Multidisciplinary study of post – seismic deformation for the April 6, 2009, L'Aquila earthquake

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The 6 april 2009 L'Aquila seismic event produced coseismic surface ruptures and vertical motion of the ground along the Paganica Fault, already mapped in the Sheet L'Aquila of the CARG project (Servizio Geologico d'Italia, 2006), and also recorded more than 10 years ago in the ITHACA database, the inventory of Italian capable faults (Vittori et al., 1998).
These deformations have been amplified in the days and weeks after the earthquake; in particular, post-seismic slip along the coseismic surface ruptures increased by 1.8 cm about 119 day after the main shock near the water pipeline broken by the Paganica fault (Fig. 1).

Fig. 1: Post-seismic evolution of strain-meter and optical leveling measurements collected by the Provincia di Trento Team across the Paganica ruptures

The seismic sequence is still going on in October 2009, also with events above 4 Mw in the epicentral area, and presumably is still deforming the ground.
In order to analyze the relationship between coseismic deformations documented in the days after the main shock (EMERGEO working group, 2009; ISPRA, 2009;) and the long term post-seismic deformations, we conducted a set of monitoring activities and field investigation, at different time and space resolution, on the Paganica fault and the adjacent faults (Fig. 2):

1) LIDAR survey on five sites along the surface ruptures of the Paganica fault (UK LiDAR Group);
2) Robotic total station survey at the site where the Paganica water pipeline ruptured coseismically (CNR IRPI - Torino);
3) Strain meter survey and high-precision optical leveling along the nearby segment of the rupture (Provincia di Trento; http://www.protezionecivile.tn.it/frame.asp?Site=6&Area=2);
4) GPS survey on the San Demetrio ne' Vestini and the Pettino Fault (CNR IRPI - Torino).
5) GPR survey on the Paganica fault (in the same sites where the LIDAR survey has been performed) in order to link the surface ruptures to the shallow structure of the fault (UCL *Birkbeck*; University of Insubria).

Fig. 2: Location area of the monitored sites and indication of the monitoring techniques

The amplitude, wavelength and timescales associated with post-seismic deformation can help to constrain the seismic cycle and the mechanics of continental deformation as they

can reveal whether motions are driven by fluid and poro-elastic effects, visco-elastic creep in the underlying crust and mantle, or after-slip on fault zones within the shallow crust, or a combination of the above. They can also help discriminate between the relative contributions of coseismic and post-seismic slip for historic/palaeoseismic earthquake ruptures, where measurements of offset were made many years after the earthquake.
We provide here some preliminary results of the surveys, which will continue until the complete end of the deformation.
Through our collaboration with Durham University[4] & others[3&5], the still developing interpretation of data from a lidar survey at one of the five sites along the Paganica rupture show approximately 2 cm post-seismic throw across the rupture and about 2.5 cm of post-seismic extension in the 124 days since the main event (McCaffrey et al., 2009). The 2 cm throw on the rupture is accompanied by 3 cm subsidence in the hangingwall, some of which may be co-seismic, associated with syncline development.
GPS shows a length change of 15 mm until the 29th of August across the rupture between stations CAMP and ACQU, situated ca. 1km apart; No significant length change was detected further away from the rupture. The combined strain meter, leveling and LIDAR data, account for the whole 15 mm of post-seismic extension within hundreds of metres of the rupture trace. So, the post-seismic deformation appears to be confined within a modest distance from the fault trace.
These issues will be addressed in the future of this research:
Is the post-seismic deformation controlled by shallow creep in the fault zone?
Is the post-seismic slip working to alleviate the slip-deficit close to the surface, considering that modelling of InSAR data suggests that slip during the mainshock was mostly confined at depth (Atzori et al., 2009; Walters et al., 2009)?

References

Atzori S., I. Hunstad, M. Chini, S. Salvi, C. Tolomei, C. Bignami, S. Stramondo, E. Trasatti, A., Antonioli, E. Boschi, 2009: Finite fault inversion of DInSAR coseismic displacement of the 2009 L'Aquila earthquake (central Italy), Geophys. Res. Lett., 36, L15305, doi:10.1029/2009GL039293.

EMERGEO Working Group, 2009: Rilievi geologici nell'area epicentrale della sequenza sismica dell'Aquilano del 6 aprile 2009. Quaderni di Geofisica, 70.

ISPRA, (Blumetti A.M., Comerci V., Di Manna P., Guerrieri L., Vittori E.) 2009: Geological effects induced by the L'Aquila earthquake (6 april 2009, ml = 5.8) on the natural environment. Preliminary report. 38 pp. www.ispra.gov.it

McCaffrey K., Wilkinson M, Roberts G., Cowie P., Phillips R., Wright T., Barba S., La Rocca L., Vittori E., Blumetti A. M., Guerrieri L., Guzzetti F., Lollino G., Porfido S., Esposito E., Piccardi L., Campedel P., Cocco S., Sileo G., Michetti A. M. 2009: A LiDAR and field study of post-seismic slip for the 6th April 2009 L'Aquila Earthquake (Mw 6.3). VII forum Italian di Scienze della Terra, Rimini, 9 – 11 Settembre 2009

Michetti A.M., Esposito E., Guerrieri L., Porfido S., Serva L., Tatevossian R., Vittori E., Audemard F., Azuma T., Clague J., Comerci V., Gurpinar A., Mc Calpin J., Mohammadioun B., Morner N.A., Ota Y. & Roghozin E. 2007: Intensity Scale ESI 2007. In. Guerrieri L. & Vittori E. (Eds.): *Memorie Descrittive Carta Geologica. d'Italia.,* vol. 74, Servizio Geologico d'Italia – Dipartimento Difesa del Suolo, APAT, Roma, 53 pp

Servizio Geologico d’Italia, 2006: Foglio 359 L’Aquila, scala 1:50.000, SELCA Firenze.

Vittori E., Maschio L., Ferreli L., Michetti A.M., & Serva L., 1998: Carta e base di dati delle faglie capaci per l'Italia centro-meridionale: presentazione e stato di avanzamento del progetto ITHACA. Il Quaternario 10 (2), 305-312.

Walters R. J., J. R. Elliott, N. D'Agostino, P. C. England, I. Hunstad, J. A. Jackson, B. Parsons, R. J. Phillips, G. Roberts, 2009: The 2009 L'Aquila earthquake (central Italy): A source mechanism and implications for seismic hazard, Geophys. Res. Lett., 36, L17312, doi:10.1029/2009GL039337.