Evidences of possible reservoir-induced seismicity by the Pertusillo artificial lake (Southern Italy): preliminary results and ongoing activities

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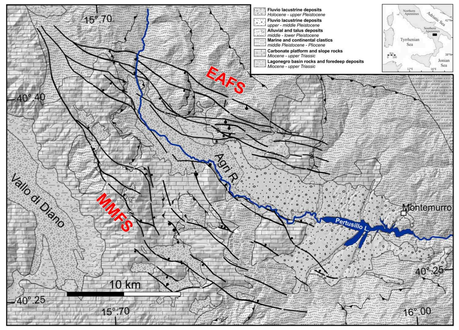
The reservoir-induced seismicity by filling artificial lakes has been observed over the last 60 years in several regions of the Earth. The presence of water reservoirs in regions with high seismogenic potential, such as the Pertusillo artificial lake in Agri Valley (Southern Italy), can modify the occurrence of earthquakes and influence the seismic hazard of the area. In particular, the Pertusillo lake is a relatively large water reservoir with a capacity of 1.5×10^8 m^3, maintained by a 95 m high concrete dam that was constructed in the Agri River from 1956 to 1962. In this study, we compare the reservoir filling history over the last 30 years with the correspondent spatio-temporal pattern of the observed small to moderate earthquakes (Ml ≤ 3.2), to interpret possible correlations that could point-out an induced seismicity by the Pertusillo artificial lake. Preliminary results are discussed and ongoing activities in the area of study are presented. This study is funded by the project "Study of the Local Seismicity" at the Val d'Agri Environmental Observatory (Southern Italy), under the agreement between the Basilicata Region and the Italian National Research Council – Institute of Methodologies for Environmental Analysis (CNR-IMAA).

Seismotectonic framework



The Val d'Agri is a NW-SE trending intermontane basin formed during the Quaternary times along the axial zone of the Southern Apennines thrust belt chain. This basin is about 30 Km long and 12 Km wide and is filled by Quaternary continental deposits which cover down-thrown pre-Quaternary rocks of the Apennines chain. Pre-Quaternary rock assemblages are constituted by Mesozoic-Cenozoic shallow-water and slope carbonates (Monte Marzano – Monti della Maddalena Unit) thrust on coeval pelagic successions (Lagonegro Units) and their Miocene synorogenic cover. The Quaternary deposits, which filled the basin, are essentially Lower-Middle Pleistocene talus breccia, Middle-Upper Pleistocene alluvial-lacustrine sediments and Upper Pleistocene-Holocene alluvial deposits.

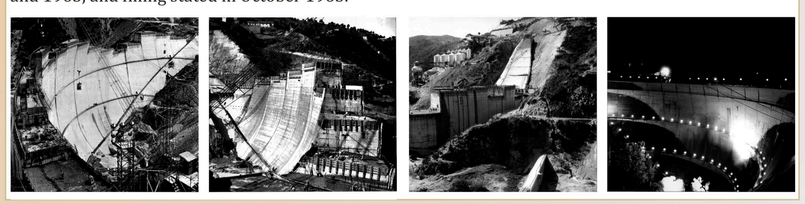
Brittle tectonics has strongly controlled the formation and evolution of the Val d'Agri basin up to the present. The Agri Valley was hit by the M 7.0, 1857 Basilicata earthquake (Branno et al., 1985), whose macroseismic field covered a wide sector of the Southern Apennines chain. So far, conflicting seismogenic models for the Val d'Agri area are discussed in the recent literature. Altogether there are two different hypothesis about seismogenic fault systems in the basin:

1) the Eastern Agri Fault System (EAFS) - NW-trending, SW-dipping normal-fault system bounding the eastern side of basin (Benedetti et al., 1998).

2) the Monti della Maddalena Fault System (MMFS) - NW-trending, NE-dipping normal-fault system cross-cutting the mountain range to the west (Maschio et al., 2005).

The Pertusillo dam

The Pertusillo dam is located on the Agri River, approximately 2 km south of the village of Montemurro, Basilicata Region, Southern Italy. The Pertusillo reservoir is prevalently located on the Miocene sedimentary rocks of the Gorgoglione Flysch. The dam principally generates power and supplies irrigation needs. The dam is an concrete arch-gravity dam enjoying 95 m high from the river bed. The crest length is 380 m, and the width on the foundation is about 40 m. The volume of the reservoir at maximum operation level of about 532 m a.s.l. is 155 million cubic meters, and the length of the lake at maximum operational level is about 8.500 m. The dam was constructed between 1957 and 1963, and filling stated in October 1963.



References:

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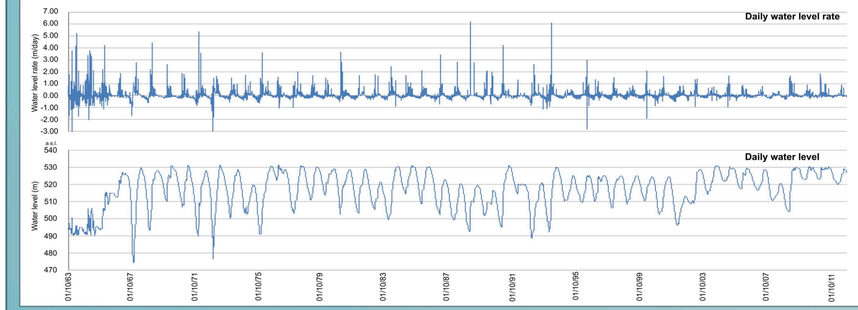
Branno A., E.G.I. Esposito, A. Maturano, S. Porfido and V. Rinaldis (1985): Studio, su base macrosismica, del terremoto della Basilicata del 16 dicembre 1857. Bollettino della Società dei Naturalisti di Napoli, 1985, 92, 249–338.

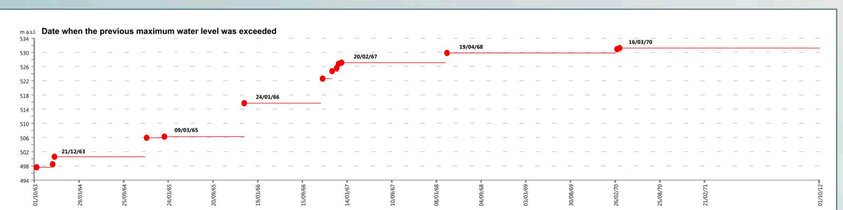
Maschio L., L. Ferranti and P. Burrato (2005): Active extension in Val d'Agri area, Southern Apennines, Italy: implications for the geometry of the seismogenic belt. Geophys. J. Int., 162 (2), 591–609

Valoroso L., L. Improta, L. Chiaraluce, R. Di Stefano, L. Ferranti, A. Govoni and C. Chiarabba (2009): Active faults and induced seismicity in the Val d'Agri region (southern Apennines, Italy), Geophys. J. Int., 178, 488–502

Data of the Pertusillo artificial lake

The water level of the Pertusillo reservoir has been monitored from the initial filling. The figures shows the temporal distribution of same factors like the exceedance of lake levels over previous maximum, the daily variation of water level and the rate of water-level change in the reservoir.



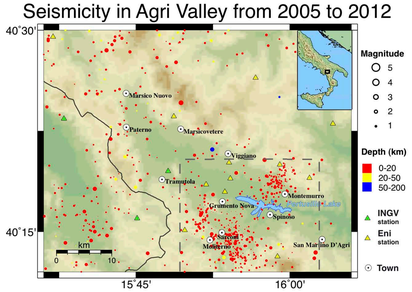


The highest water level was reached on March 16, 1970. In particular, in the figure above we show those time when the previous maximum water levels are exceeded (solid red dots), and the durations when they are not (red horizontal lines). The figure on the left shows the daily variation of water level from the initial filling to June, 2012. From this figure, it is clear that the water-level variations in the reservoir show the annual cycle of loading and unloading. In addition, the figure highlights the daily water-level rate in the reservoir. The maximum daily filling rate was 6.21 m/day during November 22, 1988 with an increment of water volume of 6.7 million cubic meters. All the reservoir data have been provided by "*Ente per lo Sviluppo dell'Irrigazione e la Trasformazione Fondiaria*" of Potenza, Italy.

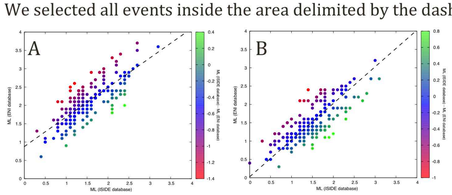
Microseismicity around the Pertusillo reservoir

We analyzed the seismicity recorded in Agri Valley by two different seismic networks from 2005 to 2012. The first one is the Italian National Institute of Geophysics and Volcanology (INGV) network, and the second one is a local seismic network owned by ENI S.p.A.

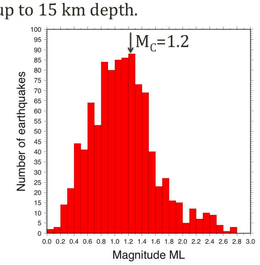
It is possible to observe that the majority of the recorded seismicity is concentrated near the Pertusillo lake, as indicated by the dashed box in the figure. This was also observed by Valoroso et al. (2009) during a 13-months-long seismic experiment, and the authors suggested that this seismicity is reservoir-induced.



We selected all events inside the area delimited by the dashed box, up to 15 km depth.



We compared magnitudes estimated by INGV (ISIDE catalogue, http://iside.rm.ingv.it) and by ENI for earthquakes reported in both the catalogue, noting a magnitude overestimation in the ENI catalogue (panel A) and a linear correlation between catalogues. We corrected the overestimation (panel B) by a linear regression.

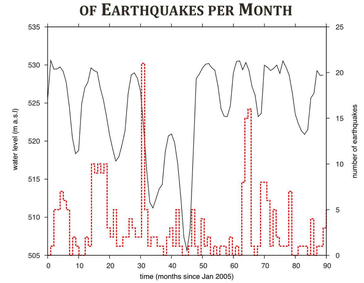


The histogram shows the number of events for different classes of magnitude. The completeness magnitude (M_C) is also reported.

Number of events (initial dataset)	Magnitude range	Completeness magnitude (M_C)	Events with ML > M_C (final dataset)
739	0.2 ≤ ML ≤ 2.7	1.2	402

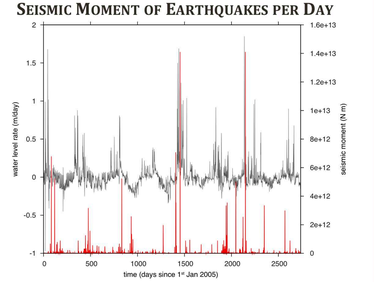
Preliminary results and ongoing activities

Maximum Monthly Water Level Vs Number of Earthquakes per Month



Comparison between the water level (black line) and the number of earthquakes per month (red dashed bars). The seismicity drastically reduces in correspondence of the water level minima, and in particular when the water levels were kept low for a long time. Moreover, it is possible to observe higher seismicity at the beginning of the annual emptying phase of the reservoir.

Daily Water Level Rate Vs Cumulative Seismic Moment of Earthquakes per Day



Comparison between the daily water level rate (black line) and the cumulative seismic moment of earthquakes per day (red line). A rapid impoundment of the reservoir (water level rate ~ 0.5 m/day) is followed by earthquakes with higher seismic moment within maximum 40 days.

Ongoing and future activities

Research
- High resolution relative location of seismicity
- Focal mechanisms and source parameters
- Relationship between fault systems and reservoir-induced seismicity
- Characterization of the Pertusillo reservoir
- Statistical analysis on acquired data

Technological improvement
- Additional seismic stations
- Continuous seismic and electromagnetic data
- New geophysical sensors

Quantitative analysis of the reservoir-induced seismicity