RECENT TECTONIC STRESS FIELD STATE IN ITALY FROM NUMERICAL MODELLING ANALYSIS

Simona Pierdominici[1] and Oliver Heidbach[2]

1. Sismologia e Tettonofisica, INGV, Rome, Italy 2. Seismic Hazard and Stress Field, GFZ German Research Centre for Geosciences, Potsdam, Germany

simona.pierdominici@ingv.it; heidbach@gfz-potsdam.de

AGU FALL MEETING 2010 13-17 DECEMBER SAN FRANCISCO T21B-2156

ABSTRACT

We examine the contemporary stress in Italy studying the present-day maximum horizontal stress orientation to characterize the relationship between active stress, past tectonic setting and the seismicity. The geodynamic setting of Italy is particularly complex. Italy is involved in the N-S convergence of Africa and Eurasian plates and currently undergoing NE-SW extension perpendicular to the Apenninic fold and thrust belt and with the opening of the Tyrrhenian basin (Late Tortonian). This process happens in the presence of still active subduction system extending from Sicily to northern Apennines, as confirmed by recently seismicity.

This tectonic setting with highly variable plate boundary events and body forces induced by topography results in an inhomogeneous stress pattern. Here we quantify the spatial changes of the wavelength of the stress pattern by a statistical analysis. As input data we use 600 data of SH records from the World Stress Map database release 2008 and about 100 new data records. The result of this statistical analysis is a mean orientation of the maximum horizontal compressional stress SH on a 0.1° grid and the maximum smoothing radius for which the standard deviation of the mean SH orientation is less than 25°. This latter is the wave-length of the stress pattern and reveals for Italy that the entire region has wave-length less than 200 km for Italy.

TECTONICS OF ITALY

The geological and structural setting of Italy is complex (Fig. 1). The area is involved in the N-S convergence of the Africa and Eurasia plates, which was established in Late Creataceous and is still ongoing even if more slowly (Dewey et al., 1973 and 1989; DeMets et al., 1994; Calais et al., 2003; Devoti et al., 2008). The present-day stress in Italy is characterized by a NE-SW extension perpendicular to the Apenninic fold and thrust belt (Anderson and Jackson, 1987; Westaway, 1992; Pondrelli et al., 1995; Amato and Montone, 1997), coeval with the opening of the Tyrrhenian basin (Late Tortonian; Patacca and Scandone, 1989).

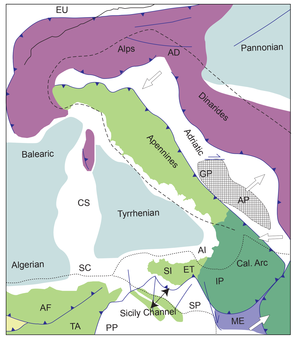


Figure 1

SC: Sardinia Channel; ME: Malta Escarpment; SI: Sicily; SP: Sicily Plate; IP: Ionian Plate; AI: Aeolian Islands; ET: Mount Etna; PP: Pelagian Plateau; CS: Corsica-Sardinia block; AP: Apulian block; GP: Gargano Promontory; AD: Adriatic plate; EU: Eurasian plate; AF: Africa plate; TA: Tunisian Atlas

THE ITALIAN STRESS DATABASE

The tectonic stress of Italy is inferred and well defined by borehole breakouts, earthquake focal mechanisms, overcoring and recent slip of faults (Fig. 2a). In addition to the dataset published by Heidbach et al., 2010, more than 100 stress data records have been added (Barba et al., 2010, Mariucci et al., 2010 and http://www.bo.ingv.it/RCMT/searchRCMT.html). The data density is high for all Italy, except for Sardinia island and southern Apulia region where little data are present (Fig. 2a). The earthquake mechanism solutions are most concentrated along the Apenninic belt and active tectonic regions (the far western and eastern part of the Alpine chain and along the subduction zone) while the borehole breakout records are located on correspondence with gas and/or oil reservoirs (particularly in the Po Plain, Adriatic and Sicilian off-shore areas, southern Apennninic foredeep and within of some intramountain basins). The active faults (Late Quaternary-Holocene) are located along the Apenninic belt and the overcoring data are mainly distributed on the Alpine belt, some in Sicily and in offshore Sicily.

From regions aforementioned, three regimes are still active. The normal faulting regime is inferred from focal mechanism solutions (Fig. 2b) and it is prevalent along the Apenninic belt and in the western part of Alps (Fig. 2a). On the contrary, the eastern part of the Alpine chain, the foredeep and foreland Apenninic belt and the northern part of Sicily are characterized by thrust faulting particularly from focal mechanism solutions but not only (Fig. 2a and b). In figure 2b, only 92 data show a strike-slip regime located close to Ancona town and to south-eastern part of Italy (Molise-Apulia area; Fig. 2a).

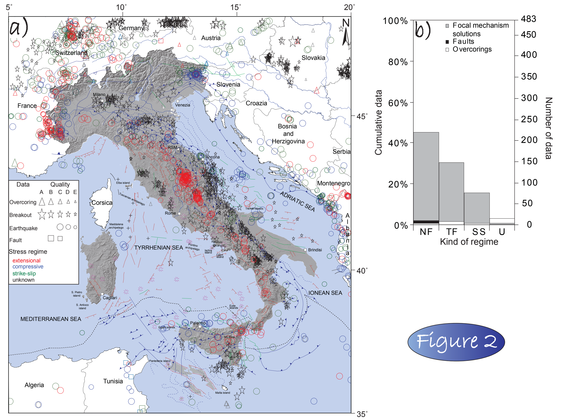


Figure 2

SMOOTHING METHOD

A lot of smoothing methods exist to understand which principal stress pattern governs in the area, to remove the local perturbations and to predict a stress field orientations also in the regions which lack data records (Hansen and Mount, 1990; Coblentz et al., 1998; Bird et al., 2006; Müller et al., 1997; Tingay et al., 2005, 2006; Heidbach et al., 2010). In this paper the authors apply the Heidbach et al.'s smoothing method (2010) which is an improvement of Müller et al., 1997 method. It consists of two steps:

I Step

Setting:
- 0.2 regular grid
- weight factor to each data quality:
  A= 1/15; B=1/20 and C=1/25
- srad_range (e.g. 50 to 1000 km)
- dist_weight _threshold: 10

Result:
- mean SH orientation
- variance of the mean SH orientation
- number of the four quadrants of the search circle
- mean distance of these data records to the grid point

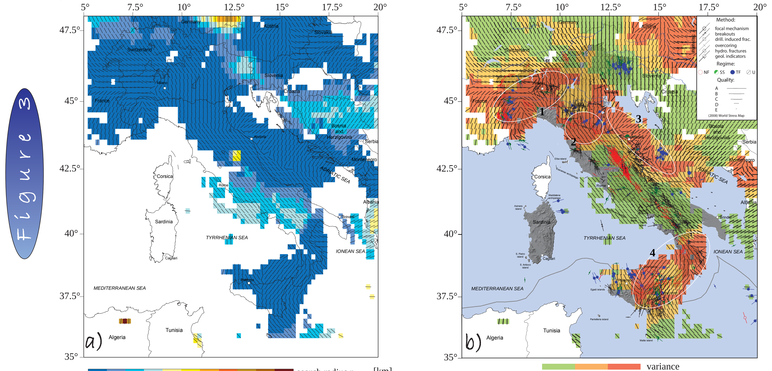
II Step

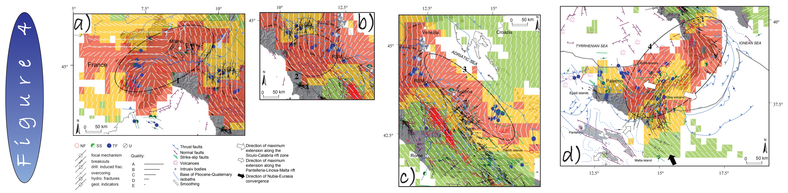
Setting:
- data number threshold (=10);
- variance threshold (≤ 25°)
- rad_min= the smallest search radius (=50km or 100km).
- dr_max= maximum ratio of mean distance and search radius (=1.0)

Result:
- mean SH orientation
- wave-length of the stress pattern in terms of maximum search radius

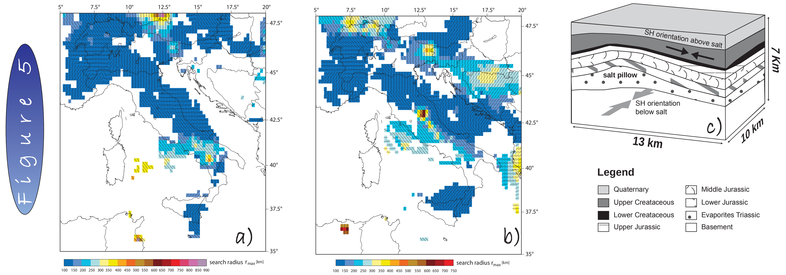
SMOOTHING MAPS

The result of the smoothing analysis (black bars) is shown in the figure 3a. The SH orientations and color-code r_{max} values are displayed. The blue and yellow colors indicate that the area is characterized by a stress pattern from regional to local wave-lenght (r_{max}<400km) while the orange-brown colors indicate a regional stress pattern (r_{max}>400km). The figure 3b represents the variance of the single SH orientations. The area with lowest variance (green color) is located along the Apennines belt while the high values (red color) are present in four zones. The high variance is probably due to the complex tectonic setting of these areas (Fig. 4a,b,c,d). The Figures 4a-d show the correlation among the smoothing value of SHmax orientation, contemporary stress data records and tectonics.



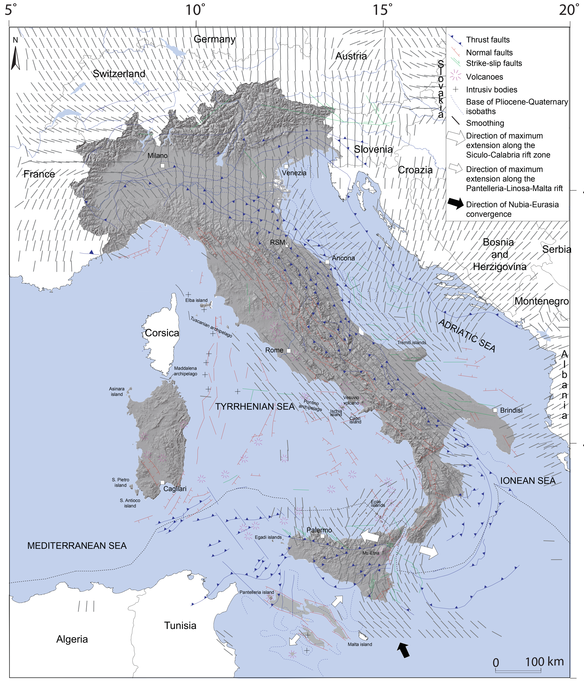


The database has been split in two subsets: I) breakouts, faults and overcorings (Fig. 5a) and II) focal mechanism solutions (Fig. 5b). The smoothing map of shallower data reflects the local trend (low wave-lenght= blue color) but the smoothing map of focal mechanism solutions shows some area with a higher wave-length (orange to red shade colors). This result might be explained by an upper part of crust mostly influenced by accommodation of sedimentary layers and by local perturbation (e.g. topography effect) than the underlying strata. The shallower block is controlled by the skin tectonics while deeper one by force of plate tectonics (Fig. 5c).



DISCUSSION

The smoothed SH orientation shows a trend that reflects the structural setting in the study area (Fig. 6). The mean SH orientation is well constrained along the Apenninic belt (NW-SE) and its orientation corresponds with one of the normal active faults. The eastern part of the Alpine arc with a NNW-SSE-orientation of SH due to the active thrusts in this area. The compression has moved from Dinarides to the Friuli and Southalpine, as deduced from focal mechanism of the major events (Slejko et al., 1999; Bressan et al., 2003; Perniola et al., 2004; Viganò et al., 2008). The western part of the Alps shows a less defined distribution of the SH orientation with rotations, probably related to the bent of the thrusts (active in the outboard of the thrusts) and to the coexistence of a widespread extension in the core of the western Alps revealed by earthquake analysis (Sue et al., 1999).



The present-day stress data records of the Po Plain and the Emilia-Romagna arc exhibit a constant NE-SW compression regime with small rotations of the SH caused by local structural features (Montone and Mariucci, 1999; Pierdominici et al., 2005; Carminati et al., 2010; Carminati and Vadacca, 2010). The present-day stress data records of the Calabrian arc and of Sicily area are more scattered, underlying the tectonic complexity of the region. Indeed, the rotations of the compressional axis are due to the presence of active structural faults (e.g. the SH orientated WNW-ESE in the Hyblean region in agreement with tectonic structures) and rift zones (Eolian islands and Mt. Etna volcano; Catalano et al., 2010).

REFERENCES

Amato and Montone, 1997 - Geophys. J. Int., 130, 519-534; *Anderson and Jackson, 1987* - Geophys. J.R. Astron. Soc., 91, 937-987
Barba et al., 2010 - Tectonophysics, 482 (1-4), 193-204; *Bird et al., 2006* - J. Geophys. Res., 111 (B08402), doi:10.1029/2005JB003882
Bressan et al., 2003 - Bull. Seism. Soc. Am., 93, 1280-1297; *Calais et al., 2003* - Earth Plan. Sci. Lett., 216, 8–92
Carminati and Vadacca, 2010 - JGR, doi:10.1029/2010JB007870 in press; *Carminati et al., 2010* - JGR, 115, B02401, doi:10.1029/2009JB006395
Catalano et al., 2010 - Tectonophysics, 486, 1-14; *Coblentz et al., 1998* - J. Geophys. Res., 103 (B1), 919–931
DeMets et al., 1994 - Geophys. Res. Lett., 21, 2191–2194; *Devoti et al., 2008* - Earth Plan. Sci. Lett., 273, 163–174
Dewey et al., 1973 - Bull. Soc. Am. Bull., 84, 3137–3180; *Dewey et al., 1989* - Alpine Tectonics, 45, 265–283
Heidbach et al., 2010 - Tectonophysics, 482, 3-15; *Hansen and Mount, 1990* - J. Geophys. Res., 95 (B2), 1155–1165
http://www.bo.ingv.it/RCMT/searchRCMT.html; *Mariucci et al., 2010* - Geophys. J. Int., 182, 1096-1102
Montone and Mariucci, 1999 - J. Geodynamics, 28, 251-265; *Montone et al., 2004* - J. Geophys. Res., 109, doi:10.1029/2003JB002703
Müller et al., 1997 - Tectonophysics 275, 199–219; *Patacca and Scandone, 1989* - Accad. Naz. dei Lincei, pp. 157-176, Rome, Italy
Perniola et al., 2004 - Geophys. J. Int. 156, 297–306; *Pierdominici et al., 2005* - Annals of Geophysics, 48 (6), 867-881
Pondrelli et al., 1995 - Geophys. J. Int., 122, 938-952; *Slejko et al., 1999* - Bull. seism. Soc. Am., 89, 1037–1052
Sue et al., 1999 - J. Geophys. Res., 104, 811, 25611-25622 ; *Tingay et al., 2005* - Lead. Edge, 24 (12), 1276–1282
Viganò et al., 2008 - Tectonophysics, 460, 106/115; *Westaway, 1992* - J. Geophys. Res., 97, 15437-15464