GNGTS

Gruppo Nazionale di Geofisica della Terra Solida

BOOK OF ABSTRACTS
41st NATIONAL CONFERENCE

7-9 FEBRUARY 2023

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Sperimentale

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EUROPEAN ASSOCIATION OF GEOSCIENTISTS & ENGINEERS

SEG
SOCIETY OF EXPLORATION GEOPHYSICISTS

SEZIONE ITALIANA
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DOI: 10.13120/2tf2-1j75

Session 1.1

Recent advances in the study of earthquakes, seismogenic structures and capable faults

The hydrogeological response of the Sibillini Mts. carbonate aquifer to the M_w 6.5 Norcia earthquake: conceptual model and numerical analysis

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Introduction

Because of their complex architecture and in relation to the variability of physical parameters and geological factors, it is notoriously difficult to adequately characterize the hydrologic behavior of fault zones within the Earth's crust. The estimation of the hydraulic properties of fault zones remains a challenge and the lack of data, related to the inability to obtain direct measurements especially in depth, represents an important gap in hydrogeological modeling. Fault zones can generally act as hydraulic conduits, barriers, or combined conduit-barrier systems, depending on the different relative permeability between fault core and damage zone and as a function of the stress and strain conditions (Caine *et al*., 1996; Bense *et al*., 2013).

Since the Earth's crust can be considered a biphasic medium, consisting of a solid skeleton and voids filled with fluids (Fyfe, 2012; Albano *et al*., 2019) with a poroelastic behavior (Biot, 1941; Wang, 2000; Albano *et al.*, 2019), the stress variations induced by a seismogenic fault rupture can change the hydrologic properties of the crustal rocks; thus changes in rock permeability and fluid mobility are expected following an earthquake (Manga *et al*., 2012; Manga & Wang, 2015).

A general increase in bulk permeability occurs after an earthquake, due to several mechanisms related to the dynamic stress caused by the seismic waves propagation, which include the fracture cleaning effect induced by the pore pressure increase. The "aquifer fault rupture" is a further interpretative mechanism to explain the aquifer response to earthquakes (Manga *et al*., 2012; Manga & Wang, 2015; Mastrorillo *et al*., 2020; Saroli *et al*., 2022): the seismogenic fault rupture creates a new flow section to favor a groundwater transfer through the fault. This involves a variation of the hydraulic gradient and of groundwater divide in hydrogeological systems.

The 2016 Central Italy seismic sequence, which resulted from the rupture of different segments of the Vettore-Bove normal fault system, caused an important hydrogeological imbalance of the carbonate aquifers of the Sibillini Mts. Sustained variation in groundwater flow occurred especially after the M_w 6.5, 30 October main shock which struck Norcia town, the most important of which include: i) a general increase in discharge at the springs bordering the western side of the Sibillini Mts. and along the main drainage system of the Nera River basin; ii) the reappearance of Torbidone spring in the Norcia plain, dry since 1979 (Valigi *et al*., 2019; Petitta *et al*., 2018); iii) a strong discharge reduction and water-table decrease at the springs located on the eastern side of the Sibillini Mts., such as to cause several problems with regard to the water supply system for the Marche region. According to Mastrorillo *et al*. (2020), the “aquifer fault rupture” mechanism better explain the observed permanent variations, suggesting an eastward shift of the piezometric divide of Vettore Mt. The purpose of this work is to assess the hydrodynamic response of the fractured carbonate aquifer system of the Sibillini Mts. to the coseismic dislocation of Vettore fault, through the realization of 2D and 3D numerical models. We collected geological and hydrogeological data from the available literature to create a geomechanical model of the seismogenic fault rupture and a hydrogeological model to simulate the groundwater flow before and after the 30 October earthquake.

Preliminary results

We first defined a hydrogeological conceptual model, which represents the supporting structure of numerical analysis. We created a simplified 3D geometric model at surface scale (up to 2 km depth) to define the spatial relations between the main tectonic structures and the boundaries of the hydrogeological complexes (Fig.1).

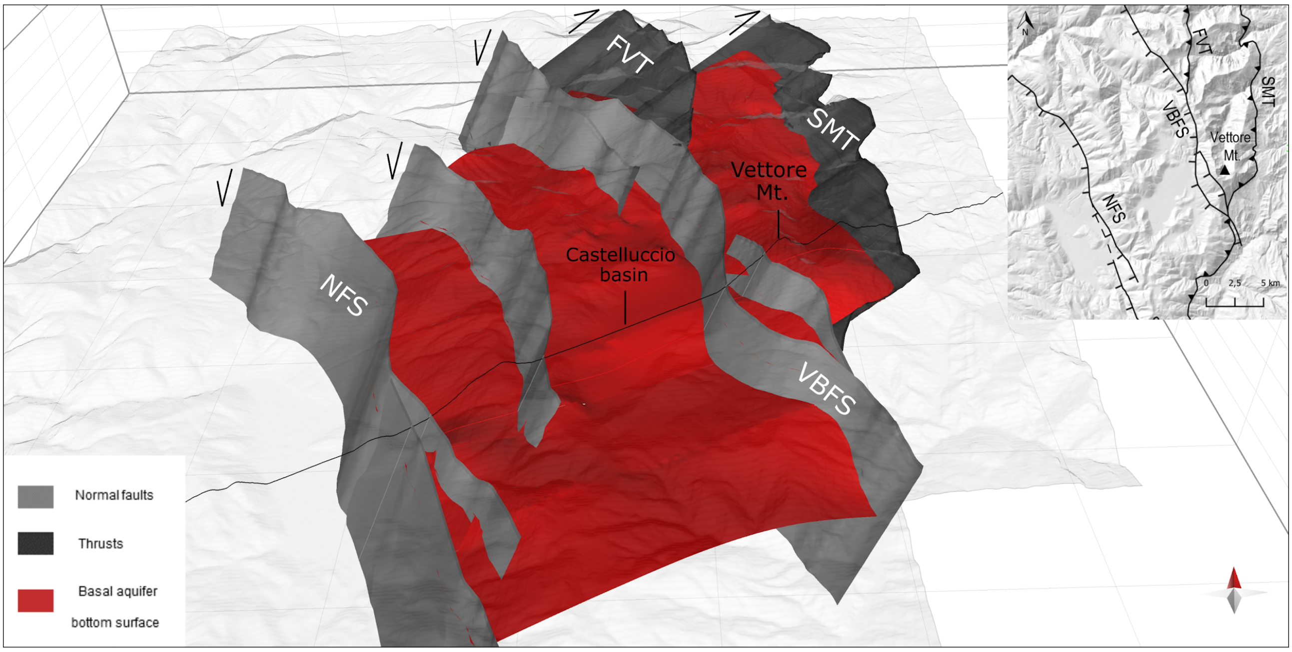

Fig. 1 - 3D simplified geometric model representing the main regional structures and the reconstructed bottom surface of the Basal aquifer of the Sibillini Mts. SMT: Sibillini Mts. Thrust; VBFS: Vettore-Bove Fault System; FVT: Fiegni-Vettore Thrust; NFS: Norcia Fault System.

Then a numerical analysis was performed by using the USGS MODFLOW 6 code to create a regional scale hydrogeological model in steady-state conditions, to simulate the groundwater flow before the earthquake. We defined a modelled area of about 1020 km^2, according to tectonic and hydrogeological features. To evaluate the groundwater filtration along fault zones and the effect of faults as hydraulic barrier during the pre-rupture condition, we implemented both the Vettore-Bove and Norcia faults in our hydrological model by assigning them a lower permeability value. The result is a distribution of the hydraulic head very close to faults (Fig. 2), reflecting a high loss of hydraulic gradient and a prevailing north-westward direction of groundwater flux. This qualitative result is consistent with the pre-seismic measured discharge values and water-levels observations.

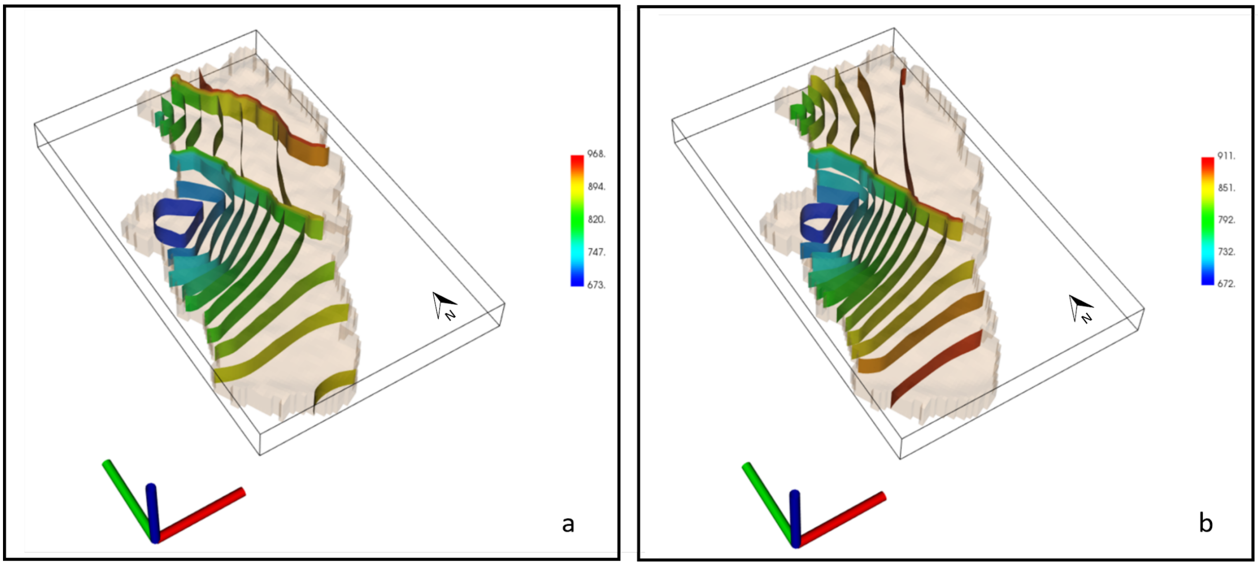

Fig. 2 – 3D numerical model with the isopiezometric distribution a) before Vettore fault rupture and b) after fault rupture.

Future developments

We are going to create a geomechanical failure model to assess the crustal stress-strain field variation related to the seismogenic fault dislocation. The model will be calibrated using a fem numerical inversion of interferometric SAR data available for the 30 October earthquake.

The calculated volumetric strain changes will be helpful to calibrate the hydraulic parameters in the hydrological model of groundwater filtration.

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