THE SECOND WORLD LANDSLIDE FORUM

Landslides Induced by the 1908 Southern Calabria: Messina Earthquake (Southern Italy)

Valerio Comerci, Anna Maria Blumetti, Elisa Brustia, Pio Di Manna, Luca Guerrieri, Mauro Lucarini, and Eutizio Vittori

Abstract

Five hundred and two different testimonies of coseismic environmental effects of the 1908 Southern Calabria-Messina earthquake have been identified and catalogued, based on a careful screening of contemporary documents, i.e. technical and photographic reports, newspapers and other archive material. Out of the 348 independent occurrences, landslides are the most represented category with 150 cases (43 % of the whole set of effects). The area, which is prone to slope instability even without seismic triggering, due to its lithological characters and rugged topography, undergoes now a much higher seismic risk because of the unconcerned strong urban development of recent decades. So, the obtained scenario of landslides distribution triggered by the 1908 earthquake helps to evaluate the impact on this region of a 1908-like future event.

Keywords

1908 earthquake • Induced landslides • Hazard evaluation

The Earthquake Environmental Effects database

The December 28, 1908, Southern Calabria - Messina earthquake (Intensity MCS XI, Mw 7.24) has been the strongest seismic event to hit Italy during the twentieth century and the most devastating, with a death toll of at least 80,000 (Boschi et al. 1995; Gruppo di lavoro CPTI 2004). The impact of the earthquake was particularly catastrophic along the coastlines facing the Messina Straits, mostly because of building collapses and tsunami waves. The macroseismic epicentre is located close to Reggio Calabria town (Guidoboni and Mariotti 2008). The estimated hypocentral depth was between 5 and 15 km (Pino et al. 2000).

We collected 502 contemporary testimonies related to 348 earthquake environmental effects, that were found in newspapers, the Official Gazette and tens of reports, several of them compiled by true authorities of that time on this subject, such as Mercalli, Baratta, etc. Our basic geological and geophysical documental sources were Baratta (1909, 1910), Cortese (1923), Crema (1909, 1921), Di Stefano (1909), Franchi (1909), Galli (1910), Luiggi (1909), Gor'kji-Meyer (1909), Martinelli (1909), Marzolo (1909), Mercalli (1909), Novarese (1909), Occhiuto (1909), Oddone (1909), Oldham (1909), Omori (1909), Platania (1909), Ricciardi (1909, 1910), Riccò (1909), Rizzo (1909), Taramelli (1909), Sabatini (1909) and Società Fotografica Italiana (1909). Once pertinent descriptions of effects were found in the original sources, they were classified in one of 12 categories (based on the ESI - Environmental Seismic Intensity - scale, Michetti et al. 2007): slope movement, ground crack, ground lowering and uplift, differential lowering, coastline retreat, sinkhole, liquefaction, hydrological anomaly, gas emission, light and rumble. In Fig. 1, the

V. Comerci (✉)
ISPRA, Italian Institute for Environmental Protection and Research, Geological Survey of Italy, Via Curtatone 3, Rome 00185, Italy
e-mail: valerio.comerci@isprambiente.it

A.M. Blumetti • E. Brustia • P. Di Manna • L. Guerrieri • M. Lucarini • E. Vittori
ISPRA, Italian Institute for Environmental Protection and Research, Geological Survey of Italy, Rome, Italy

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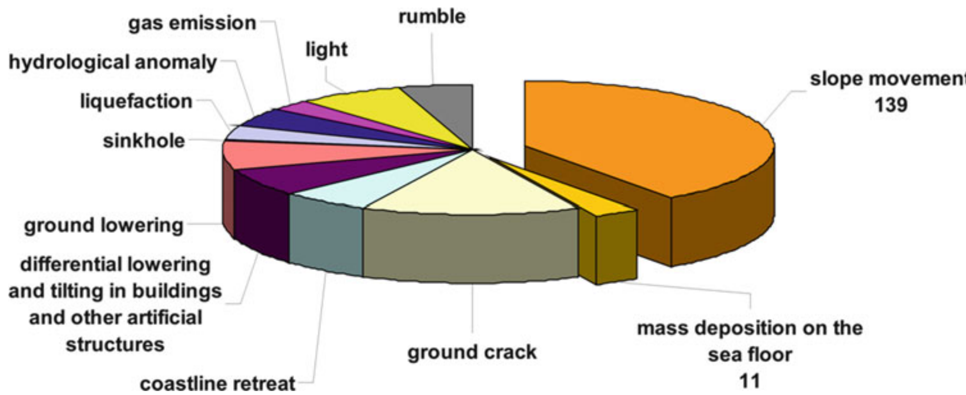

Fig. 1 Distribution by type of the 348 collected effects induced by the 1908 earthquake

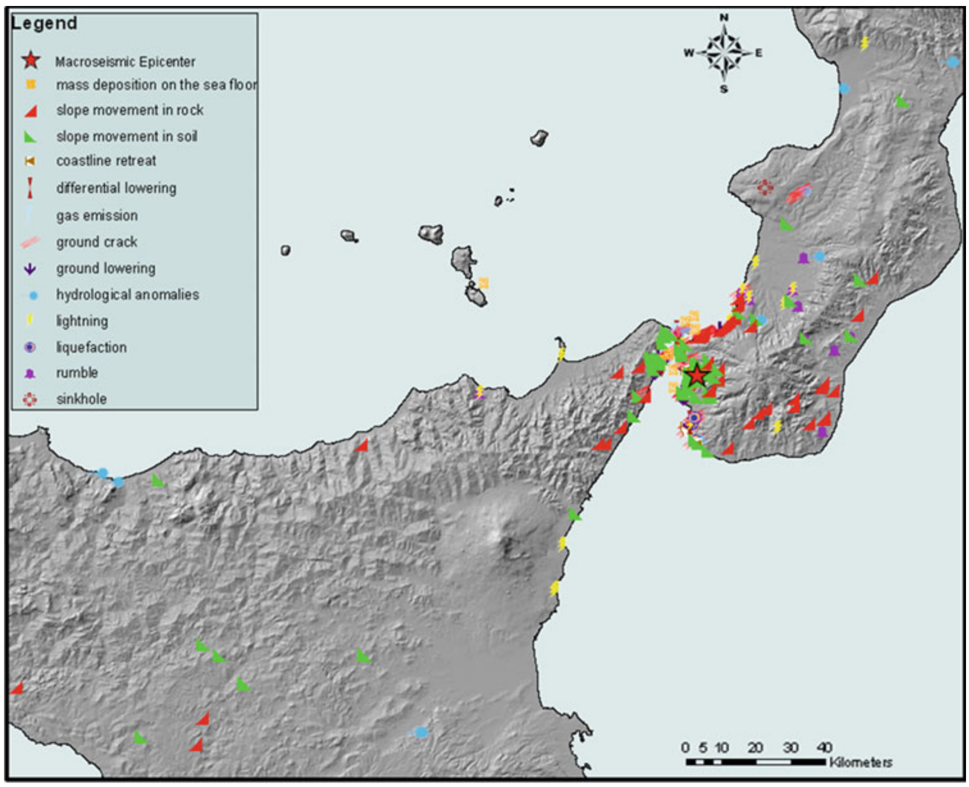

Fig. 2 The 348 effects on the environment described by the contemporary sources. Their geographical distribution is uneven, because the territory was mostly investigated in inhabited and most accessible areas. At this scale many of the symbols overlap

percentage distribution of landslides (150), compared to the other 198 collected effects is reported.

Geo-referenced and placed on a map, some of the 348 collected effects overlap (Fig. 2) and in general, their geographical distribution is strongly uneven. The latter could be directly caused by the irregular pattern of investigation conducted then on the territory by the surveyors: they concentrated their efforts in the towns and villages and roads along the coastal area, which were much more accessible than the inner mountain region.

Out of the 348 effects, 140 are located in Calabria, 197 in Sicily, and 11 at sea (mass depositions on the sea floor). The locality with the largest number of effects (123) is Messina. If we exclude the effects collected at Messina and Reggio Calabria (40), the number of effects in Calabria (100) is larger than that in Sicily (74).

Landslides Induced by the 1908 Earthquake

Slope movements represent the largest part of the reported effects: 150 (43 % of the total). Of them, 52 occurred in Sicily (35 %), 87 in Calabria (58 %) and 11 at sea (7 %). In fact, bathymetric measurements, taken soon after the earthquake in the Straits area, detected reductions of depth of the

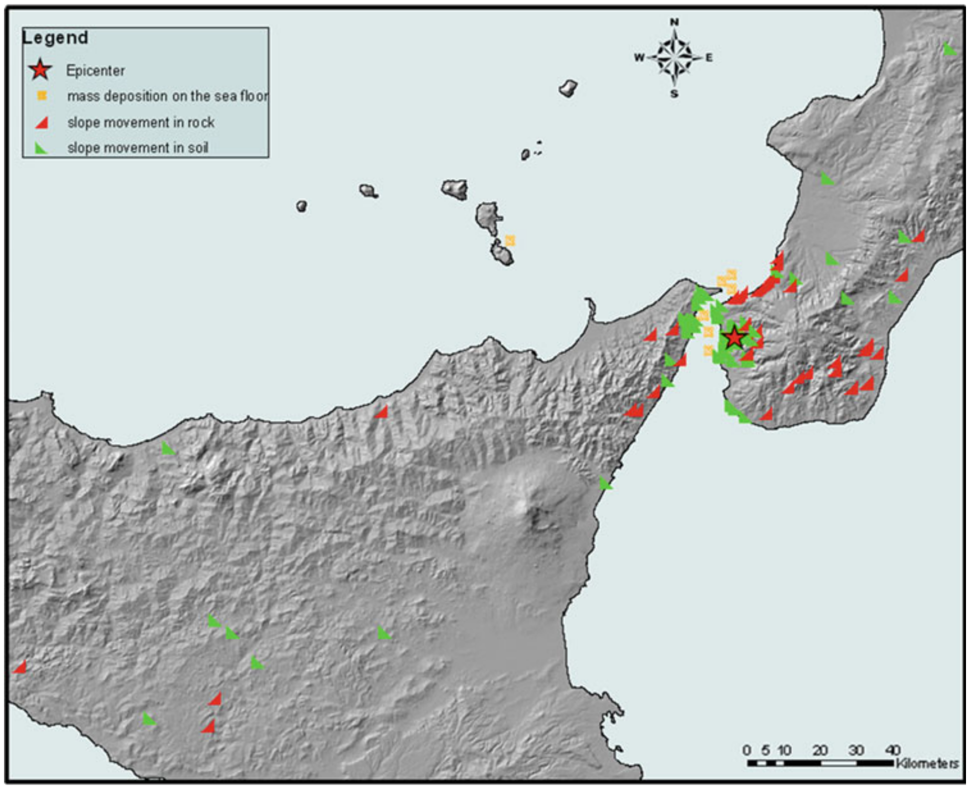

Fig. 3 The 1908 earthquake triggered many landslides inland and also underwater. We collected the description of 59 slope movements in rock, 80 slope movements in soil and 11 mass deposition on the sea floor

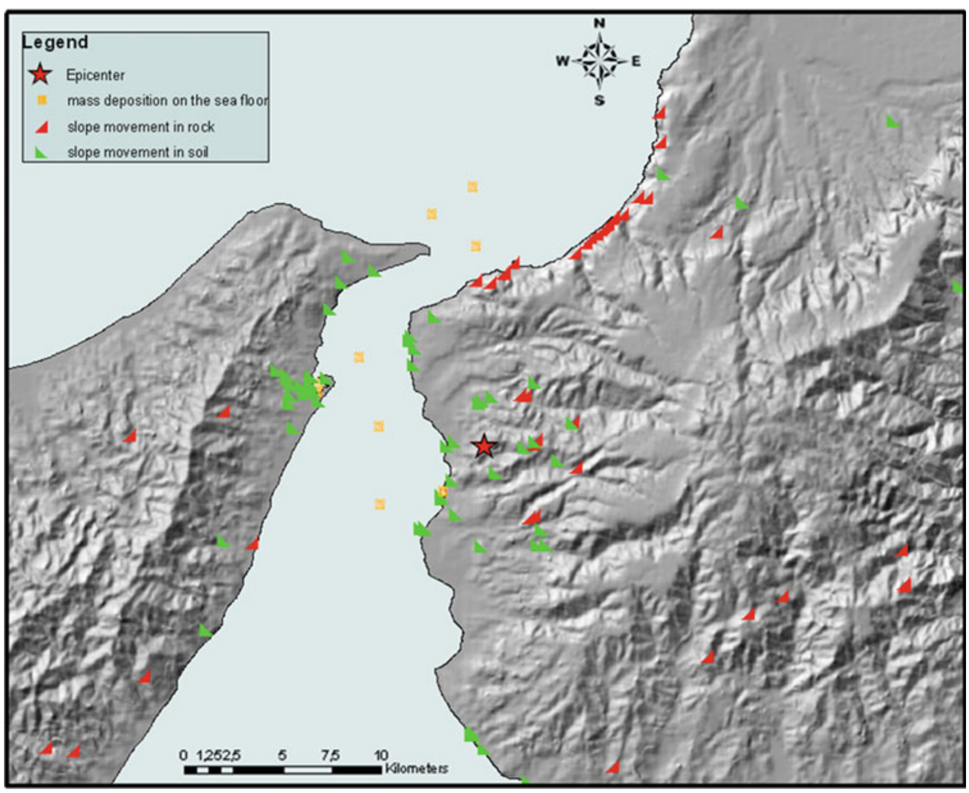

Fig. 4 Landslides triggered by the 1908 earthquake: close-up of the epicentral area

Fig. 5 Rockslides and rockfalls occurred along the railway line in Favazzina (Società Fotografica Italiana 1909)

Fig. 6 Rockfalls along the railway line in Favazzina (Società Fotografica Italiana 1909)

sea floor at eight sites, where underwater mass depositions of sediments very likely occurred. Moreover, the interruptions (burial or severing) of communication cables laid on the sea floor between Milazzo and Lipari, Gazzi and Gallico, and Malta and Zante, are attributed to underwater landslides or turbidity currents (Ryan and Hezen 1965).

Inland, the landslides are distributed on different lithologies and many of them are reactivations of pre-existing slope movements. We differentiated them into two main categories, on the basis of the competence of the affected lithology: slope movement in rock (coherent and stiff lithology) and slope movement in soil (sand, clay and loose material in general). The lithologies were obtained from the Calabrian and Sicilian sheets of the Geological map of Italy at the scales 1:50,000 and 1:100,000 (http://www.isprambiente.gov.it/site/en-GB/Cartography/Geological_and_geothematic_maps/default.html). Figures 3 and 4 show the location of all the slope movements, 59 were in rock, 80 in soil and 11 underwater, probably in loose sediments. Unfortunately, most of the descriptions do not allow recognition of the type of slope movement. In addition there are few cases well documented and also photographed by the contemporary authors. In many sites between Bagnara and Favazzina, altered gneiss slid down along the steep slopes, interrupting the railway line (Figs. 5 and 6). At Cannitello a considerable landslide was photographed by Mercalli, as well as the rock fall that damaged the small village of Orti Superiore, near Reggio Calabria (Fig. 7). Also a rockslide occurred and was photographed (Fig. 8) on the mule track between Cataforio and S. Salvatore (East of Reggio Calabria): it killed three muleteers with their animals (Taramelli 1909).

The Coseismic Effects in Messina

We collected many accounts (123) of environmental effects in Messina: ground cracks, ground lowering, slope movements, tsunami waves (that in this area reached 3 m of run-up), etc. (Fig. 9). The wharf area was severely damaged and a large part of it collapsed, because of the combined action of seismic shaking and tsunami.

Moreover, several reporters described a generalised ground movement toward the sea. In fact, the recent loose alluvial deposits forming the coastal area as well as the sands and gravels constituting the Pleistocene terraces could have been affected by slope movements toward the sea, triggered by the earthquake. Therefore, many of the described effects (ground cracks, ground settlements, ground uplifts, ground deformations, etc.) could be interpreted as a consequence of slope movements involving a large part of the Messina seacoast. Tectonic slip along the faults bordering the coastal area might have also contributed to coastal subsidence (Franchi 1909).

Landslides Area Versus Magnitude

The area affected by landslides (ca. 20,000 km^2) was determined by drawing a polygon around the mapped landslide localities. If we plot this value in the graph drawn by Keefer (1984), which relates the area affected by landslides with earthquake magnitudes (Fig. 10), the resulting magnitude matches exactly the one estimated for the 1908 earthquake. Therefore, the area distribution of the collected accounts of landslides is in good agreement with the Keefer's database.

Moreover, the distance (216 km) of the farthest landslide (in south-western Sicily) from the 1908 epicentre results in good agreement with the plot of Keefer (1984) of maximum distance of landslides from epicentre versus magnitude (Fig. 11). Because we do not know if the farthest landslide

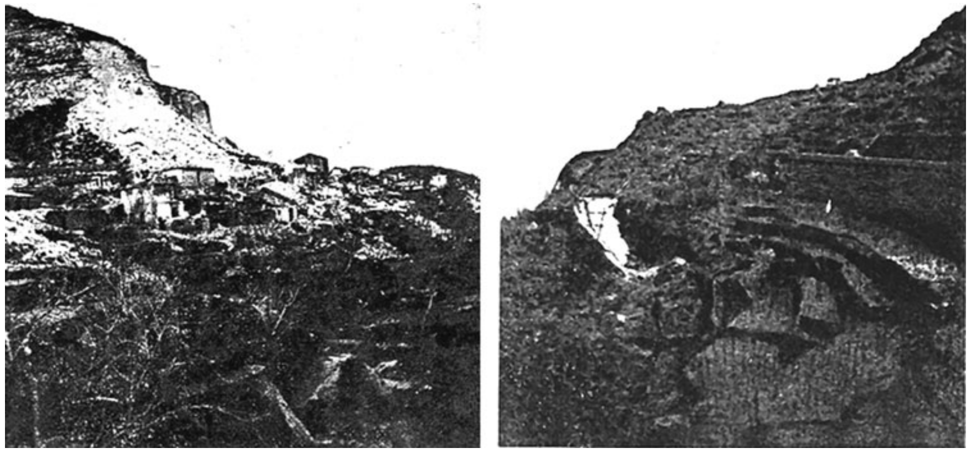

Fig. 7 (*left*) The village of Ortì Superiore damaged by a rockfall; (*right*) A considerable landslide disrupted the road between Scilla and Cannitello (These photographs were taken by Mercalli in April 1909 (Mercalli 1909))

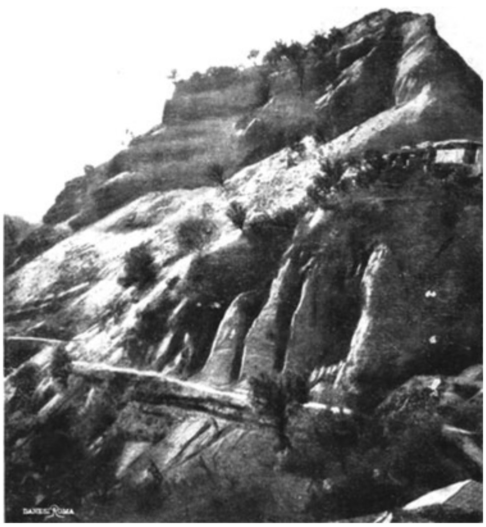

Fig. 8 The rock fall on the mule track between Cataforio and S. Salvatore (East of Reggio Calabria), that killed three muleteers (Taramelli 1909)

was a disrupted fall or slide, or a coherent slide, the magnitude value in Fig. 11 is bracketed between 7 and 7.2, which is consistent with the uncertainty affecting the estimation of the magnitude of the 1908 earthquake.

The distribution of slope movements, as commonly observed (Esposito et al. this volume), rarefies moving outward from the epicentre. The area significantly affected has a radius of ca. 40 km: 129 out of the 150 collected events (86 %) fall within this distance. This spatial distribution is consistent with a crustal seismic event such as the 1908 event; in fact, for deeper earthquakes, with focal depths $\geq$30 km, generally landslides extend over much larger areas (Keefer 1984).

Discussion and Conclusions

Despite the fact that a large portion of the mesoseismal area falls at sea, the areal distribution of the 1908 induced landslides scales well (see also Esposito et al. 2011, in this volume) with the areal distribution of landslides triggered by other seismic events along the Apennines (e.g. 1980, 1997, 2009) and can be used as a diagnostic element for intensity assessment by means of the ESI scale (Michetti et al. 2007). The envelop of all the compiled seismically induced landslides gives a total area of at least 20,000 km^2, corresponding to intensity XI (ESI), in agreement with the MCS estimated maximum intensity (Guidoboni et al. 2007).

Secondary effects induced by earthquakes can highly contribute to increase the seismic damage, e.g., by direct impact on buildings or interrupting/threatening crucial lifelines, consequently, they have to be considered in order to define a realistic seismic hazard scenario. The picture here presented of the landslide distribution caused by the 1908 earthquake offers a valid tool to estimate the potential impact of a 1908-like event on the Straits area, which is already prone to slope instability even without seismic triggering, and has seen an unconcerned broad urban and infrastructural development in the last decades.

The detailed knowledge of the environmental effects occurred in 1908 e.g. at Messina (where damages were described carefully) offers the possibility to (1) carry out appropriate surveys targeted to test the susceptibility of the territory to the same phenomena (landslides, liquefaction, inundation, etc.); and (2) improve our preparedness to face the land changes that a strong seismic event commonly produces.

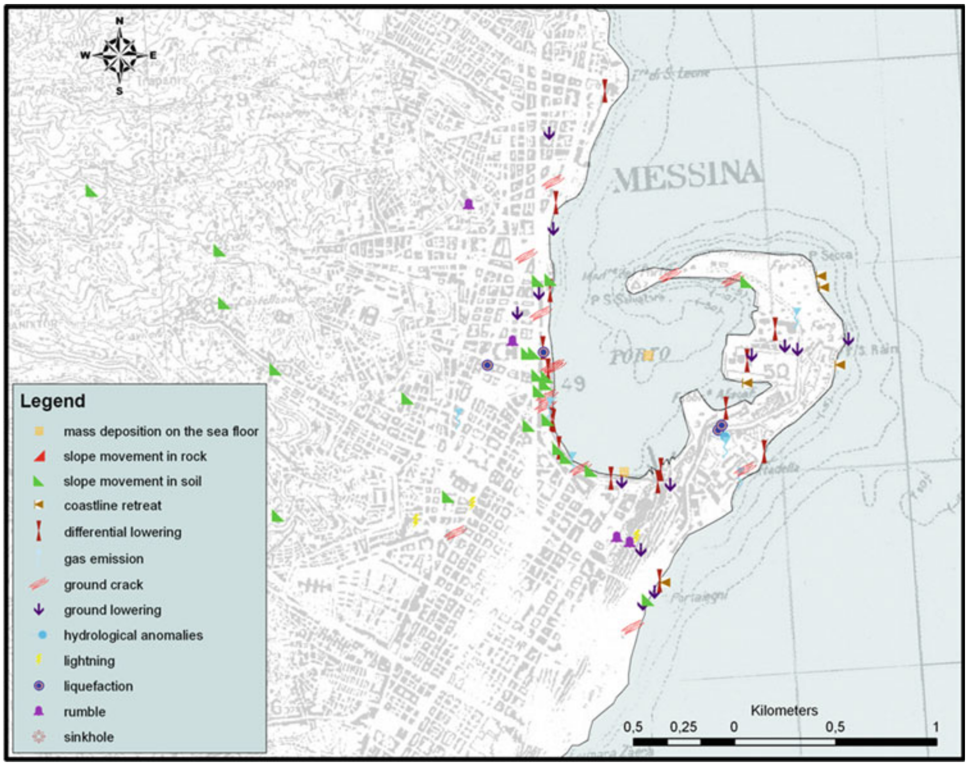

Fig. 9 The environmental effects occurred in Messina. Many of them are related to slope movements that involved a large part of the town's seacoast

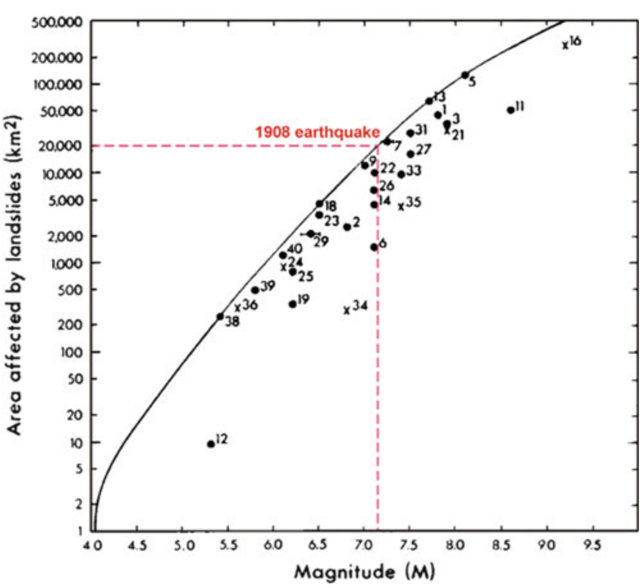

Fig. 10 Area affected by landslides versus earthquake magnitude (After Keefer 1984), with the plot of the 1908 affected area

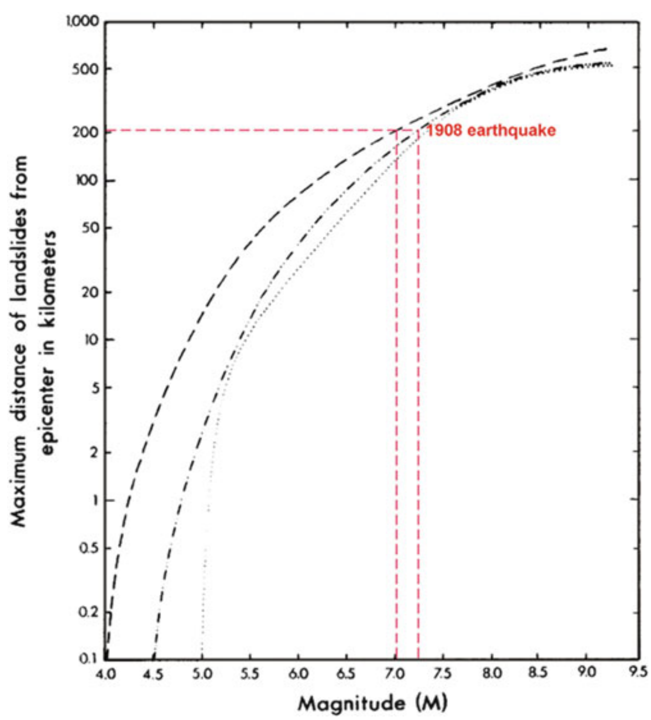

Fig. 11 Maximum distance from epicentre of landslides versus earthquake magnitude (After Keefer 1984), with the plot of the 1908 landslide farthest from the epicentre. *Dashed line* is the upper boundary for disrupted falls and slides, *dash-double-dot line* is the upper boundary for coherent slides

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