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New constraints to the geodynamic evolution of the southern sector of the Calabria–Peloritani Arc (Italy)

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Abstract – New studies have been carried out on the Tertiary of the Stilo Unit, the uppermost of the Calabria–Peloritani Arc southern sector, and the Stilo–Capo d'Orlando Formation, sealing the whole nappe stack. The Tertiary terrains linked to the Mesozoic cover of the Stilo Unit consist of the lowermost Oligocene Palizzi Formation and the Late Rupelian–Aquitanian Pignolo Formation. The possibility that they deposited before the emplacement of this unit as the highest tectonic sheet of the sector is suggested. The base of the Stilo–Capo d'Orlando Formation resulted of Burdigalian age in both type areas. This interpretation, together with the existing and new data, allows proposing an age close to the Aquitanian–Burdigalian boundary for the stacking of the whole Calabria–Peloritani Arc southern sector. ***To cite this article: G. Bonardi et al., C. R. Geoscience 334 (2002) 423–430.*** © 2002 Académie des sciences / Éditions scientifiques et médicales Elsevier SAS

calcareous nannoplankton / larger foraminifera / Tertiary / geodynamic evolution / Calabria–Peloritani arc / Italy

Résumé – Nouvelles données sur l'évolution géodynamique du secteur méridional de l'Arc Calabro-Péloritain (Italie). Les dépôts tertiaires de l'unité de Stilo et de la formation de Stilo–Capo d'Orlando, dans le secteur méridional de l'arc Calabro-Péloritain, ont été réexaminés. Les premiers, constitués par les formations de Palizzi, de l'Oligocène inférieur, et de Pignolo, d'âge Oligocène inférieur–Aquitanien, ont été interprétés comme des dépôts précédant la mise en place de l'unité tectonique de Stilo, la plus haute du secteur. La formation de Stilo–Capo d'Orlando, déposée en discordance sur toutes les nappes du secteur, s'est révélée partout d'âge Burdigalien à partir de sa base. Cette interprétation ainsi que les données disponibles permettent de proposer un âge voisin de la limite Aquitanien–Burdigalien pour la structuration de tout le secteur méridional de l'arc Calabro-Péloritain. ***Pour citer cet article : G. Bonardi et al., C. R. Geoscience 334 (2002) 423–430.*** © 2002 Académie des sciences / Éditions scientifiques et médicales Elsevier SAS

nannoplancton calcaire / macroforaminifères / Tertiaire / évolution géodynamique / arc Calabro-Péloritain / Italie

Version abrégée

Le secteur méridional de l'arc Calabro-Péloritain (Fig. 1) est constitué de nappes de socle, à matériel hercynien ou plus ancien, scellées par les dépôts turbiditiques de la formation de Stilo–Capo d'Orlando [3, 7]. Seules les unités de Longi–Taormina et de Stilo, c'est-à-dire l'unité la plus basse et l'unité la plus haute de la pile de nappes, présentent une couverture alpine bien développée, tandis que, dans les nappes intermédiaires, la couverture sédimentaire est totalement absente ou n'est représentée que par des mégaboudins de roches mésozoïques.

La couverture sédimentaire de l'unité de Longi–Taormina est caractérisée par une succession continue, dont la

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formation la plus haute (Flysch de Frazzanò) a été considérée comme d'âge Éo-Oligocène, selon Ogniben [22].

La succession sédimentaire de l'Unité de Stilo, au contraire, est caractérisée par beaucoup de lacunes et la présence de terrains cénozoïques a été objet de discussion [2, 3, 7, 10, 23]. En particulier, des calcarénites néritiques, concordantes ou faiblement discordantes sur les calcaires mésozoïques dans la région de Stilo et considérées comme d'âge Oligocène inférieur à Aquitanien, ont été interprétées comme un membre à la base de la formation de Stilo–Capo d'Orlando. Par conséquent, la structuration du secteur méridional de l'arc Calabro-Péloritain se serait accomplie durant l'Oligocène [3, 5, 7, 10, 12, 20, 23, 25].

Cette interprétation a été remise en discussion par la présence d'un métamorphisme, daté de 25–22 Ma, affectant les unités de l'Aspromonte et de Mandanici [1, 6, 8], et de nannoflores aquitaniennes dans le flysch de Frazzanò [13] ; par conséquent, la possibilité d'un diachronisme dans l'âge de déformation du secteur méridional de l'arc Calabro-Péloritain doit être prise en considération.

L'unité de Stilo est constituée par des métamorphites paléozoïques et des granites tardi-varisques, ainsi que par des terrains mésozoïques, représentés essentiellement par des carbonates de plate-forme, d'âge compris entre le Trias supérieur et le Crétacé supérieur, avec des lacunes mises en évidence par les données paléontologiques et, par endroits, soulignées par des surfaces paléokarstiques. Sur ces terrains repose, avec interposition d'argiles bauxitiques, une succession de marnes palustres passant vers le haut à des calcaires néritiques, d'âge Oligocène inférieur (formation de Palizzi ; Figs. 1 et 2H) [9]. L'analyse de cette formation sur le terrain a confirmé son évolution de faciès de transition à faciès franchement marins et, de plus, a permis de reconnaître l'apparition d'un apport clastique (grains de quartz arrondis, fragments millimétriques de lydites et métarénites) dans les niveaux les plus hauts de la même formation, témoignant du début de l'érosion du soubassement pré-alpin à la suite des premiers mouvements tectoniques.

Dans la région de Stilo même, la formation de Palizzi n'a jamais été identifiée et, sur les calcaires du Jurassique et du Crétacé, surmontés par endroits par des argiles bauxitiques, on retrouve, concordants ou faiblement discordants, des calcaires, des conglomérats calcaires à débris jurassiques et crétacés, ainsi que des calcarénites riches en lépidocyclines (Figs. 1 et 2A–D). Ces sédiments de plate-forme carbonatée, caractérisés par la présence d'abondantes algues, échinides et *Solenomeris*, parfois sous faciès de type récifal, deviennent vers le haut de plus en plus riches en fragments de phyllites et de granitoïdes, provenant du soubassement préalpin de l'unité de Stilo, dont ces fragments témoignent de l'émersion. Au lieu-dit Pignolo (Figs. 1 et 2D), le long de la route Titi–Placanica, on peut observer le passage progressif des sédiments calcaires à des grès, en couches dont l'épaisseur va jusqu'à 30–40 cm, alternant avec des niveaux de marnes jaunâtres. Pour les terrains décrits, calcaires, gréseux et marneux, on propose la dénomination informelle de formation de Pignolo.

Dans toute l'aire comprise entre les torrents Stilaro et Precariti (Figs. 1 et 2A–D), les conglomérats, pélites et grès turbiditiques de la formation de Stilo–Capo d'Orlando ont été décrits comme la continuation des terrains de la formation de Pignolo, qui, par conséquent, a été considérée comme un membre à la base de la formation de Stilo–Capo d'Orlando, en particulier dans la région de Stilo [2, 3, 5, 10, 11, 23].

Au lieu-dit Molinaro, entre les calcarénites à lépidocyclines et à débris de phyllites et granitoïdes de la formation de Pignolo et la formation de Stilo–Capo d'Orlando, on peut observer une surface d'érosion, durcie, imprégnée d'oxydes de fer et karstifiée. Cette surface permet de séparer la formation de Pignolo des pélites et grès fins de la formation de Stilo–Capo d'Orlando, qu'on retrouve même en filons sédimentaires dans les calcarénites à lépidocyclines sous-jacentes (Figs. 1 et 2C). De plus, l'analyse des calcarénites à macroforaminifères, qui, localisées par endroits hors de la dorsale calcaire de Stilo, ont été reconnues à la base de la formation de Stilo–Capo d'Orlando [3, 5, 11, 16] et considérées comme équivalentes des calcarénites de la formation de Pignolo, a mis en évidence qu'il s'agit de turbidites à débris calcaires néritiques, présentes à différents niveaux dans la succession de la formation de Stilo–Capo d'Orlando, qui ne peuvent donc pas être attribuées à la formation de Pignolo. Les formations de Pignolo et de Stilo–Capo d'Orlando appartiennent en conclusion à deux cycles sédimentaires différents, séparés par une période d'émersion et de karstification ; les terrains de la formation de Pignolo ne peuvent donc pas être considérés comme étant la base de la formation de Stilo–Capo d'Orlando, ainsi qu'on l'avait jusqu'à présent admis.

Nos données biostratigraphiques confirment l'âge Oligocène inférieur de la formation de Palizzi [9]. En ce qui concerne la formation de Pignolo, la présence de *Nephrolepidina* sp. indique un âge compris entre le sommet de l'Oligocène inférieur et le Miocène inférieur pour les niveaux calcarénitiques et conglomératiques [14]. La reconnaissance de *Geminilithella rotula*, *Helicosphaera mediterranea* et *Sphenolithus dissimilis* dans les marnes qui alternent avec les grès au sommet de la même formation permet d'affirmer que la formation de Pignolo date au moins de l'Aquitanien (zones CN1c = NN2).

En ce qui concerne l'âge de la formation de Stilo–Capo d'Orlando, on a pu mettre en évidence, dans les niveaux basaux de toutes les sections étudiées, la présence, avec des taxa du Miocène inférieur (*Discoaster druggii*, *Helicosphaera carteri*, *Helicosphaera mediterranea*, *Triquetrorhabdulus* cf. *milowii*), de taxa d'âge Burdigalien moyen–supérieur. En particulier, on a reconnu, aux environs de Stilo (coupes de Calcarella et de Molinaro ; Figs. 1, 2B et C), *Helicosphaera scissura* et *Sphenolithus calyculus* (zone CN2 = NN3) [26], dans la région de Monte Scifa–Antonimina (6–7 km au nord de Locri ; coupes de Monte Scifa, Torrente San Paolo et Monte Tronato ; Fig. 1E–G), *Discoaster aulakos*, *Helicosphaera scissura* et *Sphenolithus belemnos* (zone CN2 = NN3), et enfin, en Sicile, dans la coupe de Capo d'Orlando (Fig. 1I), *Calcidiscus* cf. *lep-*

toporus, *Discoaster stellulus*, *Discoaster* cf. *variabilis* et *Sphenolithus heteromorphus* (zone CN3 = NN4). Ces données biostratigraphiques confirment l'existence d'une lacune, liée à l'émersion et à l'érosion, entre la formation de Pignolo et la formation de Stilo–Capo d'Orlando.

En considérant les données biostratigraphiques et de terrain, on peut donc supposer une évolution géodynamique du secteur méridional de l'arc Calabro-Péloritain différente de celle proposée au cours des vingt dernières années [3, 5, 11, 23]. La présence d'une surface paléokarstique au sommet de la formation de Pignolo, d'âge Rupélien supérieur–Aquitanien, et l'*onlapping* des sédiments basaux de la formation de Stilo–Capo d'Orlando, d'âge Burdigalien moyen–supérieur, sur des niveaux stratigraphiques différents de la même formation de Pignolo, nous permet d'interpréter cette dernière formation, jusqu'à présent considérée comme la base de la formation de Stilo–Capo d'Orlando, comme étant la formation la plus haute de la succession de l'unité de Stilo, précédant la mise en place de cette unité, et comme étant représentative d'un cycle sédimentaire tout à fait différent du cycle de la formation de Stilo–Capo d'Orlando. Par conséquent, la déformation du domaine de Stilo se serait réalisée dans un très court intervalle de temps, proche de la limite Aquitanien–Burdigalien, entre la fin du dépôt de la formation de Pignolo et le début de la sédimentation de la formation de Stilo–Capo d'Orlando.

Cet âge s'accorde bien avec l'âge de déformation indiqué par de Capoa et al. [13] pour l'unité de Longi–Taormina, la plus basse de la pile de nappes du secteur méridional de l'arc Calabro-Péloritain, ainsi qu'avec les données géochronologiques relatives à la ré-équilibration métamorphique affectant les unités de Mandanici et de l'Aspromonte (25–22 Ma) [1, 6, 8]. En conclusion, la déformation des domaines du secteur méridional de l'arc Calabro-Péloritain et la structuration des nappes se seraient réalisées dans un très bref intervalle de temps (Aquitanien supérieur–Burdigalien inférieur) ; aucune hypothèse de diachronisme dans l'âge de la déformation ne peut être prise en considération.

1. Introduction

The southern sector of the Calabria–Peloritani Arc (CPASS) is a crystalline basement nappe stack sealed by the late orogenic turbiditic deposits of the Stilo–Capo d'Orlando Formation (SCOF; Fig. 1) [3, 7].

The lowermost (Longi–Taormina Unit) and the uppermost (Stilo Unit) nappes of the tectonic stack are provided with a well developed preorogenic sedimentary cover, whereas an Alpine cover is either completely lacking or represented by small tectonic slices of Mesozoic rocks in the intermediate tectonic units.

The sedimentary cover of Longi–Taormina Unit is characterised by a continuous sequence, whose uppermost formation (Frazzanò Flysch) has been generally referred to Eo-Oligocene following Ogniben [22].

On the contrary, the sequence of the Stilo Unit sedimentary cover shows many disconformities. Therefore, the occurrence of preorogenic Cenozoic terms, besides the well-known lignitiferous continental deposits bearing *Anthracotherium magnum* [17, 21], has been matter of debate. Shallow water calcarenites, disconformably resting on Mesozoic limestones in the Stilo area, have been considered as a basal member of SCOF since [3]. Different ages, partly based on the faunas of that calcarenites, have been proposed for the very base of the SCOF (Late Aquitanian [3]; Early Oligocene [25]; Late Oligocene [11, 12, 20, 23]). All the above data point to a piling up of the CPASS tectonic building during the Oligocene. This interpretation was implicitely questioned both by the occurrence of a greenschist facies metamorphic overprint, radiometrically dated 25–22 Ma, affecting older medium–high-grade metamorphics of the Aspromonte Unit [6, 8] and Mesozoic cover of the Mandanici Unit [1], and by new biostratigraphic data, based on calcareous nannofloras, about the Frazzanò Flysch, showing that the formation reaches the Aquitanian [13]. The possibility of a diachronic piling up of the CPASS also arose from these data.

The aim of the present paper is to provide, through new field observations and biostratigraphic data, better chronological constraints to the tectonic evolution of the CPASS.

2. The sedimentary cover of the Stilo Unit

The Stilo Unit is composed of Palaeozoic metamorphics intruded by Late-Variscan granitoids [19], with minor and discontinuous outcrops of a Meso-Cenozoic sedimentary cover (Fig. 1). The latter, only few hundreds of meters thick, is characterised by Mesozoic shallow water carbonates with several disconformities marked by palaeo-karst surfaces. According to the data up to now available, the stratigraphic succession [2, 5, 24] is made up of continental Verrucano-like deposits and palaeosoils, probably Late Triassic in age, Upper Triassic–Lower Liassic dolomites, disconformably covered by Jurassic calcareous breccias and neritic limestones, disconformably followed by Cretaceous limestones with Rudistids and breccias with rudistid fragments, cut by Neptunian dykes with larger foraminifera.

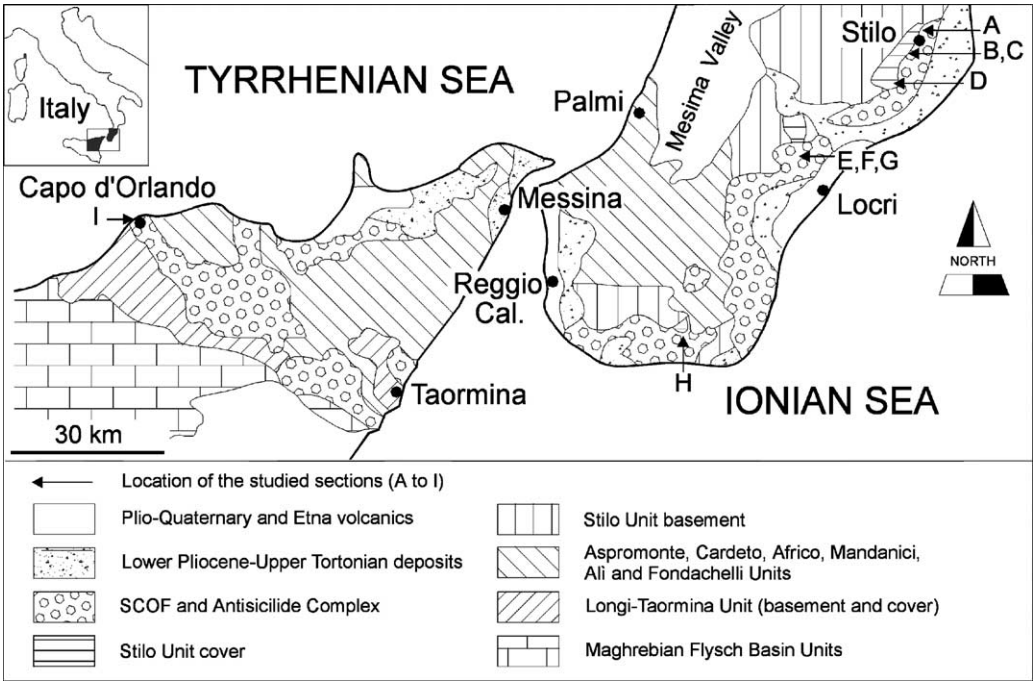

Figure 1. Schematic geological map of the Southern sector of the Calabria–Peloritani Arc and location of the Stilo Unit and the Stilo–Capo d'Orlando Formation studied sections. **A.** Torrente Stilaro = long. 16°28′22″E, lat. 38°29′55″N. **B.** Calcarella locality (Pazzano–Titi Road) = long. 16°27′12″E, lat. 38°27′56″N. **C.** Molinaro locality = long. 16°26′40″E, lat. 38°27′28″N. **D.** Pignolo locality (Titi–Placanica Road) = long. 16°26′18″E, lat. 38°25′52″N. **E.** Monte Scifa = long. 16°14′08″E, lat. 38°18′19″N. **F.** Fiumara San Paolo = long. 16°07′15″E, lat. 38°17′02″N. **G.** Monte Tronato = long. 16°08′17″E, lat. 38°16′12″N. **H.** Palizzi = long. 15°57′57″E, lat. 37°58′32″N. **I.** Capo d'Orlando = long. 14°44′55″E, lat. 38°09′52″N.

Figure 1. Carte géologique schématique de l'arc Calabro-Péloritain et situation des coupes étudiées de l'unité de Stilo et de la formation de Stilo–Capo d'Orlando. **A.** Torrente Stilaro. **B.** Localité Calcarella (route Pazzano–Titi). **C.** Localité Molinaro. **D.** Localité Pignolo (route Titi–Placanica). **E.** Monte Scifa. **F.** Fiumara San Paolo. **G.** Monte Tronato. **H.** Palizzi. **I.** Capo d'Orlando.

Above this Mesozoic sequence, besides continental deposits near Agnana, few remnants of transitional to shallow marine Tertiary deposits are present.

On the southern side of the Aspromonte Massif, near the village of Palizzi, Bouillin et al. [9] described as the Palizzi Formation a sequence, 25 m thick, resting on bauxitic clays filling a palaeokarst surface cut in Jurassic limestones. It can be subdivided in three intervals: the first one is made up of greenish marshy marls with gastropods, bivalves, oysters, ostracods and plants and is followed by shallow marine marly limestones with bivalves, gastropods and larger foraminifera, and finally, by algal-rich limestones (Fig. 2H).

A surveying of this area confirmed that this formation shows a transgressive evolution from transitional to shallow marine realms, and evidenced the occurrence in the uppermost level of a clastic supply (rounded quartz, metarenites and lidite pebbles) with a coarsening upwards organisation.

The top of this sequence is overlaid by the SCOF and locally by the Palaeozoic phyllites. These metamorphites can be interpreted as a thrust slice emplaced before the SCOF deposition [9], or as one of the olistoliths, coming from basement and cover of the Stilo Unit, recognised in many places at the base of the SCOF [4, 5, 7].

The Palizzi Formation is the oldest Tertiary sedimentary cycle of the Stilo Unit preorogenic cover and may constitute a depositional sequence bound, to the bottom and to the top, by two unconformities. It shows a transgressive but coarsening upward evolution, which could be related to an incipient tectonics.

In the Stilo area, the Palizzi Formation is absent and a different formation, that we propose to name Pignolo Formation, crops out (Fig. 2). This stratigraphic unit lies disconformably over the Mesozoic carbonates, both Cretaceous (Rudistid limestones and breccias) and Jurassic (calcareous breccias and limestones with *Clypeina jurassica*), as can be observed on the left side of the Stilaro River Valley, at the top of Monte Consolino, and all along the eastern side of Monte Stella, Monte Mammicomito and Monte Gallo. The contact between Tertiary and older sediments is locally marked by the presence of bauxitic clays, 1 m thick, as can be observed along the Placanica–Titi road. The Pignolo Formation is mainly made up of carbonates (calcareous conglomerates with Juras-

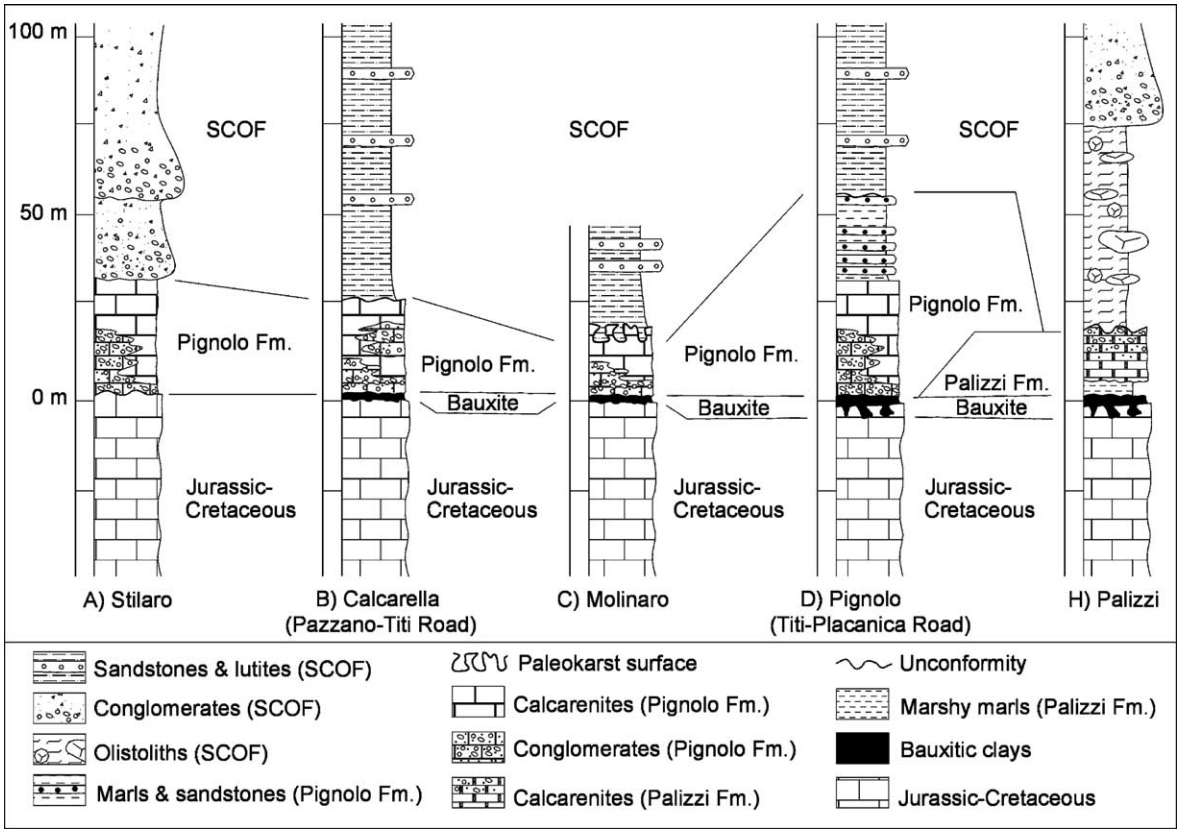

Figure 2. Schematic stratigraphic sections of the Tertiary deposits of the Stilo Unit and their bearing with the Stilo–Capo d'Orlando Formation, in the Serre–Aspromonte area. The ubication of the sections is reported in Fig. 1.

Figure 2. Sections stratigraphiques schématiques des dépôts tertiaires de l'unité de Stilo et leurs relations avec la formation de Stilo–Capo d'Orlando dans la région Serre–Aspromonte. La situation des sections est indiquée sur la Fig. 1.

sic and Cretaceous pebbles, calcarenites). The basal interval is characterised by limestones with larger foraminifera, mainly lepidocyclines, *Lithothamnium*, very abundant echinids and *Solenomeris* and coral-rich layers, forming a reef-like system. They progressively change upward into calcarenites with abundant lepidocyclines, frequently rich in phyllitic and granitic clasts, derived from the underlying basement. Finally, along the road Titi–Placanica, at Pignolo locality, the calcarenites grade upward to sandstones and yellowish marls, which constitute the uppermost 30 m of the formation.

The formation can be interpreted as a fan delta system with conglomerates in the canalised areas, and reef-like limestones in the marginal areas of the delta. Prodelta marls and calcarenites can also be related to the distal areas of the system. This realm was probably located near emergent reliefs, which were eroded, providing clasts from the Mesozoic carbonates. The occurrence at the top of the formation of phyllitic and granitic clasts testifies the unroofing of the basement.

Between the Stilaro and Precariti Valleys, conglomerates, lutites and sandstones of the SCOF have been described as following the Pignolo Formation [2, 3, 5, 10, 11, 23], which has been considered as a basal member of the SCOF peculiar of the Stilo area.

At the locality Molinaro, where a new concrete trail departs from the Pazzano–Titi road reaching the top of the calcareous ridge, the relationships between the Pignolo Formation and the SCOF prove to be particularly interesting (Fig. 2C). Here, an unconformity surface with a related palaeokarst, separating the lepidocycline and algal-rich limestones of the Pignolo Formation from marls and thin-bedded sandstones at the base of the SCOF can be observed. This palaeokarst, showing infilling with greyish marls from the SCOF, is marked by the presence of dissolution and a Fe-oxidised hard ground-like surface. This fact clearly indicates a period of emersion and subaereal erosion, which allows distinguishing as two different formations, belonging to two different sedimentary cycles, the SCOF and the Pignolo Formation. The unconformity between them has been also described by Patterson et al. [23] and Cavazza et al. [11], but they still consider the Pignolo Formation as a basal member of the SCOF, in agreement with Bonardi et al. [3]. Moreover, the analysis of the calcarenites containing larger foraminifera, locally resting above the crys-

talline basement out of the Stilo area, which have been considered as the base of the SCOF and to be equivalent to the calcarenites of the Pignolo Formation [3, 5, 11, 16], evidenced that these deposits represent turbiditic strata. These turbidites, made up of neritic calcareous clasts, including nummulites, occur at different stratigraphic heights in the SCOF. Therefore, these calcarenites cannot be compared with those of the Pignolo Formation, but they indicate the erosion of both this latter formation and other neritic deposits, now completely disappeared, during the sedimentation of the SCOF.

In conclusion, in the Stilo Unit, the Tertiary deposits are represented by two formations: the older Palizzi Formation and the younger Pignolo Formation. They have never been found in contact; their relationships, therefore, cannot be directly observed, but it is reasonable to hypothesize an unconformity between them.

3. The Stilo–Capo d'Orlando Formation

The SCOF unconformably overlies all the terrains of the Stilo Unit, from the Tertiary terms of the sedimentary cover to the metamorphites of the basement. This regional unconformity can be observed in the main outcrop of the unit from the Alli River to the Antonimina River, as well as in the outcrops on the southern side of the Aspromonte Massif (Fig. 1). Furthermore, the SCOF rests unconformably over all the tectonic units of the entire CPASS, sealing the nappes stack. Both in Calabria and in Sicily, varicoloured clays with megablocks of Numidian sandstones from the Maghrebian Flyschs Basin Domain tectonically overlay the SCOF (Antisicilide Complex of Ogniben [22]; Fig. 1). This geometry is interpreted as the result either of a back-thrust related to the collisional stage [7], Middle Langhian in age [3], or of the emplacement of a large olistostrome [11, 15, 23]. The SCOF, therefore, must be interpreted as a new sedimentary cycle, following the stacking of the CPASS and predating its collision with the Ragusa continental margin.

Several sections of the SCOF among the more representative have been re-examined (see Figs. 1 and 2 for location). They are located at the Stilaro Valley, on the eastern side of the Monte Stella–Monte Mammicomito ridge, between Pazzano and Titi (Figs. 1 and 2A–D), at Monte Tronato, Torrente San Paolo and Monte Scifa in the surroundings of Locri (Fig. 1E–G), and finally at Capo d'Orlando (Fig. 1I).

Three broad assemblages can be recognized [10]: (*i*) lutites and marls representing the hemipelagic sedimentation in the basin, (*ii*) large conglomerates bodies with depositional structures evidencing mass or debris flow-like deposition, related to marine palaeocanyons, and (*iii*) thin-bedded sandy turbidites, frequently associated with thicker sandstone beds. Close to the top of these assemblages, some silexite strata can be found, classically related to a Burdigalian volcanoclastic event [18]. At the base of the succession, olistoliths, made up of neritic carbonates and metamorphites, as well as calcareous breccias with green matrix, have been described in many localities [3, 7]. Clasts (granodiorites, andesitic porphyrites, neritic limestones) derived from the Stilo Unit are widespread in the SCOF conglomerates [3]. Finally, calcareous turbiditic beds, up to 3–4 m thick, consisting of neritic bioclasts (reworked larger foraminifera, *Lithothamnium*, echinids, etc.), have been recognized, mainly in the basal levels, both in the Stilo area (Monte Tronato; Torrente San Paolo [3, 5]) and in Sicily [16]. As already pointed out, they erroneously have been considered an equivalent of the Pignolo Formation [3], thus providing a main argument to interpret the latter as the base of the SCOF.

The SCOF sediments are arranged in a transgressive depositional sequence, where conglomerates usually appears in proximal areas to the bottom of the formation, while in distal areas, marls and marls with sandy turbiditic levels are found. Toward the top, the formation grades to marly sediments with silexites horizons, evidencing a deepening upwards evolution. This sedimentation can be interpreted as due to the erosion of important reliefs created after the nappe stacking of the whole CPASS.

4. Biostratigraphic data

4.1. Palizzi Formation

An Early Oligocene age was assigned by Bouillin et al. [9] to the Palizzi Formation taking into account the pollinic record and the presence of Stampian gastropods, oysters and larger foraminifera such as *Halkyardia maxima*. New biostratigraphic studies have confirmed the occurrence of *Halkyardia maxima* and the absence of *Lepidocyclina* sp. in the calcareous layers. The absence of *Lepidocyclina* sp. in these sediments allows us to restrict to the earliest Oligocene the age of this formation according to the zonation of Drooger and Laagland [14].

4.2. Pignolo Formation

The unique fossils with biostratigraphic significance of the calcarenites with larger foraminifera are lepidocyclines: *Nephrolepidina* sp. subgenus indi-

cates a late Early Oligocene (Latest Rupelian) to Early Miocene age [14].

The top of the formation, consisting of yellowish marls and sandstones, has provided calcareous nannoplankton assemblages characterised by the occurrence of *Geminilithella rotula*, *Helicosphaera mediterranea* and *Sphenolithus dissimilis*, whose first occurrence according to Young [26] is Aquitanian (zones CN1c = NN2). Reworked nannofossils, ranging in age between Cretaceous and Late Oligocene, are very abundant.

The occurrence of *Nephrolepidina* sp. indicates at least a late Early Oligocene age for the basal levels of the formation, while at the top of the sequence an Aquitanian age is testified by the calcareous nannoplankton.

4.3. Stilo–Capo d'Orlando Formation

The base of the formation has been investigated by means of calcareous nannoplankton in different sections from Stilo to Capo d'Orlando (Fig. 1A–I). Together with taxa occurring from the Aquitanian (*Discoaster druggii*, *Helicosphaera carteri*, *Helicosphaera mediterranea*, *Triquetrorhabdulus* cf. *milowii*), all the sections bear taxa indicating an age not older than Burdigalian. In detail, in the Stilo area the basal layers of the formation (Figs. 1 and 2A–D) are characterised by *Helicosphaera scissura* and *Sphenolithus calyculus* (zone CN2 = NN3, according to Young [26]), and in the Monte Scifa and Antonimina areas (Fig. 1E–G) by *Discoaster aulakos*, *Helicosphaera scissura* and *Sphenolithus belemnos* (zone CN2 = NN3). Finally, at the Capo d'Orlando section (Fig. 1I), the occurrence, in the basal levels, of *Calcidiscus* cf. *leptoporus*, *Discoaster stellulus*, *Discoaster* cf. *variabilis* and *Sphenolithus heteromorphus*, indicates the zone CN3 = NN4. In this case, too, Cretaceous and Palaeogene reworked taxa are frequent in all the sections.

5. Age of deformation of CPASS

Field and biostratigraphic data suggest an hypothesis about the geodynamic evolution of CPASS different from the interpretation of many authors during the last two decades [3, 5, 23, 11]. Both the presence of karstified and Fe-oxidised surfaces at the top of a mainly calcareous succession (Pignolo Formation), Latest Rupelian–Aquitanian in age, and the onlapping of the base of the SCOF, Middle–Late Burdigalian in age (zones NN3–NN4), over different stratigraphic layers of the same Pignolo Formation, allow to consider the latter, till now regarded as the base of the SCOF, as resulting from a different sedimentary cycle. Taking into account that the SCOF unconformably transgresses the whole CPASS tectonic building, whereas the Palizzi and Pignolo formations are exclusive of the Stilo Unit, it is possible to interpret the last two formations as the youngest deposits of the Stilo Unit sedimentary cover, predating its emplacement as the uppermost nappe of the CPASS tectonic stack. Thus, the deformation of the Stilo domain should have occurred in a very restricted span of time, close to the Aquitanian–Burdigalian boundary, between the end of Pignolo Formation deposition and the beginning of the SCOF sedimentation.

This age is in a good accordance with the age of deformation, not older than Aquitanian, reported by de Capoa et al. [13] for the Longi–Taormina Unit, the lowermost of the CPASS nappe pile, and with the radiometric age (25–22 Ma) of the metamorphic re-equilibration affecting both the Aspromonte Unit [6, 8] and the Mandanici Unit [1]. Therefore, the tectogenesis of the whole CPASS also should have occurred in a very restricted time span (Late Aquitanian–Early Burdigalian) and any hypothesis of tectonic diachronism must be refused.

6. Conclusions

The proposed interpretation allows to outline the late history of the Stilo Domain in the framework of the geodynamic evolution of the CPASS, as follows.

The last sedimentary episodes predating the tectogenesis of the Stilo Domain are represented by two depositional sequences (Palizzi and Pignolo formations). The first one consists of a transgressive and coarsening upwards sequence, recording an evolution from transitional to shallow marine environment during the Earliest Oligocene. The presence to the top of the sequence of rounded quartz, metarenite and lidite pebbles indicates an incipient tectonics. Source areas should undergo uplift and erosion, providing terrigenous sediments to the marginal realms of the earliest Oligocene basin under late pre-tectonic conditions.

The second depositional sequence disconformable over the Mesozoic begins during the late Early Oligocene, which evidences a new transgressive evolution. At its base, the formation seems to be fed from the calcareous Mesozoic cover, while during the Aquitanian a siliciclastic supply appears, evidencing the erosion of the phyllitic-granitic basement. The increasing of the clastic supply can be interpreted as related to the incoming tectogenesis.

The sedimentation of the SCOF begins in the Stilo area as elsewhere in the Burdigalian, in a thrust top basin developed after the piling up of the CPASS tectonic building and predating the docking of that exotic terrane to the Ragusa continental margin, testified by the emplacement of the Antisicilide Complex.

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