

Ground effects of the MI 5.2, November 24, 2004, Salò earthquake, Northern Italy: a case study for the use of the INQUA scale

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On November 24, 2004, at midnight (23.59 PM, local time), a moderate earthquake (MI 5.2, Mw 5.0; focal depth 8 km; source INGV, <http://www.ingv.it/terremoti/brescia2004/mecc-focale.html>) hit the Lake Garda region, within the active fold and thrust belt of the Southern Alps (Figure 1). This earthquake was felt in the whole Northern Italy, from Venice to Milan and Genoa, and abroad, for instance in Switzerland; the epicentral area includes the town of Salò and its surroundings, where where significant damage occurred and more than 200 people were left homeless. Epicentral intensity of VII-VIII in the MCS scale has been assigned in a preliminary way based on severe damage at the villages of Clibbio and Pompegnino.



Figure 1: Digital elevation model of the study area including instrumental epicentre of the 24th November 2004 Salò earthquake (source INGV), focal mechanism (from the MEDNET Database) and the field stations where observations on coseismic ground effects have been collected. The inset box (a) shows a more detailed map of the epicentral area.

Field surveys have been conducted since the day after the earthquake in order to collect all the information on earthquake's ground effects. The analysis of its environmental effects is of some interest for two reasons, a) this is the first damaging seismic event in Italy after the release of the INQUA Scale (http://www.apat.gov.it/site/en-GB/Projects/INQUA_Scale/), and b) the same area was hit in 1901 by an earthquake of a similar size, which produced well-described rockfalls, effects on springs and lake water level, and liquefaction induced fissures along the lake shore. This makes it possible to compare the damage on buildings and the "damage" on the environment from both events. This will provide a significant test for the reliability of the INQUA scale within the assessed range of epicentral intensity.

Our preliminary data show that environmental effects are considerable in the area of Salò and along the Chiese River Valley ("Val Sabbia").

As of yet, we observed 5 sites with multiple rockfalls (max volume in the order of some 10^2 m³), 3 sites with landslides (max volume ca 10^3 m³), 5 sites showing fractures on the ground and on paved roads, 2 sites with fractures along the lake shore, 2 sites showing turbidity of the water (1 aqueduct and 1 small river).

In particular, the most significant effects occurred at the following sites:

- Clibbio: along the Chiese River large rockfalls with dolostone boulders up to ca. 75 m³ detached from the mountain slope of Mt. Acuto; two houses were hit by the boulders, and the main road to Clibbio has been strongly damaged; new big rockfalls occurred also in the days following the mainshock;
- Pompegnino: several cracks on the ground and on the paved roads have been observed in the downtown area; these cracks show widening (from 1 cm to 2 cm) with time, especially after the strong rain occurred on Nov. 29 and 30, 2004;
- Salò: evidence of liquefaction and localized (over an area of ca. 500 m²) lateral spreading and settlement, with fissuring up to 30 cm wide parallel to the waterfront area have been observed in the harbor (Figure 2); these effects replicated those occurred during the 1901 event.



Figure 2: Fissure parallel to the waterfront, affecting the concrete in the Salò harbor area. This feature is an evidence of liquefaction and localized lateral spreading.

In general, most severe environmental effects and damage to buildings occurred in the same areas, and intensity assessed from the MCS scale is in good agreement with intensity assessed with the INQUA scale. From our data, INQUA intensity of VIII should be assigned to Clibbio and Salò, and VII to Pompegnino.

More detailed analysis of the structural setting, of the distribution of ground effects out of the epicentral area, and of the chemical variations of springs and ground water are in progress, and will be presented during the meeting.