LOCAL VERSUS REGIONAL ACTIVE STRESS FIELD IN 5900m SAN GREGORIO MAGNO 1WELL (SOUTHERN APENNINES, ITALY)

EGU2009-2494

Istituto Nazionale di Geofisica e Vulcanologia (Italy)

Simona Pierdominici, Paola Montone and Maria Teresa Mariucci
Istituto Nazionale di Geofisica e Vulcanologia, Rome - Italy
montone@ingv.it

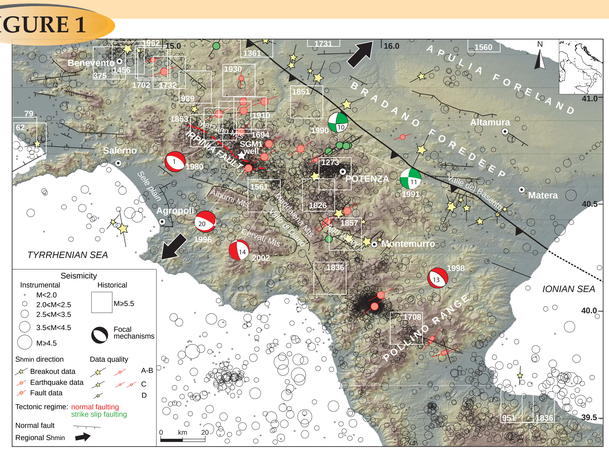
European Geosciences Union
19.-24. April 2009, Vienna, Austria

INTRODUCTION

The southern Apennines are a NE-verging fold-and-thrust belt, which formed from late Oligocene to Pleistocene times in response to deformation processes induced by the convergence between the African and European plates. The post-collisional phase includes the early Pleistocene development of strike-slip faults, responsible of lateral variations and of the segmentation of the belt. The last tectonic phase that affected the belt is relative to an extensional regime characterized by NW-SE faults and is still acting.
Present-day stress state can be assessed by different techniques, such as borehole breakouts, focal mechanism solutions, active faults, hydrofracturing, overcoring, crustal deformation and differential strain.

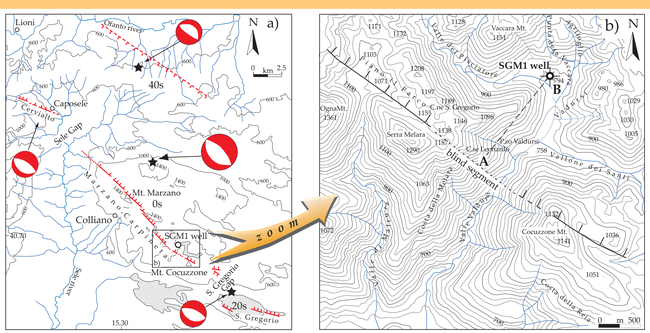
Our goals are **to compare the local versus regional active stress** in Irpinia region and **to identify active shear zones** along a deep well using borehole breakout and downhole log data. The selected area is characterized by diffuse low magnitude seismicity, although in historical times it was repeatedly struck by moderate to large earthquakes. On 23rd November 1980 a strong earthquake (M=6.9) occurred in this area producing the first unequivocal historical surface faulting ever documented in Italy. The mainshock enucleated on a 38 km-long normal fault, 308° striking and 60°-70° northeast-dipping, named Irpinia fault. The surface trace of this fault is very close to the San Gregorio Magno 1 deep oil well which should cross it approximately within an interval depth of 1500m.
To discriminate the presence of the Irpinia fault and other possible active shear zones and to define the present-day stress along San Gregorio Magno 1 well, we have analyzed in detail borehole breakout and downhole geophysical data. Our analysis of stress-induced wellbore breakouts shows **a direction of minimum horizontal stress N18°±24°**, quite consistent to the regional Shmin trend (N44°±20°). Although some breakout zones with a different trend from the regional one have been identified, these have been related to slip on nearby faults. Comparing the breakout rotations with the downhole logs **we have defined two most probable intervals where the Irpinia fault crosses the borehole around the depth of 2300 and 3800m**. We conclude by considering the more general implications of our data for this area considered one of the regions with the highest probability (25%) of occurrence of an earthquake (M>5.5) for the next 10 years.

FIGURE 1



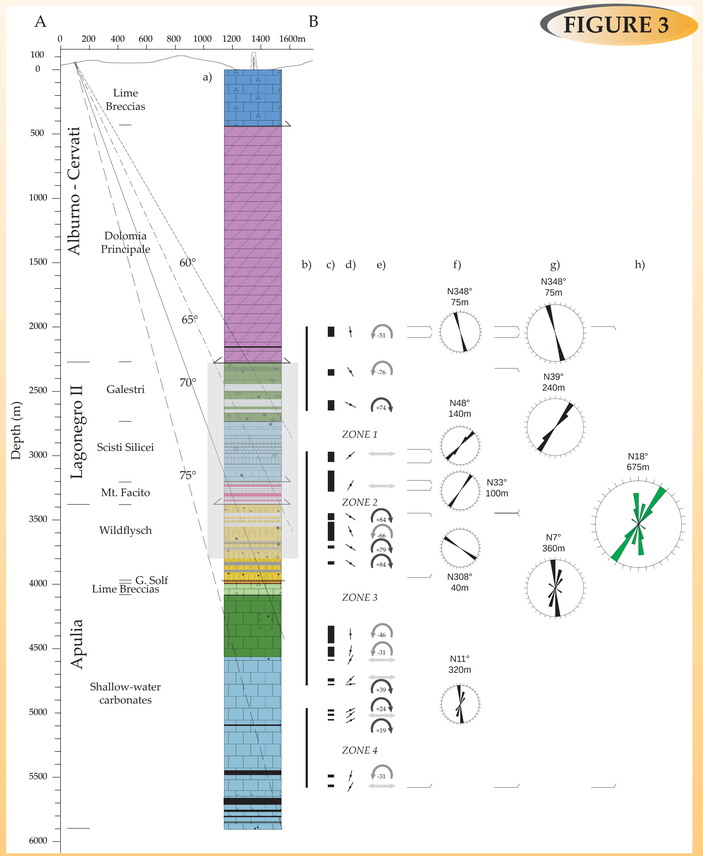
Active Stress Field
The active stress field in this area shows a **NE-SW T-axes with prevalent normal faulting focal mechanisms** and also inferred **from geological-structural analysis and borehole breakout data**.

FIGURE 2



The 1980 M6.9 Irpinia Earthquake
The Irpinia earthquake occurred on November 23, 1980 (M=6.9), enucleated at a depth of 10-12 km with a focal mechanism characterized by NW-SE normal faulting planes. This earthquake consists of three subevents, at 0s (the mainshock), at ~20s and ~40s from the mainshock. **The Irpinia fault is N308° striking, 60-70° northeast-dipping with an average value of normal slip of 61cm along the fault with a total vertical throw of about 300m during the Pleistocene**. The first shock (at 0 sec) is associated both to the Marzano-Carpineta segment and to the Cervialto scarp (~8-10 km long) and the second one at 20s on San Gregorio Magno scarp along a 8km segment. Considering only seismological data, the last event (40s) is supposed to be located on an antithetic branch fault SW-dipping in front of the Cervialto and Marzano-Carpineta structures; any surface rupture evidence does not exist for this event.

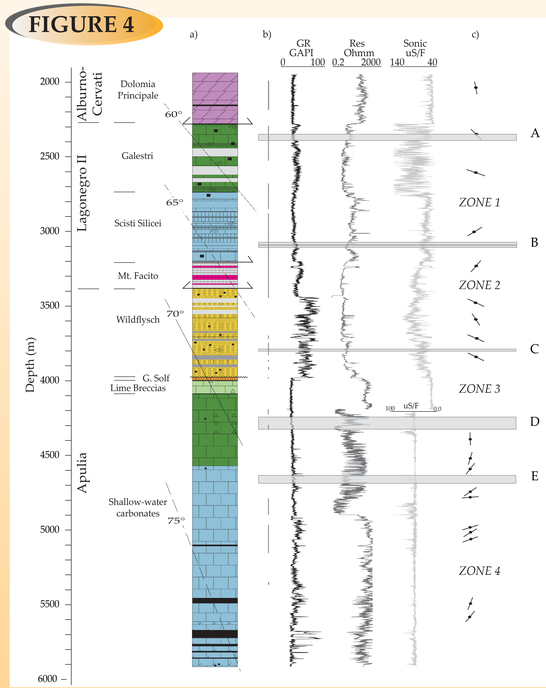
FIGURE 3



The Irpinia Fault
The SGM1 well was drilled at 797m elevation down to a depth of 5900m and located near the Marzano-Carpineta fault scarps. **The well is located eastward of the Irpinia fault (1.3km from the surface rupture of the fault) and the borehole should intersect it in an interval between 2300-3800m according to its geometry.** The fault has not been well recognized either on stratigraphic log or on seismic profiles probably because of the youngness of the fault that has not yet developed mature geomorphological features to be detected at depth. For this reason we have used different methods to identify the possible active shear zones and the Irpinia fault by breakout and downhole logs (Figure 3 and 4).

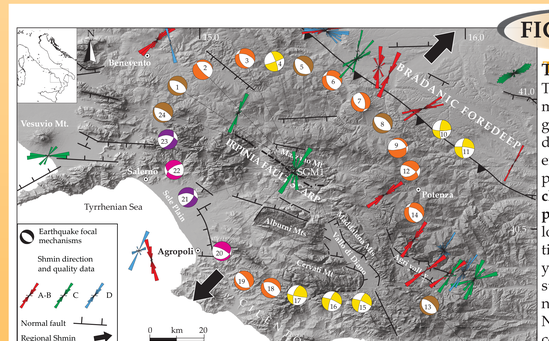
Borehole Breakout Analysis
Breakouts are used as indicators of the direction of maximum and minimum horizontal stress (SHmax and Shmin, respectively) and they are shear failures of the borehole wall that form when the compressive stress exceeds the rock strength. The breakout analysis of SGM1 well was performed by four-arm caliper log from 1200m to 5900m depth. **The result shows a cumulative breakout length of 675m with an average Shmin orientation of N18° and a standard deviation of 24°** (Figure 3h), **with a quality C**.
To understand the scattering of breakout data, a more detailed breakout analysis was performed for each lithological and tectonic unit (Figure 3f,g).
With the purpose of identifying the Irpinia fault, a comparison between the stress field along the well and the regional stress orientation has been done. Any deviation from the regional value has been considered as a local rotation of stress field if the breakout orientation deviates from the regional one more than 15° and is shown as clockwise or anticlockwise rotation (Figure 3e). When the breakout trend abruptly changes from the next one (Figure 3d) it is possible to identify faults and/or fracture zones. We observe the following depth intervals that separate zones with different breakout directions (Figure 3): from 2650m to 2950m (**zone 1**), 3275m to 3450m (**zone 2**), 3855m to 4320m (**zone 3**), and 5057m to 5460m (**zone 4**). Three of the anomalous zones (zone 1, 2 and 3) are located around the area where the Irpinia fault is supposed to cross the well, in fact according to the most Authors the Irpinia fault has a dip between 60° to 70°, that correspond to a depth approximately between 2300m to 3800m (Figure 3).

FIGURE 4



Downhole Logs
We analyzed three downhole curves (Figure 4) and we have discarded all the anomalous trends corresponding to variations in lithology within the same unit. The remaining sectors showing anomalies are located at the following depth (Figure 5): around 2350m (**sector A**), around 3100m (**sector B**) with two small areas, around 3800m (**sector C**), around 4300m (**sector D**) and around 4700m (**sector E**). Considering the Irpinia fault geometry (60°-70° dipping) we can exclude the two deeper sectors (D and E).
The **sector A** shows a decreasing sonic curve with respect to its mean value.
The **sector B** has two small zones showing anomalous picks in all the curves (a decreasing in gamma ray and sonic logs and an increasing in resistivity.
The **sector C** has a well defined pick showing an increasing in the sonic curve and a decreasing in the resistivity curve trend.
The location of abrupt breakout rotations indicates the presence of active shear zones then for this reason we can suppose the Irpinia fault to be located around 2350m (sector A) or around 3800m (sector C). In both zones we have more confident data revealing not only abrupt breakout rotations (~NW-SE oriented) but also washout presence, geophysical log anomalies not directly connected to the lithology, consistency with the fault dip deduced from focal mechanisms and surficial data.

FIGURE 5



The Irpinia Active Stress Field
The SGM1 breakouts are shown as rose diagram with two main directions which are representative both of the regional and the local tectonic. Concerning the seismological data, in the Irpinia area a lot of earthquake focal solutions exhibit both normal faulting and strike slip mechanisms. In particular **the focal mechanism solutions closer to the well clearly show T-axis ~N-S oriented with a strike-slip component on ~E-W nodal planes** (solutions from 20 to 23). Colours correspond to different types of focal mechanism solutions: brown: normal faulting with NE–SW extension; yellow: strike-slip faulting; orange: normal faulting with strike slip component and NE–SW to E–W extension; pink: normal faulting with strike slip component and N-S to NNE-SSW extension; violet: normal faulting with strike slip component and NW-SE extension.

Discussion and Conclusions

Borehole breakouts in SGM1 well point out significant local variations in the direction of the minimum horizontal stress. We hypothesize that the localized stress rotations probably result from slip on nearby faults and are indicative of active deformation in the crust. Also the geophysical logs collected from a depth of 2000 to 5900m show significantly anomalous physical properties interpreted to be in correspondence of two major active shear zones. These two major active shear zones were intersected by the borehole **at 2350m (sector A) and around 3800m (sector C)**, depths in which we suppose Irpinia fault to be located. The derived Shmin (N18°±24°) direction is not exactly at 90° with respect to the N308° Irpinia fault mean direction, but it is quite consistent to the zig-zagging trend of the fault and to the local tectonic structures displaying ~E-W directions.

Acknowledgement

We gratefully acknowledge ENI S.p.A. for the San Gregorio Magno 1 well records. This work was partially funded by the Italian Ministry of University and Research (Project FIRB "Research and Development of New Technologies for Protection and Defense of Territory from Natural Risks", W.P. C3 "Crustal Imaging in Italy").