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FORELAND TECTONICS IN THE SOUTHERN ADRIATIC SEA

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ABSTRACT

Two major deformation belts occur in the portion of the Adriatic Sea offshore the Gargano Promontory. The NE-SW – trending Tremiti Deformation Belt, located north of the Gargano Promontory, originated during the Plio-Quaternary, while the E-W-trending South Gargano Deformation Belt, located south of the Gargano Promontory, formed in a time span from Eocene to Early Pliocene. These deformation belts may have originated by tectonic inversion of Mesozoic extensional faults. This inversion tectonics, of Tertiary age, can be related to the evolution of the fold-and-thrust belts surrounding the Adriatic Sea.

The whole of the study area is, at present, seismically active and represents a preferential site of deformation.

KEY WORDS: *Southern Adriatic Sea, foreland tectonics, seismic reflection profiles, seismicity.*

RIASSUNTO

Nel bacino Adriatico sono state individuate, al largo del Promontorio del Gargano, due fasce principali di deformazione: quella delle Tremiti, di età Plio-Quaternaria, avente direzione NE-SW, e quella sud garganica, di età compresa fra l'Eocene e il Pliocene inferiore, orientata E-W. Tali fasce deformative, individuate sulla base dell'analisi di profili sismici multicanale e di stratigrafie di pozzi, possono essere state originate da un processo di inversione tettonica che ha riattivato preesistenti faglie dirette mesozoiche. Tale inversione, avvenuta nel Terziario, viene messa in relazione all'evoluzione delle catene periadriatiche. La sismicità osservata testimonia che il Promontorio del Gargano e le aree marine circostanti sono tuttora sede preferenziale di deformazione all'interno del blocco adriatico generalmente asismico.

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INTRODUCTION AND GEOLOGICAL SETTING

This study aims to investigate an area of the Southern Adriatic Sea where tectonic structures of possible regional significance have been reported and where seismic activity is present. The area, located offshore the Gargano Promontory, is part of the so-called «Adria continental block» (fig. 1). Using a data set consisting of exploration wells and seismic profiles, mostly commercial but also purposely collected, we attempt to define geometry, trends and geologic evolution of the above mentioned structures and to relate them to the observed seismicity. The results, although still preliminary, show a complex picture that may be relevant to interpreting the kinematics of the region.

Adria represents the foreland area of the Apennines, Southern Alps and Dinarides fold-and-thrust belts and is deflected in response to the load applied by these mountain belts (Moretti & Royden, 1988). Seismicity (ING, 1990) marks the deformed belt surrounding Adria, defining the main plate boundary between Adria and Europe.

Several authors interpreted Adria as a portion of the African plate (Argand, 1924; McKenzie, 1972; Channell et al., 1979; D'Argenio & Horvath, 1984; Dewey et al., 1989) while others (Vanderberg & Zijderveld, 1982; Morelli, 1984; Jongsma et al., 1987; Anderson & Jackson, 1987; Favali et al., 1990; Westaway, 1990) consider present Adria as a separate microplate, although differing on where the plate boundary is situated. Lithospheric thickness in the Adriatic is of the order of 100 – 110 km (Calcagnile et al., 1982; Mueller & Panza, 1984) while the crust is 30 km thick on average (Morelli et al., 1969; Geiss, 1987). Moho depth underneath the Gargano Promontory is estimated to be less than 25 km. This is considerably shallower than the adjacent regions where Moho depths are of the order of 35 km (Geiss, 1987).

Bouguer gravity anomaly contours follow the E-W trend defined by the Gargano Promontory

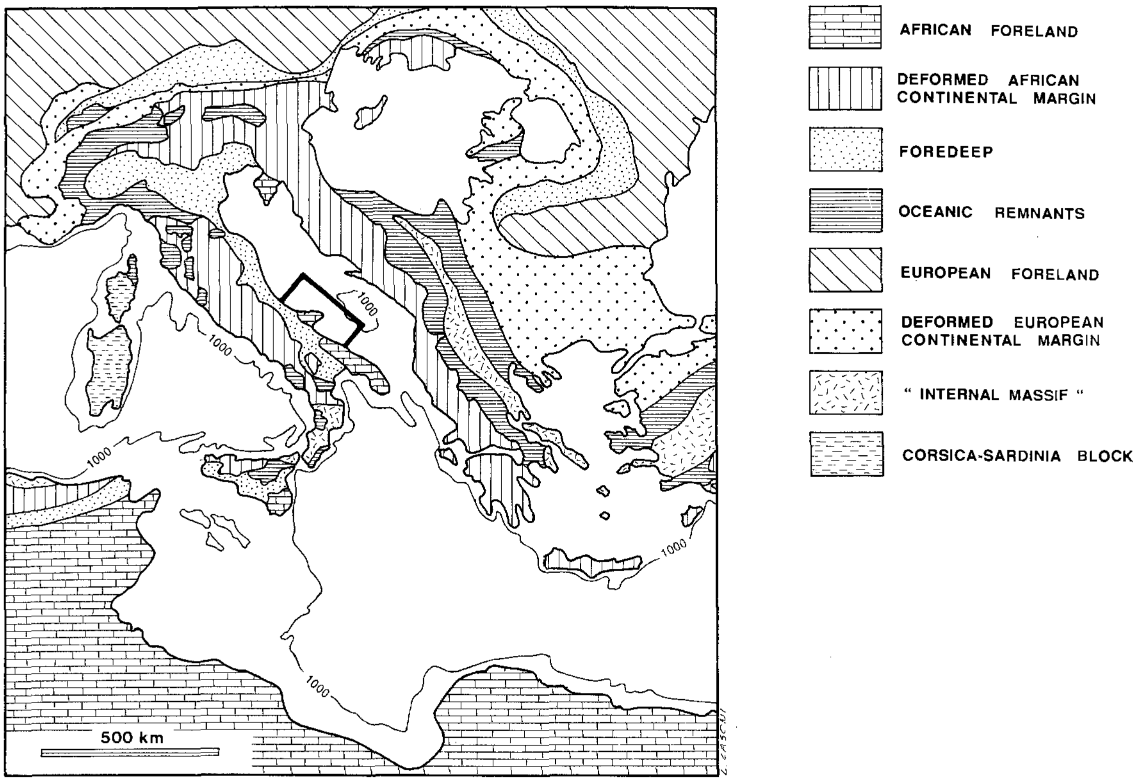

Fig. 1 – Simplified geology of the central Mediterranean region. The bold outline surrounding the Gargano Promontory represents the study area. Oceanic remnants indicate ophiolites and sediments related to oceanic crust.

(fig. 2). The positive anomaly, that reaches 110 mGal over the Promontory, continues offshore following the same trend (Finetti & Morelli, 1973). The same applies to the magnetic basement underneath the Gargano Promontory and its offshore area, that is about 2 km higher than beneath the surrounding regions, where it is deeper than 10 km (Cassano et al., 1986).

Units belonging to the foreland sedimentary cover outcrop in the Gargano Promontory (Martinis & Pavan, 1967; Cremonini et al., 1971) and are made up of essentially carbonate rocks ranging in age from Jurassic to Middle Miocene with a thickness of over 4000 m. Exploration wells have found Triassic evaporites at depths of about 6000 m in the Foresta Umbra area (Martinis & Pieri 1963). The Gargano Promontory appears as a broad east-west-elongated high affected by faults trending NW-SE, E-W and, to a minor extent, NE-SW. Few papers have been devoted to the study of this Promontory, with some authors putting more emphasis on sinistral strike-slip tectonics acting along the E-W trending Mattinata fault system (Funiciello et al., 1988) while others favour N-S and NE-SW compressional phases (Ortolani & Pagliuca, 1987).

The Tremiti Islands, located north of the Gargano Promontory, consist of four islands where a Tertiary succession about 500 m thick outcrops. Sediments range in age from Paleocene to upper Pleistocene and bedding planes generally dip SE-wards defining a NE-SW trending monocline (Cremonini et al., 1971). Minor folds, trending NE-SW and WNW-ESE, affect only Paleocene and Eocene sediments, while faults with little throw, mainly trending NW-SE but also E-W, cut across sediments older than Middle Pliocene, Plio-Pleistocene sediments record a progressive southeastward tilting of the monocline of about 5°-6° (Cremonini et al., 1971). A micro- and meso-structural study carried out in these islands (Montone & Funiciello, 1989) suggests that the Tremiti Islands represent a pushed up ridge within a E-W dextral strike-slip system, with the main faults located, however, in an unknown offshore position.

Offshore Gargano, Finetti (1984) suggested the presence of two major dextral strike-slip faults,

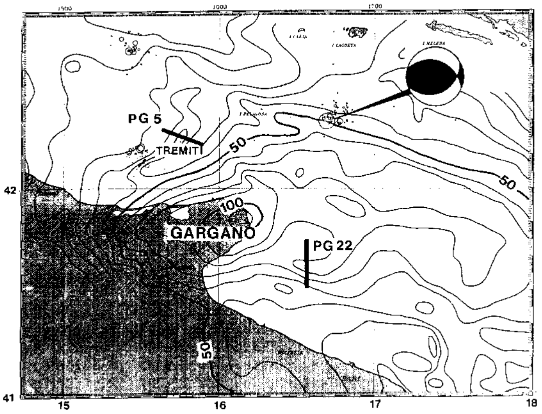

Fig. 2 – Bouguer gravity anomalies and epicentral location of the Adriatic seismic sequence occurring in 1986-1990. Bold lines are tracks of seismic profiles in fig. 4. The focal mechanism refers to the 5.3 magnitude earthquake of April 1988.

the NE-SW trending Tremiti fault and the E-W trending Mattinata fault, located north and south of the Gargano Promontory respectively. The area south of Gargano was further investigated (De' Dominicis & Mazzoldi, 1987; Colantoni et al., 1990) and an E-W trending structural high was observed. The authors interpret this structure either as a salt wall formed during Mesozoic salt tectonics, later reactivated by strike-slip faulting (De' Dominicis & Mazzoldi, 1987), or as a positive flower structure due to dextral strike-slip movement active until the basal Pliocene (Colantoni et al., 1990).

The Gargano Promontory and its neighbouring area are a seismically active zone. A detailed analysis of the Italian seismic catalogues (Postpischl, 1985; ING, 1990) shows out the occurrence of seismic activity offshore Gargano. Data from the Italian Telemetered Seismic Network, of which the Istituto Nazionale di Geofisica (ING) is in charge, show that during 1986-1990 three seismic sequences of low magnitude occurred associated with the Tremiti fault zone (fig. 2) demonstrating that this structure is seismically active (Console et al., 1989, 1993). Only the main shock of the 1988 sequence (mb = 5.3) allowed the computation of a reliable focal mechanism using a «double couple» model also supported by the Centroid-Moment Tensor (CMT) method (Dziewonski et al., 1981). Both solutions show a thrust component, more evident in the CMT, and a (sinistral) strike-slip component, more evident in the «double couple». The actual fault plane was interpreted as striking ENE-WSW (Console et al., 1993).

DATA SET

This study is based on a data set consisting of several exploration wells in the public domain and of a rather dense grid of seismic profiles (Argnani et al., 1993). Most of these profiles are commercial but a new grid was collected during a cruise carried out in 1991. A set of about 15 exploration wells has been used to constrain the stratigraphy of the area and, whenever possible, well data have been tied to seismic profiles in order to put stratigraphic constraints to seismic interpretation.

INTERPRETATION

Zone North of Gargano

A prominent NE-SW striking structural high comprising the Tremiti Islands (the Tremiti Deformation Belt – TDB) characterizes the area north of the Gargano Promontory. A coast to offshore transect comprising three wells (fig. 3a) illustrates the gross stratigraphy of this zone. Drowning of a carbonate platform system is well documented in the two offshore wells and not recorded in the near coast one. Thickness variations of Mesozoic pelagic sediments probably reflect deposition in half grabens as shown by the seismic profiles (Argnani et al., 1993).

It is noteworthy that above a depocentre of Mesozoic pelagics (well Famoso) the Paleogene section is incomplete and mostly shallow water in facies, while in an area of reduced Mesozoic pelagics (well Stella) the same section is complete, more expanded and made up of deeper water sediments. Upsection, the Messinian evaporites are overlain by fine grained clastic sediments of the Apennine foredeep that thin northeastwards.

Line PG-5 (fig. 4) crosses the TDB and illustrates its general folded appearance. The TDB trends NE-SW and is asymmetric with a steeper southern flank. Plio-Quaternary sediments are folded until very recently. The upward decrease in amplitude of the fold indicates that the sediments were deposited during deformation. On the other hand, below the "M" unconformity no significant thickness change is observed, suggesting that folding is mainly of Plio-Quaternary age.

Zone South of Gargano

The major feature south of the Gargano Promontory is the roughly E-W trending South Gargano Deformation Belt (SGDB). Wells are located on either side of the structure as well as on its top. A N-S transect perpendicularly crossing the structure is shown (fig. 3b). The Mesozoic is characterised by

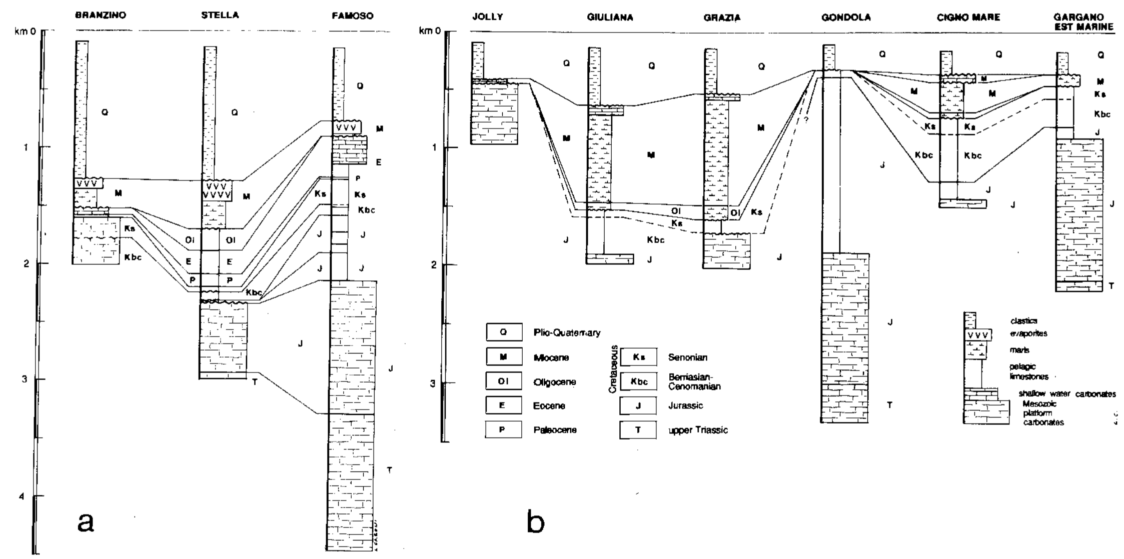

Fig. 3 – Schematic stratigraphy of the Gargano offshore area derived from exploration wells, a) north of Gargano, from south (Branzino) to north (Famoso); b) south of Gargano, from south (Jolly) to north (Gargano Est Marine).

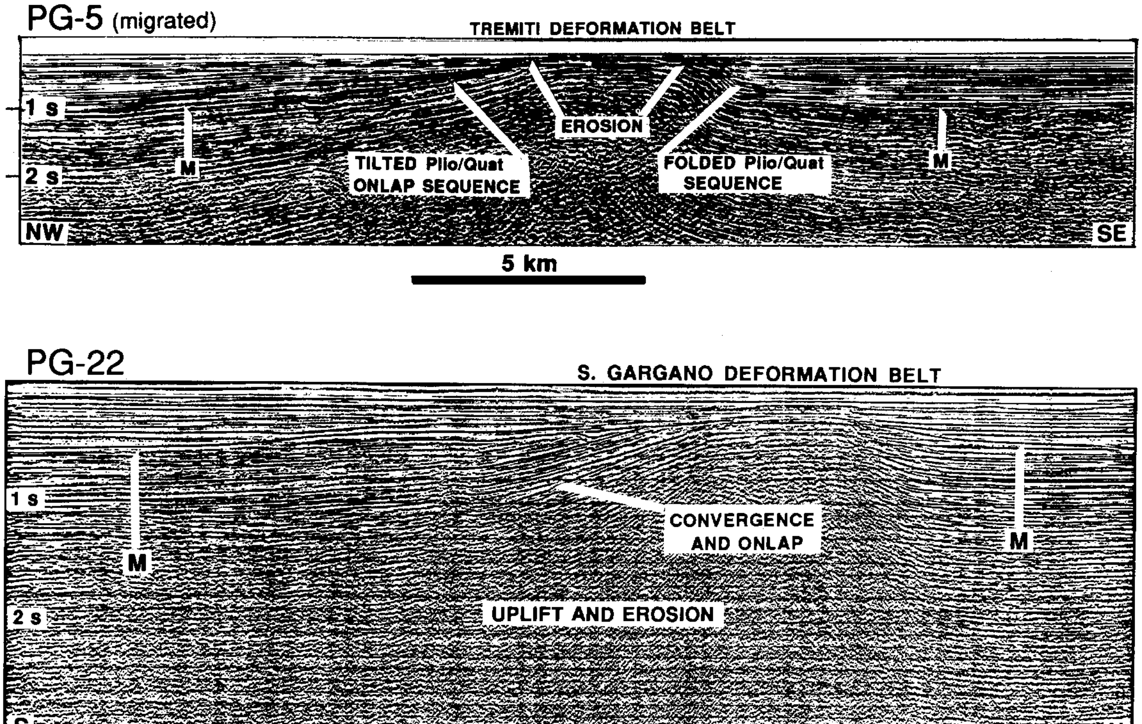

Fig. 4 – Seismic reflection profiles crossing the Tremiti Deformation Belt (TDB), above, and the South Gargano Deformation Belt (SGDB), below. Location in fig. 2.

the presence of Triassic and Early Jurassic platform carbonates overlain by pelagic sediments. This transition from platform to basin sediments does not occur in the near coast well Jolly. Note that Gondola, located right on the top of the SGDB, shows the most expanded Mesozoic pelagic sequence, notwithstanding the probable erosion of its younger part, since Plio-Quaternary clastics rest directly onto Lower Cretaceous pelagic limestones (about 110 Ma of missing section). These sediments have been relatively uplifted with respect to the adjacent coeval sediments. Tertiary sediments are noticeably absent over the SGDB while they occur in two depocentres on either side of the structure. Since all wells in the area are located on relative structural highs, it is not known if the lack of Paleocene and Eocene sediments is representative of the whole area or if it represents a bias.

Line PG-22 (fig. 4) crosses the SGDB where it is wider and is better developed. The well Gondola is located a few km to the east of this line. On the southern flank of this broad asymmetric fold a seismic unit with parallel reflections onlapping at its base and truncated at its top by the «M» unconformity is well displayed. Such a unit probaby represents the Oligo-Miocene sequence resting on the Mesozoic pelagic sediments. Successive onlap of Plio-Quaternary sediments onto the «M» reflection is clearly seen.

In summary, Late Triassic rifting affected the entire offshore area investigated, favouring the accumulation of great thickness of shallow water carbonates. The ensuing breakup of the carbonate platforms resulted in the deposition of Mesozoic pelagic sediments within half-grabens over most of the area.

North of the Gargano, hiatuses, lateral facies changes and thickness variations within the Paleogene sediments, together with pulses of subsidence and uplift, suggest that tectonic activity occurred during this period, but it did not produce any major compressional structure. The main activity occurred after the Messinian: to the north the onset of the Apennine foredeep and, close to the Gargano Promontory, the growth of the TDB that lasted for almost the whole Plio-Quaternary.

South of the Gargano, onlap of Oligo-Miocene sediments onto tilted Mesozoic units indicates that tectonic activity occurred sometime during the Paleocene and Eocene, originating the SGDB. The structure was reactivated in Messinian time, as documented by the tilted Oligo-Miocene sediments and by the onlapping Plio-Quaternary strata. The SGDB does not show activity during the Plio-Quaternary. The broadly folded reflectors of the SGDB, its position above a Mesozoic extensional fault and the presence at its core of a depocentre of Mesozoic pelagic sediments (well Gondola) suggest that the SGDB can be related to tectonic inversion of a previous extensional fault.

DISCUSSION AND CONCLUSIONS

The main deformational episode affecting the TDB occurred during the Plio-Quaternary while in the SGDB it occurred during the Eocene. Given the position of the two deformation belts, it appears reasonable to link these episodes to the evolution of the adjacent chains. In particular, the SGDB seems to have recorded the onset of the Dinaric foredeep and of the Alpine collision, while the deformation in the TDB appears to be related to the evolution of the Plio-Quaternary Apenninic foredeep. It is likely that the Eocene episode was also recorded, to a minor extent, in the northern zone where indications of tectonic activity have been observed. In our opinion, this Eocene event marks the transition from an evolution controlled by extensional tectonics to one where contraction is the dominant feature.

The seismicity of the Gargano Promontory occurs in a portion of the continental block where a great deal of structural deformation is also observed. It seems therefore that the Gargano Promontory and its offshore area represent a portion of foreland where deformation has preferentially concentrated since the emplacement of the surrounding fold-and-thrust belts.

We propose that tectonic inversion of Mesozoic extensional faults can explain the observed geologic features and fits in with the regional geologic setting of a foreland area surrounded by fold-and-thrust belts. The stress propagating from the adjacent Apennines, Alps and Dinarides is believed to have caused tectonic inversion through the reactivation of inherited Mesozoic weakness zones. The timings of deformation in the chains and in the Garganic area are, in fact, almost coincidental. Moreover, the presence of Triassic evaporites, acting as a decollement horizon, may have favoured the deformation of the sedimentary cover.

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