is testified by the occurrence of Sannio-derived olistostromes at the top of the upper Tortonian siliciclastic flysch deposits of Matese (Pietraroia Formation). The forward migration of the frontal thrust in latemost Tortonian times shown in the second step is suggested by the existence of megabreccia beds with Matese-derived shallow-water limestones at the base of the siliciclastic flysch deposits of Frosolone (Cantalupo Flysch in PATACCA *et alii*, 1991). The subsequent out-of-sequence backward thrust migration is indicated by the occurrence of lowermost Messinian terrigenous deposits stratigraphically covering the deformed Matese carbonates (San Massimo Sandstone) which in the south-eastern Matese area include cannibalized huge blocks of Upper Cretaceous and Miocene shallow-water limestones (e.g. Monte Cigno). The fourth step is documented by the tectonic superposition of the Sannio Nappe over the lower Messinian thrust-top deposits of Eastern Matese. In this stage the Sannio Nappe did not yet reach the Molise basin where sedimentation continued until the FCO of *T. multiloba*. The fifth step, finally, shows the final forward transport of the Sannio Nappe over the Molise flysch deposits and the complete disappearance of Sannio beneath the Alburno-Cervati Nappe west of the present-day confluence between the Calore and Volturno rivers.

The lateral ramp of the Sannio Nappe, measuring about 80 kilometers in length, establishes the minimum shortening between the Alburno-Cervati Unit and the Simbruini-Matese Unit. This shortening took place in late Tortonian-early Messinian times. The existence of such a large-scale lateral ramp implies abrupt longitudinal changes in the thrust trajectories that had to be controlled by different conditions of the shear stress. Different mechanical conditions between two segments of the same sedimentary basin were likely related to lateral variations in the pore pressure gradients.

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