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From regional seismic hazard to "scenario earthquakes" for seismic microzoning: A new methodological tool for the Celano Project

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Abstract

We present the results of a probabilistic seismic hazard assessment and disaggregation analysis aimed to understand the dominant magnitudes and source-to-site distances of earthquakes that control the hazard at the Celano site in the Abruzzo region of central Italy. Firstly, we calculated a peak ground acceleration map for the central Apennines area, by using a model of seismogenic sources defined on geological-structural basis. The source model definition and the probabilistic seismic hazard evaluation at the regional scale (central Apennines) were obtained using three different seismicity models (Gutenberg–Richter model; characteristic earthquake model; hybrid model), consistent with the available seismological information. Moreover, a simplified time-dependent hypothesis has been introduced, computing the conditional probability of earthquakes occurrence by Brownian passage time distributions.

Subsequently, we carried out the disaggregation analysis, with a modified version of the SEISRISK III code, in order to separate the contribution of each source to the total hazard.

The results show the percentage contribution to the Celano hazard of the various seismogenic sources, for different expected peak ground acceleration classes. The analysis was differentiated for close (distance from Celano <20 km) and distant (distance from Celano >20 km) seismogenic sources. We propose three different "scenario earthquakes", useful for the site condition studies and for the seismic microzoning study: (1) large ($M = 6.6$) local (Celano-epicentre distance $\sim$16 km) earthquake, with mean recurrence time of $\sim$590 years; (2) moderate ($M = 5.5$) local (Celano-epicentre distance $\sim$7.5 km) earthquake, with mean recurrence time of $\sim$500 years; and (3) large ($M = 6.6$) distant (Celano-epicentre distance $\sim$24 km) earthquake, with mean recurrence time of $\sim$980 years.

The probabilistic and time-dependent approach to the definition of the "scenario earthquakes" changes clearly the results in comparison to traditional deterministic analysis, with effects in terms of engineering design and seismic risk reduction.

Keywords: Seismic hazard; Seismogenic sources; Time-dependency; Seismic microzoning; Scenario earthquake; Disaggregation analysis

1. Introduction

We present a multidisciplinary approach to obtain different "scenario earthquakes" for the seismic microzoning of the Celano town (Abruzzo, Italy), during a project ("Celano Project") which involved different research groups (e.g., Refs. [1,2]).

It is common practice in seismic microzoning studies to use "scenario earthquakes" which are well-known historical or instrumentally recorded significant earthquakes, possibly occurred near the area of interest or having seismotectonic affinity with the region within which the area is located. In the case of the town of Celano, the most easiest way is to choose the Avezzano earthquake of January 13, 1915 ($M_s = 7.0$, according to Ref. [3]; see also Refs. [4,5] for the source parameters discussion), located only 8 km SSW of Celano. This earthquake was one of the most destructive events in the seismic history of Italy (epicentral Intensity of XI on the MCS scale); it produced damages up to IX MCS in the Celano site. Nevertheless, basic principles of earthquake geology suggest that the fault responsible for the 1915 event needs a period of recharge; therefore, this is not

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the only fault which contributes to the seismic hazard at Celano in the near future, but there are other important active faults which might strongly contribute to the Celano hazard.

One of the benefits of probabilistic seismic hazard assessment is that it sums the hazard to a site from all relevant earthquake sources, integrating over all potential earthquake occurrences and ground motions to estimate the mean frequency of exceedance of any given spectral acceleration at the site. However, for design analysis or other seismic risk decisions, a single "scenario earthquake" (characterized by a single magnitude, distance, and perhaps other parameters) is often desired. Performing geographic hazard disaggregation allow us to determine predominant sources of seismic hazard, identifying plausible scenario earthquakes. Important contributions to seismic hazard disaggregation methods and applications are found in Refs. [6–11].

In order to consider the possible contribution of active faults to the Celano hazard, we use a multidisciplinary probabilistic seismic hazard model which combine geological data (fault length, slip rate and paleoearthquake data) with historical and instrumental seismicity data to estimate the future ground motion.

The seismic hazard calculations are disaggregated, in order to separate the relative contribution of each source to the total hazard of the Celano site, and formulate the hypothesis of three different "scenario earthquakes": large local earthquake ($M > 6.0$; distance < 20 km); moderate local earthquake ($M < 6.0$; distance < 20 km) and large distant earthquake ($M > 6.0$; distance > 20 km).

2. Seismotectonic context

The town of Celano is located in the central part of the Apennines of Italy, a Late Miocene–Early Pliocene fold-and-thrust belt post-dated by Plio-Quaternary extensional tectonics. Extension produced normal faults with dip-slip to normal-oblique kinematics, striking on average NNW–SSE and determining the formation of intramontane continental basins (Fig. 1). The Fucino basin, extending for $\sim 250\,km^2$ south of Celano, is one of the main expression of Plio-Quaternary extension in central Apennines (see Ref. [12] for a comprehensive stratigraphic and tectonic description). Normal faults are still active along the Apennines, as testified by geologic and morphologic evidence ([13–19] and references therein), paleoseismology (e.g., Refs. [20–23]) as well as by strong historical earthquakes with associated surface faulting (e.g., Ref. [24]) and recent earthquake focal mechanisms ([25–30]; Fig. 1). The Avezzano earthquake of January 1915, ($M_s = 7.0$) located in the Fucino basin, demonstrated the primary role played

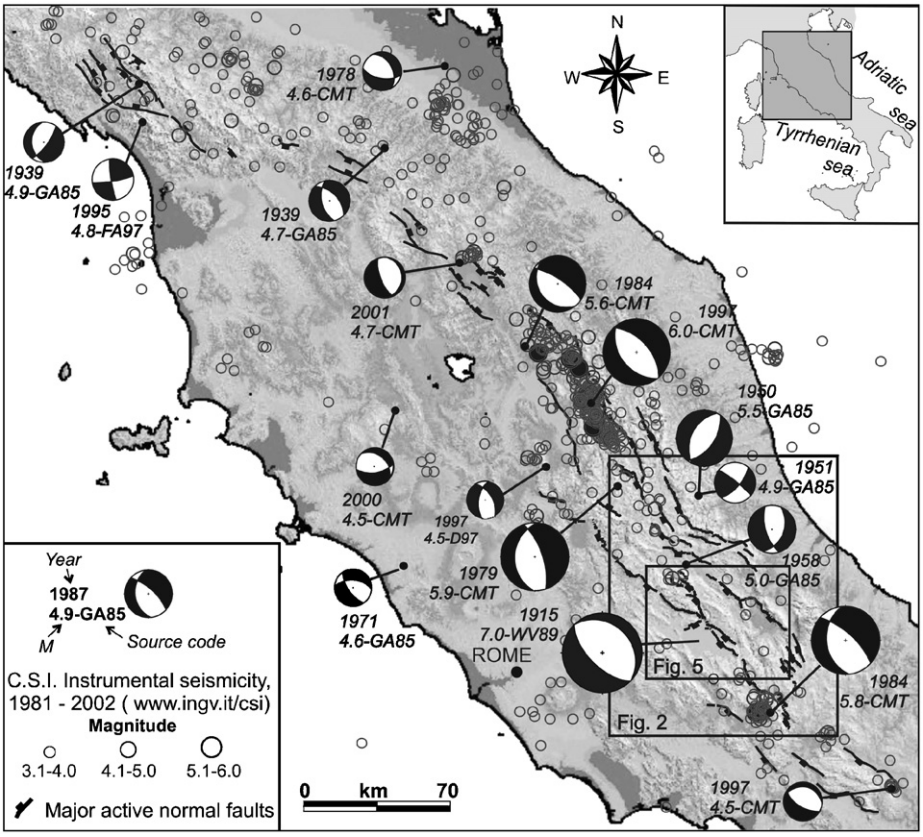

Fig. 1. Shaded relief of central-northern Italy with active normal faults and earthquake focal mechanisms within the Apennine belt; focal mechanisms are for earthquakes with magnitude $\geqslant 4.5$ from 1915 to 2002 (data selection from Ref. [16], implemented); cited sources: CMT [17]; FA97 [18]; D97 [19]; GA85 [20]; R89 [21]; and WV89 [5].