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Composition, provenance and thermal history of sedimentary successions from the Cilento Group (southern Apennines)

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INTRODUCTION

The Cilento Group represents the first deep-marine foreland clastic wedge, deposited since the early Langhian, onto deformed oceanic-derived rocks and shallow-water carbonate rocks of the Adria margin. The Cilento Group, is an impressive turbiditic system, which records the earliest collisional phases of the Calabria and Adria microplates in southern Apennines and extends from the Tyrrhenian coast to the NE to the Ionian coast to the SE. The terrains of the Cilento Group unit unconformably overlie carbonate rocks of the apenninic platform to the east and, more extensively, the Liguride and Sicilide oceanic-derived terranes.

The Cilento Group, Langhian to Tortonian in age (AMORE *et alii*, 1988 and many others) 1200-2000 m thick, rests unconformably on the Liguride Complex, and in turn it is unconformably overlain by the upper Tortonian Gorgoglione Formation, and the upper Tortonian to lower Messinian (?) Monte Sacro, Oriolo and Serra Manganile Fms (CRITELLI, 1999; CRITELLI *et alii*, 2011). The Cilento Group consists of different turbidite depositional systems. In addition to siliciclastic turbidite beds, the Cilento Group includes numerous carbonato-clastic megabeds (from a few meters to 65 m thick), olistostrome beds (ten to hundreds of meters thick), and coarse volcaniclastic debris flows and turbidites. It has been divided into four formations: the Pollica FmFm, the San Mauro Fm, the Torrente Bruca FmFm and the Albidona FmFm, from the northwest to the southeast (Fig. 1).

Generally, the Cilento Group is an upward-coarsening megasequence where thick sections are exposed. The lower part of the Cilento Group section (Monte della Stella locality) consists of a deep-sea fan. The lower part of the Pollica Formation is characterized by a section of intensely folded fine sandy-shaly turbidite beds over 300 m thick. The upper part of the Pollica Formation (undeformed or slightly deformed) consists of 250 m of coarse-grained sandstones locally interbedded with conglomerates of the inner-fan turbidite facies association.

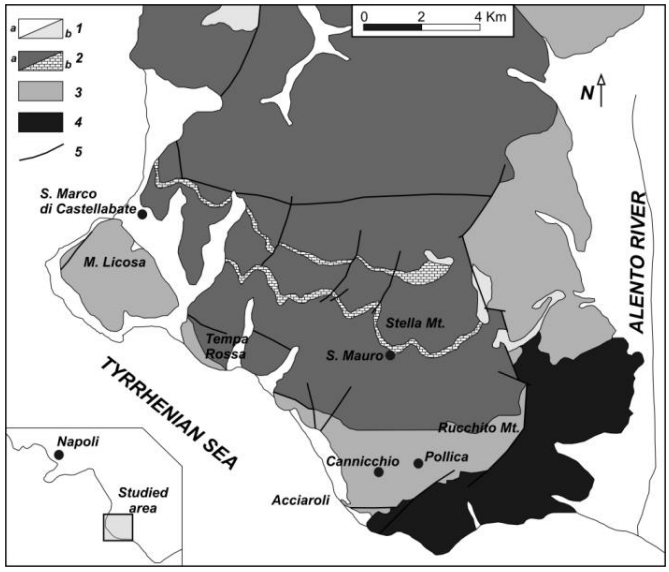

Fig. 1 – Geological map of the study area (modified from CRITELLI, 1999). 1. Holocene-Pleistocene deposits; 2. San Mauro FmFm; 3. Pollica FmFm; 4. Santa Venere Fm; 5. Faults.

The San Mauro and Torrente Bruca formations are the upper portions of the Cilento Group. They occur widely in the Monte della Stella (San Mauro FmFm) and in the Monte Sacro (Torrente Bruca FmFm) structures. The San Mauro Fm consists of 1400-1600 m of the outer-fan, middle-fan, and inner-fan turbidite facies association. In the Mote Sacro section, the Torrente Bruca Fm exhibits good exposures and a complete lateral and vertical outcrops. It includes the same turbidite facies association of the San Mauro Fm, including the two thick carbonate megaturbidite beds. The only significant peculiarity of the Torrente Bruca Fm, is the presence, in the upper portions of very thick olistostrome beds (more than 100 m in thickness), including olistholiths and broken formations of variegated shales, chert and ophiolitiferous rocks. The Albidona Fm outcrops along the Ionian margin between Calabria and Lucania. The thickness of the entire

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succession cropping out in this area is about 1000-1200 m. This turbiditic succession represents the infilling of thrust-top or foredeep basins which developed on the frontal part of the accretionary wedge of the Apenninic Chain during its Middle-Late Miocene northeastwards migration.

COMPOSITION AND PROVENANCE

Sandstones of the Cilento Group are quartzolithic, volcanolithic and quartzofeldspathic (CRITELLI & LE PERA, 1994). Hybrid arenites and calcarenites characterize the carbonatoclastic megabeds. Sandstone strata of the lower portions are metamorphiclastic quartzolithic and quartzofeldspathic, resting on quartzolithic sandstones of the Liguride Complex. Volcanic and plutonic lithics increase upward in the upper Pollica Formation and lower San Mauro, Torrente Bruca and Albidona formations. A volcaniclastic interval in the lower San Mauro Formation includes abundant felsic (rhyodacite to rhyolite) calcalkaline volcanic clasts (CRITELLI & LE PERA, 1994). Sandstones of the upper Cilento Group are plutoniclastic quartzofeldspathic, and consist of abundant phanerites of plutonic and metamorphic fragments. In the upper Cilento Group, thick carbonatoclastic and olistostroma megabeds record major tectonic events in the active thrust belt and the forebulge (e.g. CRITELLI & LE PERA, 1994). Carbonatoclastic megabeds record huge volumes of sand-sized and mud derived from the flexed Adria margin.

The mudstones are characterized by narrow compositional changes for Al_2O_3, K_2O, Fe_2O_3 and MgO which have concentrations higher than UCC (Upper Continental Crust; MCLENNAN *et alii*, 2006). SiO_2, Na_2O and P_2O_5 are strongly depleted relative to UCC. The distribution of Al, Ca, Na and K used to estimate the degree of alteration of source areas (e.g., CIA index; NESBITT & YOUNG, 1982), suggests a low to moderate weathered sources. Palaeoweathering conditions can be also determined by the K_2O-Fe_2O_3-Al_2O_3 ternary diagram (WRONKIEWICZ & CONDIE 1990). The studied samples fall between the illite-muscovite and chlorite field related to a low to moderate weathered sources, according to the CIA values. This chemical composition reflects the mineralogical data obtained on the studied mudstones, showing <2 μm grain-size fraction characterized by illite, mixed layers illite-smectite, chlorite and kaolinite.

Element geochemical proxies (e.g., MONGELLI *et alii*, 2006; PERRI *et alii*, 2012 and references therein) suggest that the source-areas have a predominantly felsic composition. Evolution of detrital modes is directly related to thrust-sheet emplacement of metasedimentary/granitoid units of the frontal thrusts of the northeastern Calabrian Arc (CRITELLI, 1999) and, to the north of the Sangineto-Pollino Line, of crystalline seamounts of the Tyrrhenian Sea. These areas evolved from metasedimentary (phyllite, fine-grained schist) to granitic-gneissic units. The compositional changes from metamorphyclastic to plutoniclastic sandstones in the Cilento Group are affected by thrust-sheet emplacement of the granitoid nappe. The studied sediments recorded a progressive increase of volcanic-plutonic supply. These compositional variations may be related to eastward displacement of the Calabrian arc and complete separation of the Calabrian terrane from the Sardinia block. The intrabasinal carbonatoclastic petrofacies (6) may be related to the abrupt flexure of the Alburno-Cervati-Pollino forebulge platform unit as response of the increasing tectonic load of the plutonic-high-grade metamorphic thrust unit (CRITELLI, 1999).

THERMAL HISTORY

A multi-method investigation (organic matter optical analyses and XRD analyses of clay minerals) has been performed to constrain 1D thermal modeling of the Cilento Group, cropping out along the Tyrrhenian margin in the Cilento promontory, among Castellabate, Pollica and Agropoli villages.
We performed two kinds of analyses:
- Vitrinite Reflectance (Ro%) of organic matter dispersed in sediments, using a Zeiss Axioplan microscope, under oil immersion in reflected monochromatic non-polarised light;
- Qualitative and semi-quantitative analyses of the < 2μm grain fraction (equivalent spherical diameter) performed by Scintag X1 X-ray diffraction system (CuKa radiation).
The thermal indicators obtained were used to calibrate 1D thermal models of the studied successions by means of the BASIN MOD software.
Samples for organic matter and X-ray diffraction analyses were collected from both Pollica and S. Mauro Fms. In addition, a few samples derive from the pelagic substratum (Crete Nere Fm).
Preliminary results of analysis on organic matter dispersed in sediments indicate that fragments of coalified woody tissues are generally very abundant throughout the entire synorogenic section. They are mainly made up of well-preserved macerals, extremely inhomogeneous in origin and preservation state. They indicate an effective reworking from thermally more mature sources and intense pre-burial oxidation. Furthermore the thermal signal due to well preserved macerals of the huminite-vitrinite group, coeval with the basin evolution, indicates the mature stage of hydrocarbon generation.
Quantitative analyses of < 2μm grain-size fraction show long-range ordered mixed layers illite-smectite indicating deep diagentic conditions in satisfactory agreement with organic matter maturity data.
According to the thermal modeling the maximum burial and thermal maturity experienced by the Cilento group decrease from older to younger stratigraphic units with an important erosional phase, at least, at the top of San Mauro Fm.

CONCLUDING REMARKS

The clastic compositions of the southern Apennines foreland basin strata reflect the thrust belt evolution through time, recording the accretion history of the Calabria microplate over the Adria margin. The Cilento Group records the main geodynamic events during the earliest collisional phase of the southern Apennines orogenic belt, and stratigraphic, compositional and thermal analyses may represent a quantitative tool for understanding the evolution history of collisional events in the central Mediterranean region.

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