SESSION 45

S02.01 - CROP - Deep Seismic Soundings in the Italian Area
SUNDAY, August 22, 2004 - 9:00
Room: 1 - Cavaniglia

Conveners:
Doglioni Carlo, Mazzotti Alfredo, Scandone Paolo

45-1 Invited Scrocca, Davide

CROP ATLAS: DEEP SEISMIC REFLECTION PROFILES IN ITALY

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Keywords: CROP Project; deep crust; reflection seismic; Italy

The CROP Atlas represents the state-of-the-art of the CROP Project, the Italian deep crust exploration project, supported by the National Research Council (CNR) and by two leading companies in the energy sector (ENI and ENEL). This Project has been carried out thanks to the efforts of a large number of scientists. The publication of the CROP Atlas was one of the main goals of the present management, as a means of displaying and disseminating the wealth of data acquired by preceding committees. The seismic sections enclosed with this Atlas amount to about 10,000 km, over 8,740 km of which are off-shore and about 1,250 km on-shore, forming a network of regional seismic lines that cover the most prominent geological features of the Italian peninsula and the surrounding seas. The seismic data presented in the CROP Atlas were acquired between 1986 and 1999. It also include profiles from ECORS-CROP project, carried out in co-operation with French colleagues, from the Central Alps, in co-operation with the Swiss NRP20, and from the very recent TRANSALP project, jointly developed with Austria and Germany. Generally, the seismic line shown is the stack version, but in a few cases the migrated version is also available (CROP-03, CROP-18 and TRANSALP).The CROP Atlas was planned when most of the scheduled seismic reflection profiles had already been acquired. The first processing of the data has now been completed, but several lines might need to be reprocessed. The geological interpretation started several years ago and is still ongoing.Interpretable seismic signals can be recognised down to 9-10 s TWT or more, well below the usual limit of previously acquired seismic data. Moreover, thanks to their regional extent, the CROP profiles can provide a valid background to properly frame the interpretation of commercial seismic lines.The CROP seismic profiles provide new valuable information on the structure and tectonic evolution of the Italian region as, for instance:- seismic images of the Moho discontinuity, both in the continental and oceanic domains (e.g. in the Alps or in the Tyrrhenian and Adriatic Seas);- insights to constrain the deep structure of the Alps and Apennines;- stratigraphic and structural setting of the pre-Norian sedimentary successions (e.g. in the Adriatic Sea).

45-2 Invited Castellarin, Alberto

RESULTS OF THE TRANSALP SEISMIC REFLEXION PROFILE ACROSS THE EASTERN ALPS

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Keywords: CRUST; LITHOSPHERE; STRUCTURE; COLLISION; OROGENE

Two main alternative crustal models of the Eastern Alps are the result of the Austrian, German and Italian Transalp Project, principally based on the seismic reflexion Profile acquired across the whole orogenic chain from the Bavarian Molasse (to the N) and the Venetian plain(to the S). The two models are expressions of typical collisional orogenic chain due to the plate convergence and to the strong mechanical wedging interactions of the facing continental margins. Double indentation processes with a couple of "Penninic" and "Adriatic" indenters define the "crocodile" Model (A). Single indentation of Adriatic lithosphere is stressed in the "extrusion" Model (B). The African southern continental margin (the N border of the Adriatic microplate) to the S, and the N European continental margin, to the N, were formerly separated by the oceanic Alpine Tethys which was consumed during the late Cretaceous-Early Eocene pre collisional convergence evolution of the Alpine domain. During the Eocene collisional evolution, the Penninic nappes, with their charge of Austroalpine units, emplaced over the European continental margin of the Tauern. North of the Insubric lineament (IL), the N verging nappe building is widely outcropping inside the Tauern Window (TW) affected by ductile deformation, rising up and exhuming for 30-35 km in the last 30 Ma(mostly in Early-Mid Miocene times). The structure of the Tauern correspond to a regional E-W trending overthrust anticlinal ramp (well documented by the deep seismic images: the "Trans-Tauern ramp"). Completely different is the structural styles in the Dolomites, S of the TW and of the IL and in the Upper Austroalpine units, N of the TW: these sectors underwent brittle deformations and thrusting (clear seismic images up to 10-15 km in depth). According to Model B, the dipping to the N of the IL in depth is consistent both with the tectonic structures present at the surface and with the deep seismic reflexion data of the Transalp Profile: a strong break in the reflective seismic facies is visible, in the seismic images, up to a depth of about 25 km underneath the Tauern window. Like in the Western and Central Alps, this deep geometry can be interpreted according to a wide and thick N indentation of the Adriatic lithosphere: the IL corresponds to the upper face of the wedge, pierced between the nappe stack of the TW zone and the European lower crust which, descending to the S, bounds the lower face of the indenter.

45-3 Invited Catalano, Raimondo

SEISMIC REFLECTION EVIDENCE OF THE CALABRIAN ACCRETIONARY WEDGE AND THE IONIAN SUBDUCTION ZONE

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Keywords: Ionian basin; Crustal seismic profiles; Calabrian accretionary wedge; Subduction

CROP seismic lines crossing the Ionian abyssal plain and the southeastern Tyrrhenian through southern Calabria offshore image a well developed SE vergent accretionary wedge and the NW dipping oceanic basement. The Ionian abyssal plain sector shows a highly reflective layered body and a transparent and unstratified band with overlapping hyperbolae; the oceanic Moho deepens northward from 9 to more than 10 s/TWT in few kilometers. The crystalline crust is still coupled with the oldest sedimentary layers.In the intermediate Ionian sector the crust progressively deepens with a complex trajectory appearing offset by a WNW-ESE lateral (?) discontinuities. Moho develops at about 11 s/TWT. The sedimentary cover is imaged as coherent thrust ramps corresponding to the tip of the socalled External Calabrian Arc.Approaching SE Calabria offshore, the faintly recognized Moho discontinuity occurs at more than 14 s/TWT. The upper crust (Layer 2 ?), strongly deformed in some tectonic slices is overlain by 2 s/TWT thick sedimentary rocks imbricated wedge, underlying in its turn a 3 s/TWT thick seismically transparent to chaotic body correlatable to the adjacent Calabrian units.The seismics images that both sedimentary and crystalline Ionian crustal bodies are progressively detached from their substrate more deeply and markedly towards NW. As a consequence sedimentary and oceanic crust units appear embricated to form the SE verging accretionary wedge. The subduction hinge zone is seismically imaged in the area where the Calabrian crystalline units overthrust the deformed oldest sediments deposited on the Ionian crust. Thickness of the Ionian crust with respect to the adjacent continental areas, petrological-physical characteristics and relic structures could have influenced the geometry of subduction and generated processes in the shallow levels. Occurrence of oceanic crust certainly favours subduction in this area, generating the Aeolian volcanic arc and the deep seismicity in the southeastern Tyrrhenian, as well as the ascent of the Etna magmas.

45-4 Invited Sulli, Attilio

SEA CROP AND LAND SEISMIC PROFILES DATA AS A PREMISE TO A DEEP CRUSTAL INVESTIGATION IN SICILY

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Keywords: Crustal seismic profiles; Sicilian-Maghrebian chain; Southern Tyrrhenian; Paleogeographic heritage

CROP profiles in Southern Tyrrhenian, land geology and deep seismic sections in Sicily shed light on the Sicilian-Maghrebian fold and thrust belt as well as the crustal structure of the offshore sector. These results are here presented as the main information available in the area that will be soon crossed by a NNW-SSE CROP profile.The seismic reflection study of the southern Tyrrhenian images a northward inflection of the Sicilian (African) continental crust below the submerged interpreted Kabilian-Calabrian continental crust, confirming a north-directed continental subduction (Doglioni et al., 1998). On land (Bello et al., 2000; Catalano et al., 2000) three main structural levels can be distinguished in the chain which lies above an apparently not involved, northward-dipping, crystalline basement showing a main flexure below the Central Sicily region. The lowest level of the chain results from the Meso-Cenozoic, mostly carbonate platform, S-vergent, 3-4 km thick ramps that overthrust the carbonate foreland located in the Iblean region. The intermediate level consists of a wedge of thin flat-lying Meso-Cenozoic basinal carbonate thrust sheets, thinning westward. The uppermost structural level is a thrust wedge made up of Sicilide-Numidian units and Gela thrust system. Syntectonic Latest Miocene-Early Pleistocene satellite basins sealed the already deformed substrate. Re-imbrication, hinterland-verging structures, back-thrusting and frontal accretion built up the tectonic wedge.These results well illustrate the Sicily chain setting, but are neither able to anchor the thrust pile at depth nor to define deep crustal geometries. The latter could provide information on the occurrence of active subduction, crustal paleogeography and nature of the (stretched ?) continental crust. REFERENCESBello M., Franchino A. & Merlini S., 2000. Mem. Soc. Geol. It., 55, 61-70.Catalano R., Franchino A., Merlini S. & Sulli A., 2000. Mem. Soc. Geol. It., 55, 5-16.Doglioni C., Innocenti F. & Mariotti G., 1998. In: Atti 17° Convegno G. N. G. T. S., Roma.

45-5 Invited Cavinato, Gian Paolo

GEOLOGICAL INTERPRETATION OF THE CROP 11 SEISMIC LINE BETWEEN THE ADRIATIC COAST AND THE TIBER VALLEY

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Keywords: CROP 11; Central Apennines; ITALY

The CROP 11 is a W-E oriented, deep seismic profile (256 Km) that crosses the Central Apennines from the Tyrrhenian to the Adriatic coasts.The shallow structure of the Adriatic crust consists of Mesozoic-Tertiary carbonates 6-7 Km thick (Apulia Platform) and of Plio-Pleistocene foredeep deposits 2-3 Km thick. The top of the Apulia Platform is represented on the line by a low-frequency/high-amplitude seismic signal that evidences a continuous horizon gently dipping westwards beneath the Apennine chain. From 4.2 s TWT (about 10 Km) to 5.7 s TWT, a reflective seismic facies, corresponds to the Permo-Triassic terrigenous deposits, stratigraphically underlying the shallow-water carbonates of the Apulia Platform drilled by the Puglia 1 and Gargano 1 wells. Below this package of reflectors, a transparent seismic facies, interpreted as a crystalline upper crust, extends as far as 10 s TWT. Between 10 and 12 s TWT, finally, a new package of well-organized reflectors should represent a layered lower crust. An Adriatic Moho at about 12 s TWT, which corresponds to a depth of 32-35 kilometres, fits the results of previous geophisycal experiments.Moving westwards, the line enters the Apennine belt. This is organized as a duplex structure formed by Mesozoic-Tertiary carbonates and Permo-Triassic terrigenous deposits detached from the Apulian basement. The roof thrust of the duplex system corresponds to the base of basin-derived allochthonous sheets (Molise nappes). Stratigraphic information contained in the Ponte1 well suggests that the Apennine frontal ramp was active in this area during Early Pleistocene times. Backthrusts are common features within the thrust-belt and may account for the regional elevation of positive structures (i.e. Bomba, Maiella and Marsica anticlines).The Permo-Triassic terrigenous deposits have been severely involved in the compressional deformation in the periadriatic area. On the contrary, the Apennine sole-thrust seems to be located at the base of the Upper Triassic dolomites and anhydrites in the Marsica and Simbruini regions. An eastward deepening of the sole-thrust during the forward thrust propagation is also suggested by an important deep-seated duplex structure recognized between Tiber Valley and Marsica region from 4.5 s TWT to 9 s TWT. Reflection events at 10 s TWT below the Fucino Plain could be attributed to the downgoing Adriatic crust or, alternatively, to the uprising Tyrrhenian mantle

wedge.

45-6 Invited Argnani, Andrea

BASEMENT GEOLOGY OF THE NORTH-WESTERN APENNINES: A DEEP SEISMIC REFLECTION STUDY

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Keywords: Northern Apennines; basement geology; deep reflection seismics

The features of the basement in the north-western Apennines has been identified and mapped using commercial deep seismic reflection profiles (ENI-AGIP). The basement is typically buried under the Tuscan and Ligurian nappes, although it crops out in the Apuane Alps window. The basement top is defined by a package of strong and more or less continuous reflections, generally dipping towards the Po Plain, down to a depth of 4 - 5 s (TWT). A NW-SE-trending line of basement culminations, spaced about 10 km, occurs in the internal sector of the Apennines. These culminations comprise the M. Pisani and Apuane Alps, where basement crops out, and two buried basement domes, one of which has been reached by Pontremoli 1 well. The regional NE-dipping surface is transversally segmented by discontinuities corresponding at surface to the Sillaro and Taro deformation belts, and likely reflecting lateral ramps of the basement. A package of SW-dipping high angle reflections have been observed within the basement, and is bounded at the base by a regional sub-horizontal reflection. A regional geological profile (La Spezia - Parma) crossing the internal extensional system, the pede-Apennine thrust front, and the buried thrust fronts of the Po Plain, illustrates the main aspect of the basement. The thrust fronts buried under the Po Plain, that were mainly active from late Miocene to late Pliocene, join a basal detachment that progressively cuts down into the basement and appears rooted within the deeper part of the orogen. Most of the thrusts of the pede-Apennines, on the other hand, seem to flat on the top of the basement which is dipping towards the Po Plain. The basal detachment of the Plio-Quaternary extensional faults that characterises the internal sector of the north-western Apennines is also joining the NE-dipping top of the basement. The geometries observed on seismic profiles suggest the presence of a basement duplex in the internal part of the north-western Apennines. We infer that the sub-horizontal surface bounding the stack of basement represents a former sole thrust later abandoned in a subsequent evolutionary stage of the northern Apennines. The observed basement geometries are used as additional constrains to interpret the geological evolution of the Northern Apennines, and the ensuing geodynamic implications are explored.

45-7 Invited Aoudia, Abdelkrim

THE SIMULTANEOUS USE OF CROP AND SURFACE WAVE TOMOGRAPHY EVIDENCES LITHOSPHERIC DELAMINATION AND BUOYANCY-DRIVEN DEFORMATIONS IN CENTRAL ITALY

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Keywords: CROP; surface wave tomography; lithosphere-asthenosphere; Central Italy; buoyancy

We study the lithosphere-asthenosphere system in Central Italy integrating deep P-wave seismic sounding profiles crossing the whole Peninsula from the Tyrrhenian, via the Tuscan Metamorphic Complex (TMC) and the Umbria-Marche geological domain (UMD), to the Adriatic with new shallow and deep tomographic inversions of surface waves.The retrieved crust and lithospheric mantle (lid) exhibit lateral variation in thickness. Lithospheric roots, more than 120 km wide, between the TMC and UMD, reach a depth of at least 130 km. A sharp and well-developed low-velocity zone in the uppermost mantle (mantle wedge), from the Tyrrhenian dying out beneath the Apennines, separates crust and lid. The model provides a new background for the still debated genesis of the TMC. Petrology and geochemistry reveal rocks rich in incompatible elements with crustal-like isotopic signatures consistent with a genesis in a sub-crustal anomalous mantle. This anomalous mantle may be associated with the identified mantle wedge that was probably metasomatized by an addition of subduction-related upper crustal material. The large lithospheric roots, inferred to be lid material delaminated from the overlying crust, can be interpreted as the remnant portions of the Adriatic and old Alpine slabs.The retrieved earth structure is used to model the mantle flow induced by the lithospheric buoyancy caused by changes of gravitational potential energy and by lateral variations of the effective viscosity of the lithosphere. The predicted flow field explains the delamination of the crust from the lid and shows how the mantle wedge is emplaced. The recent magmatism at the surface and the high heat flow values are in agreement with the computed upward flow field and suggest that this mantle wedge is partially molten mantle feeding TMC. The ages of TMC rocks with a tendency to decrease from west to east, are in agreement with the predicted eastward flow in the mantle wedge. We show how buoyancy solely can explain the juxtaposed crustal contraction and extension, and the unusual distribution of intermediate depth earthquakes. The reported unchanged time-space stress field, inferred from the magnetic anisotropy of Plio-Pleistocene sediments, and the distribution of the thick extensional Quaternary sedimentary basins, in places where our model predicts high magnitude tension, makes us think that buoyancy is the prevailing mechanism in this slow-rate deforming area since, at least, Pleistocene times.

45-8 Invited Liotta, Domenico

GEOLOGICAL INTERPRETATION OF THE CRUSTAL SEISMIC LINE CROP 18 (SOUTHERN TUSCANY)

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Keywords: Extensional Tectonics; Geothermics; Southern Tuscany

The reflection seismic line CROP 18 was acquired to investigate the crustal structures of southern Tuscany, from the Larderello (to the north) to the Monte Amiata (to the south) geothermal areas. This, along strike oriented, seismic line is divided in two transects: the northern one, (CROP 18A) and the southern one (CROP 18B). The line was processed down to 10 s TWT. Line drawings of both CROP 18 transects were compiled considering the migrated and unmigrated seismic sections. The geological interpretation was based on: (1) a geological cross section drawn along the seismic profile; (2) data from deep wells near the trace of the seismic lines; (3) further seismic lines acquired in the geothermal areas. In both Larderello and Monte Amiata geothermal areas, the Neogene extensional tectonics mainly determined low angle normal faults Early-Middle Miocene in age. These faults produced the delamination of the previously stacked tectonic units, generating megaboudins and extensional duplex structures. The CROP 18A and 18B seismic lines display a regional, mid-crustal and discontinuous reflector named K-horizon which account for fluids accumulated in selected fracture zones. In the CROP18 lines, the K-horizon ranges in depth between 1.5 and 4 s TWT (3-8 km) and it was interpreted as the roof of a kinetically active shear zone, located at the top of the present brittle-ductile transition. The Larderello geological structure is typified by NW-SE brittle extensional shear zones, Pliocene-Quaternary in age, whose interaction with the brittle-ductile transition can determine a strong attenuation of the K-horizon reflectivity. This feature is shown in the along strike CROP 18A transect. Below and above the K-horizon, several areas with low and homogeneous contrast of acoustic impedance are displayed in both CROP 18A and 18B transects, suggesting the occurrence of intrusive magmatic bodies at different crustal levels. A wide hot granitoid is supposed to be located in the mid-lower part of the crust underneath the Larderello geothermal field, and may contribute to determine the Larderello geothermal anomaly. Both CROP 18A and 18B transects display bright reflections in the lower part of the crust. These could be mainly produced by the presence of pressured pore fluids in ductile shear zones; these fluids should also favour the shearing, necessary to accommodate the extension which characterises southern Tuscany. The base of the crust is located at about 22-24 km depth.

SUN

45-9 Invited Barchi, Massimiliano Rinaldo

THE CRUSTAL STRUCTURE OF THE NORTHERN APENNINES OF ITALY: AN INSIGHT BY THE CROP03 SEISMIC PROFILE

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Keywords: Northern Apennines; crustal reflection seismic; geodynamics; seismotectonics

CROP03 NVR profile is described and re-interpreted, taking into account new data sources made available in the last years, particularly from heat flow measurements, aeromagnetics, seismic tomography, active stress determination and passive seismology, as well as from surface geology. The crustal structure of the Northern Apennines (NA) comprehends two domains, with distinctive characteristics from both geological and geophysical points of view, which also exhibit a distinct reflectivity pattern at any crustal level. In the western, Tyrrhenian domain the Upper Oligocene-Early Miocene compressive structures are no longer recognisable, because they are dissected by the subsequent, extensional structures, consisting of a set of six major, east-dipping, low-angle normal faults, extending and thinning the upper crust. In the eastern, Adriatic domain, where compressive tectonics has acted since Middle-Miocene, the pattern of shallow contractional structures is well preserved and effectively imaged by the NVR seismic profile. This crustal setting is a present-day picture of the eastward migration of coupled compression and extension, acting since Middle Miocene: in any position along the section, compression (thrust systems and associated foredeeps) is followed by extension (normal faults and related basins). The easternmost, still active, normal fault (Altotiberina fault) affects the intermediate sector of the profile, consisting of a highly reflective window, where refraction data detect a crustal doubling, about 30 km long. The strongest earthquakes are concentrated in this region, where extensional tectonics is still active, since the process of crustal thinning has not been completed yet.As highlighted by combined seismic reflection and refraction data, the Moho in the Tyrrhenian domain is shallow (<25 km), gently deepening towards the east, whilst in the Adriatic domain it is deeper (>30 km), gently west-dipping. The Adriatic Moho could be merged into the submerged lithospheric slice, imaged as a tomographic high velocity anomaly and also marked (until a depth of about 90 km) by rare seismic activity. The crustal setting and the Neogene tectonic evolution of the Northern Apennines both support a geodynamical model in which the pattern of coupled compression and extension was driven by sinking and retreating of a lithospheric slice, resulting from the delamination of the overthickened crust, originated by previous collisional tectonics.

45-10 Invited Doglioni, Carlo

ALPS VS APENNINES: TWO END-MEMBERS OF A GLOBAL SIGNATURE

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Keywords: Alps; Apennines; Geodynamics; Subduction zones; Westward drift

The Alps and the Apennines are two orogens respectively related to the SE-E-ward subduction of Europe beneath the Adriatic plate, and the W-ward directed subduction of the Adriatic plate. The two belts show a number of differences from the surface to the deep structure, as confirmed also by deep seismic soundings. Along their axis, the Alps have thicker crust (>55 km) than the Apennines (average <30 km). In the Alps the thrust planes crosscut the whole crust and the upper mantle, whereas the Apennines are mainly a thin-skinned thrust belt. This is evident also by the wider outcrops of basement rocks in the Alps, whereas the Apennines are mainly composed of sedimentary rocks. The Alps are both morphologically and structurally more elevated than the Apennines. The erosion in the Alps axis has been of a few tens of km, whereas the erosion in the Apennines has not been larger that few km. In spite of their higher elevation, the Alps have a foreland regional monocline less inclined (2-6°) than the Apennines (4-20°). The Alps have a double vergence, whereas the Apennines are single vergent. Therefore the Alps have two foredeeps, one parallel to the frontal belt, and the second located at the front of the retrobelt (Southern Alps). Subsidence rates in the foredeeps have been much slower in the Alps (<0.3 mm/yr) than in the Apennines (>1 mm/yr). The Alps show lithospheric roots down to about 200-250 km, whereas the Apennines have a slab that arrives deeper than 500 km. The Alps have not backarc spreading; on the other hand, the Apennines continue into the Maghrebides and the whole belt contains the western Mediterranean backarc basin. In spite of their higher elevation, the Alps have minor extensional tectonics; the normal faults are superficial and sin-thrusting. In the Apennines the normal faults crosscut the whole crust, they are located west of the active accretionary prism, and they migrated eastward, while the slab retreated. The Alps have smoother gravity anomalies than the Apennines, which rather present two negative and positive peaks along the frontal part and in the backarc, where there are also anomalously high heat flow values.These asymmetries visible when comparing Alps and Apennines persist worldwide between orogens associated to respectively to E-NE- and W-directed subduction zones. All this indicates a geographically controlled global geodynamic signature, which supports the W-ward drift of the lithosphere relative to the mantle.

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