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**A photographic dataset of the coseismic geological effects induced on the environment by the 2012 Emilia (northern Italy) earthquake sequence**

# 16



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## A PHOTOGRAPHIC DATASET OF THE COSEISMIC GEOLOGICAL EFFECTS INDUCED ON THE ENVIRONMENT BY THE 2012 EMILIA (NORTHERN ITALY) EARTHQUAKE SEQUENCE

Emergeo Working Group\*

INGV (Istituto Nazionale di Geofisica e Vulcanologia)



# 16



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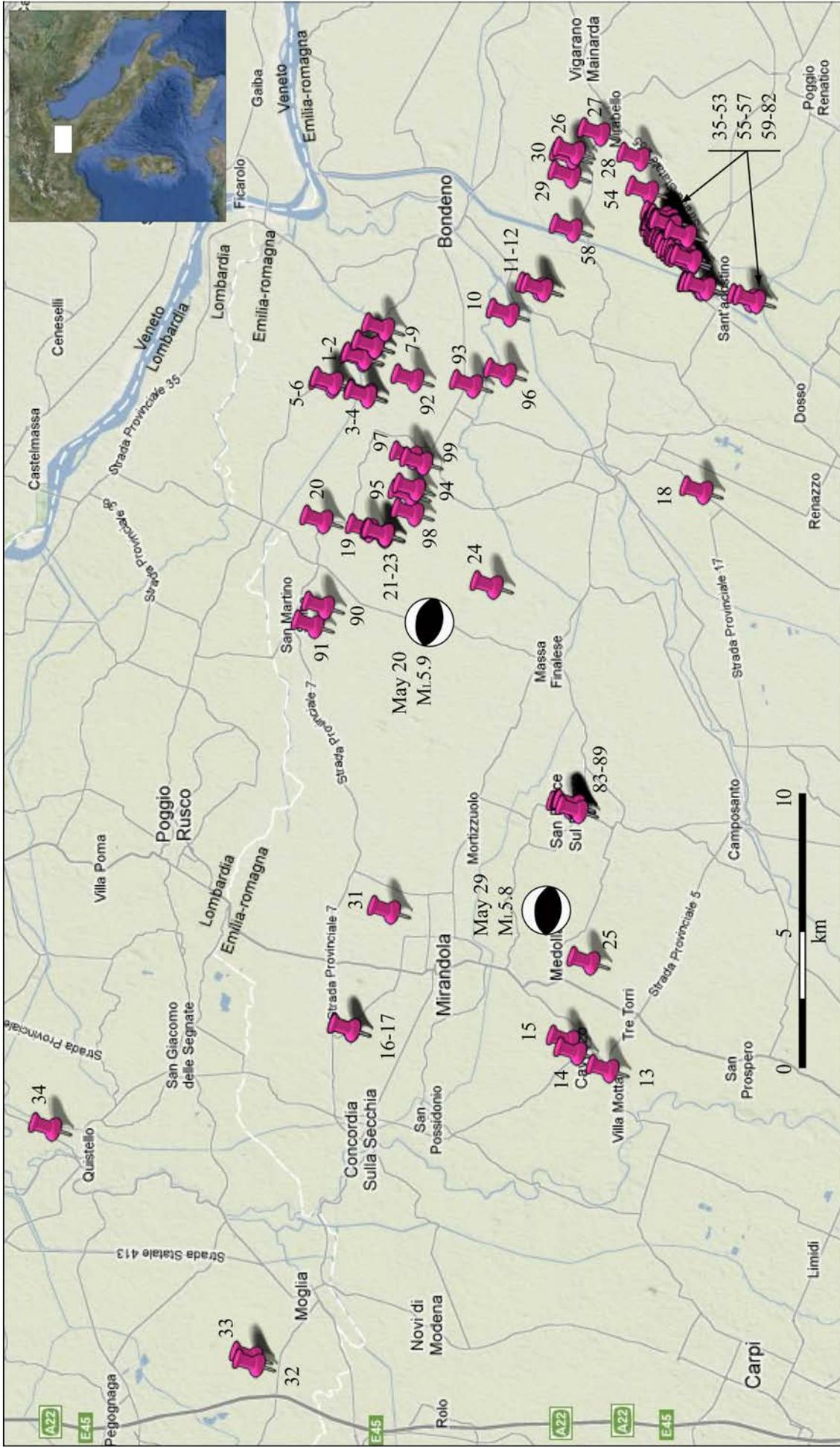
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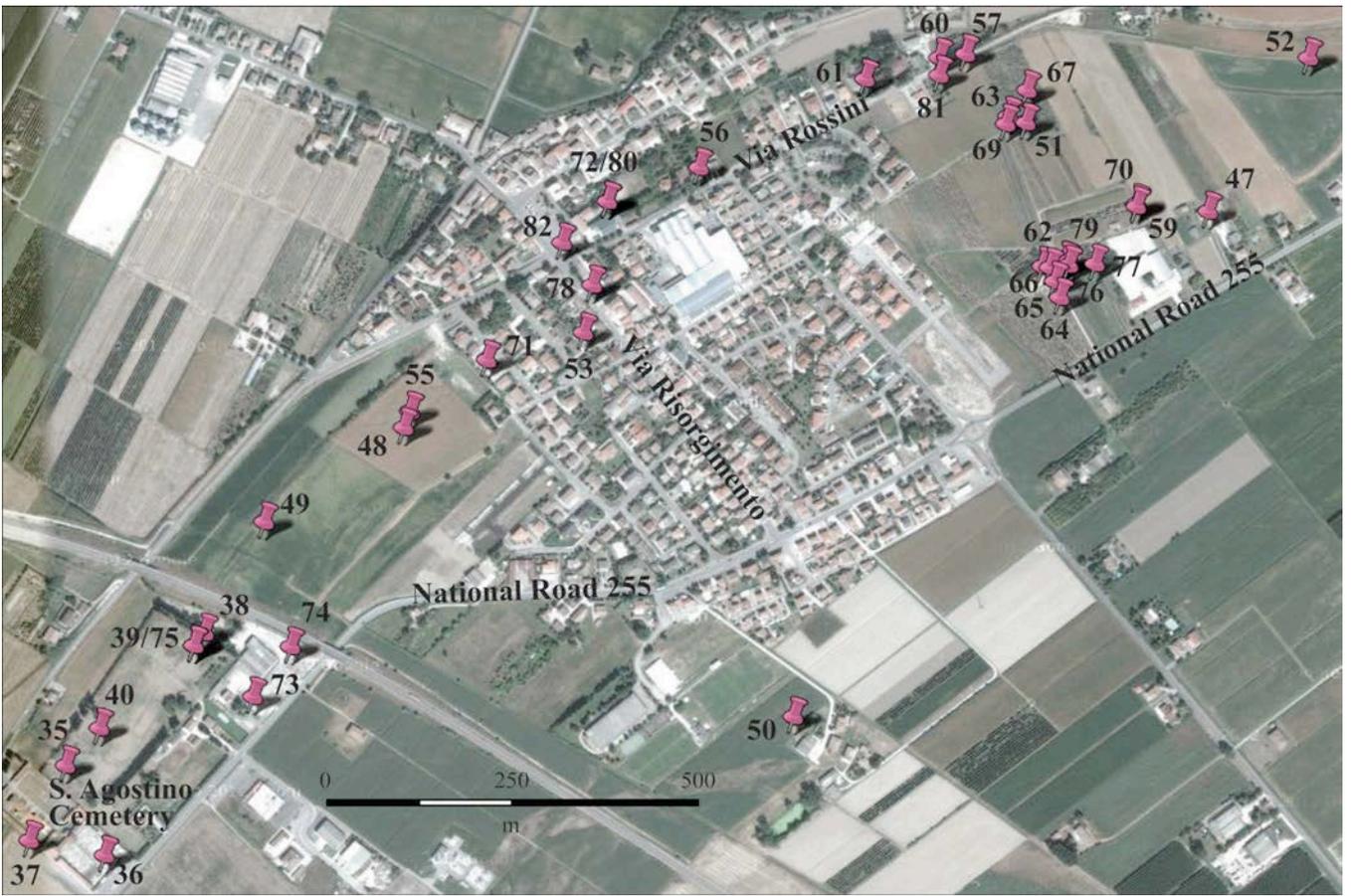


## Introduction

We present a collection of pictures of the coseismic secondary geological effects produced on the environment by the 2012 Emilia seismic sequence in northern Italy. The May-June 2012 sequence struck a broad area located in the Po Plain region, causing 26 deaths and hundreds of injured, 15.000 homeless, severe damage of historical centres and industrial areas, and an estimated economic toll of ~2 billion of euros. The sequence included two mainshocks (Figure 1): the first one, with  $M_L$  5.9, occurred on May 20 between Finale Emilia, S. Felice sul Panaro and S. Martino Spino; the second one, with  $M_L$  5.8, occurred 12 km southwest of the previous mainshock on May 29. Both the mainshocks occurred on about E-W trending, S dipping blind thrust faults; the whole aftershocks area extends in an E-W direction for more than 50 km and includes five  $M_L \geq 5.0$  events and more than 1800  $M_L > 1.5$  events. Ground cracks and liquefactions were certainly the most relevant coseismic geological effects observed during the Emilia sequence. In particular, extensive liquefaction was observed over an area of ~1200 km<sup>2</sup> following the May 20 and May 29 events. We collected all the coseismic geological evidence through field survey, helicopter and powered hang-glider trike survey, and reports from local people directly checked in the field. On the basis of their morphologic and structural characteristics the 1362 effects surveyed were grouped into three main categories: a) liquefactions related to overpressure of aquifers, occurring through several aligned vents forming coalescent flat cones (485 effects); b) liquefactions with huge amounts of liquefied sand and fine sand ejected from fractures tens of meters long (768); c) extensional fractures with small vertical throws, apparently organized in an en-echelon pattern, with no effects of liquefaction (109). The photographic dataset consists of 99 pictures of coseismic geological effects observed in 17 localities concentrated in the epicentral area. The pictures are sorted and presented by locality of observation; each photo reports several information such as the name of the site, the geographical coordinates and the type of effect observed. Figure 1 shows a map of the pictures sites along with the location of the two mainshocks; Figure 2 shows a detail of the distribution of the liquefactions in the area of S. Carlo. The complete description of the coseismic geological effects induced by the Emilia sequence, their relation with the aftershock area, the InSAR deformation area and the  $I > 6$  EMS felt area, along with the description of the technologies used for data sourcing and processing are shown in Emergeo Working Group [2012a and 2012b].



**Figure 1.** The map shows the location of the 99 pictures and the two main shocks of the 2012 Emilia sequence. Numbers beside the pins refer to the order of presentation.



**Figure 2.** Detail of the location of 39 pictures showing liquefactions in the area of S. Carlo. Numbers beside the pins refer to the order of presentation.



Locality: Burana



44.90581N 11.35342E

**Photo 1.** Fractures and liquefactions showing a complex pattern 1 km south of Burana.



44.90540N 11.35470E

**Photo 2.** A detail of the upper left corner of photo 1 showing a close up of the fractures with liquefactions.

Locality: Burana



44.90466N 11.33693E

**Photo 3.** Fractures with liquefactions in the ploughed fields 1.5 km southwest of the village.

Locality: Burana



44.90462N 11.33642E

**Photo 4.** Channel filled with liquefied sand between Burana and Scortichino.

Locality: Burana



44.91590N 11.34278E

**Photo 5.** Fractures and diffuse liquefaction in this ploughed field west of Burana.

Locality: Burana



44.9160N 11.3410E

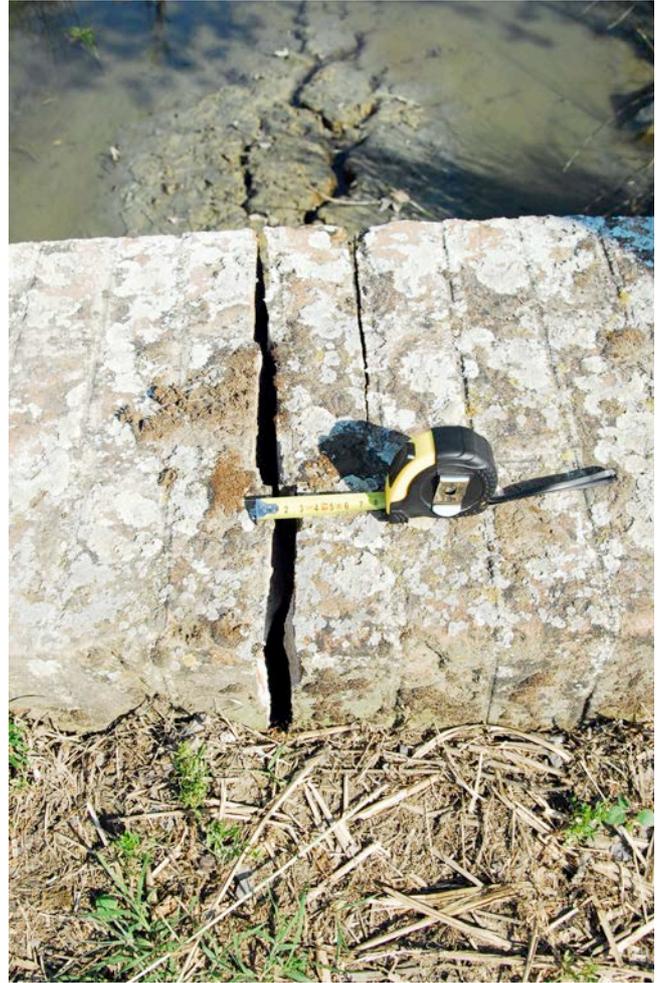
**Photo 6.** Detail of the fracture with liquefaction of photo 5. Most of the aerial observations were validated by subsequent field survey.

Locality: Burana



44.90205N 11.35971E

**Photo 7.** Fracture affecting the bridge over a channel filled with liquefied sand 1.5 km SSE of Burana.



44.90214N 11.35956E

**Photo 8.** Detail of the fractured bridge of photo 7.

Locality: Burana



44.89870N 11.36837E

**Photo 9.** Set of differently trending, ~10 m-long fractures with liquefaction between Burana and Bondeno.

Locality: Casumaro



44.85734N 11.37495E

**Photo 10.** Fractures with liquefactions 1.5 km SW of Casumaro.



44.84780N 11.38760E

**Photo 11.** Fractures with liquefactions between Casumaro and Santa Bianca.

Locality: Casumaro



44.84592N 11.38660E

**Photo 12.** 50 m-long fracture with liquefactions between Casumaro and Santa Bianca.

Locality: Cavezzo



44.82446N 11.01885E

**Photo 13.** Widespread liquefaction and silting of an irrigation ditch near via Gavioli.



44.83494N 11.02668E

**Photo 14.** This 4 m-long fracture in the soccer field of Cavezzo showed 4-5 cm of downthrown and a considerable amount of liquefied brown-grey sandy silt.

Locality: Cavezzo



44.83733N 11.03209E

**Photo 15.** This courtyard was characterized by diffuse extrusion of liquefied fine sands from a manhole, a well, and from the edge of the alley.

Locality: Concordia sulla Secchia



44.90972N 11.03802E

**Photo 16.** Close-up of a subtle fracture with ejection of liquefied light grey sand between Concordia sulla Secchia and Mirandola.



44.90975N 11.03805E

**Photo 17.** Close-up of liquefied light grey sand between Concordia sulla Secchia and Mirandola.

Locality: Dodici Morelli



44.79317N 11.29129E

**Photo 18.** Widespread liquefactions with series of sand-blows in a backyard along via Maestrola.

Locality: Forna



44.90385N 11.27363E

**Photo 19.** Set of fractures with liquefaction in the fields between Forna and Scortichino.



44.91890N 11.27721E

**Photo 20.** N160°-trending fracture with liquefaction of silty sand.

Locality: Forna



44.89877N 11.27113E

**Photo 21.** Detail of the vents and of liquefied light grey sand.



44.89899N 11.27103E

**Photo 22.** 30 m-long fracture with sand blows and ejection of grey silty sand.

Locality: Forna



44.89890N 11.27090E

**Photo 23.** Close up of the fracture with liquefaction depicted in the previous photo.

Locality: Massa Finalese



44.86245N 11.24673E

**Photo 24.** Liquefaction effect ten-of-meters long 2 km NE of the village.

Locality: Medolla



44.83051N 11.06965E

**Photo 25.** Brown sand extruded through the contact between the stump and the ground.

Locality: Mirabello



44.83559N 11.45106E

**Photo 26.** Extensive liquefaction off the road to Casumaro.



44.82724N 11.46032E

**Photo 27.** Red arrows point to zones of fracturing with liquefaction of grey silty sand in via Argine Postale.

Locality: Mirabello



44.81413N 11.44811E

**Photo 28.** Massive liquefied sands filled the track of this riding school southwest of Mirabello.



44.83672N 11.44010E

**Photo 29.** Detail of a ~5 cm-wide open fracture 2 km off the National Road 468.



44.83634N 11.44945E

**Photo 30.** 15 m-long fracture with massive extrusion of dark grey sands 1.5 km northwest of Mirabello.

Locality: Mirandola



44.89651N 11.09323E

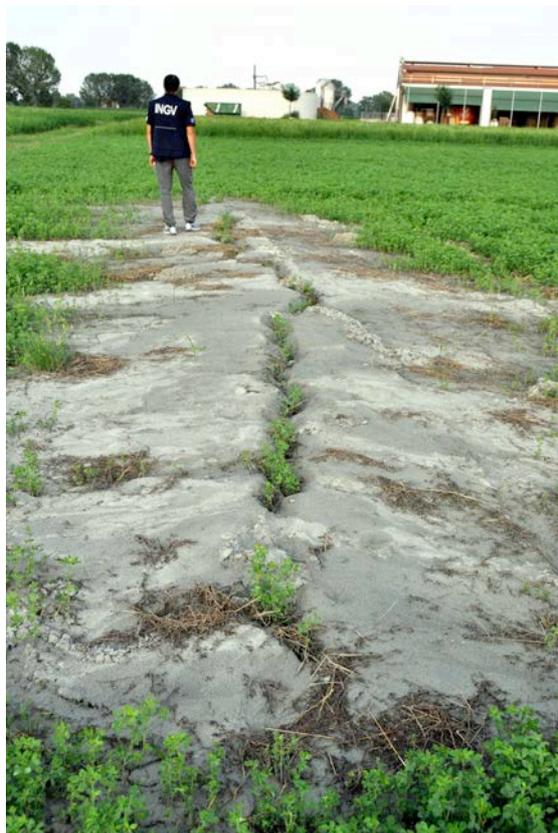
**Photo 31.** Detail of sand blows 1 km northeast of the village.

Locality: Moglia



44.94127N 10.88023E

**Photo 32.** Open fracture with liquefaction, 30 cm-wide, off the road to Bondeno (MN).



44.94226N 10.88301E

**Photo 33.** 15 m-long fracture with liquefaction of grey sands.

Locality: Quistello



45.00893N 10.99111E

**Photo 34.** The liquefaction effects in this cornfield followed the pattern of the cultivations.

Locality: S. Agostino



44.79775N 11.39981

**Photo 35.** Aerial view of the S. Agostino cemetery area, with ten-of-meters long open fractures locally filled with sand and extensive liquefaction effects.



44.79666N 11.40049E

**Photo 36.** Widespread flow of dark grey sands in the cemetery of S. Agostino.

Locality: S. Agostino



44.79683N 11.39920E

**Photo 37.** Open fracture, 8 cm-wide, affecting the paved road and the external wall of the S. Agostino cemetery.

Locality: S. Agostino



44.79937N 11.40217E

**Photo 38.** This ~200 m-long fracture between S. Carlo and S. Agostino locally showed extrusion of grey sand and up to 20 cm of vertical offset.



44.79921N 11.40200E

**Photo 39.** Close up of the fracture of photo 38.

Locality: S. Agostino



44.79821N 11.40039E

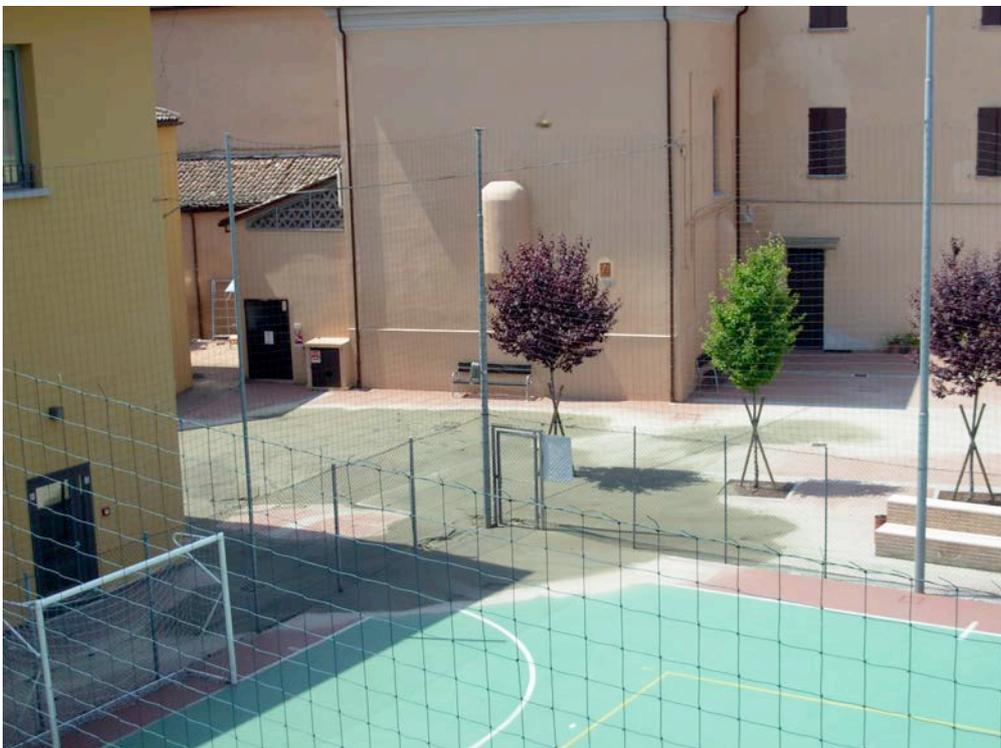
**Photo 40.** Zone of local subsidence and deformation nearby the northeastern tip of the fracture of photo 38.

Locality: S. Agostino



44.79226N 11.38753E

**Photo 41.** Effects of liquefaction close to via dei Pioppi.



44.79332N 11.38708E

**Photo 42.** Liquefaction of silty sand near via Piave.

Locality: S. Agostino



44.77725N 11.38159E

**Photo 43.** Fractures with liquefaction in the ploughed fields 1.5 km south of S. Agostino.



44.79374N 11.38804E

**Photo 44.** Widespread effects of liquefaction in the soccer field of the village.

Locality: S. Agostino



44.77554N 11.38090E

**Photo 45.** Sinkhole in via Bisana.

Locality: S. Agostino



44.79381N 11.38750E

**Photo 46.** Detail of aligned multiple sand blows in the soccer field of S. Agostino.

Locality: S. Carlo



44.80449N 11.41933E

**Photo 47.** This aerial view shows the large volume of sand outflow at the base of a paleobank off the National Road 255.



44.80186N 11.40558E

**Photo 48.** Set of up to a few hundreds m-long fractures in the fields between the village and the cemetery. Only some of the fractures show extrusion of liquefied sand.

Locality: S. Carlo



44.80072N 11.40320E

**Photo 49.** Alignment of fractures between the village and the cemetery.



44.79834N 11.41225E

**Photo 50.** Liquefaction with massive extrusion of grey sand at the southern boundary of the village.

Locality: S. Carlo



44.80557N 11.41622E

**Photo 51.** Widespread fractures and fractures/liquefactions following paleochannel morphologies along the northeastern side of San Carlo.

Locality: S. Carlo



44.80637N 11.42103E

**Photo 52.** Sand blow 20 m-wide.



44.80301N 11.40865E

**Photo 53.** Detail of aligned multiple sand blows in Via Morelli, San Carlo.

Locality: S. Carlo



44.81118N 11.43233E

**Photo 54.** Fractures with extrusion of liquefied sand affecting ploughed fields between S. Carlo and Mirabello.



44.80206N 11.40569E

**Photo 55.** Panoramic view of the set of fractures and fractures/liquefactions between the village and the cemetery.

Locality: S. Carlo



44.80503N 11.41064E

**Photo 56.** Fracture with liquefaction of silty sand in via Rossini, S. Carlo.



44.80641N 11.41519

**Photo 57.** Detail of a 10 cm-wide open fracture with ~15 cm of vertical separation.

Locality: S. Carlo



44.83641N 11.41482E

**Photo 58.** Fracture nearby via Rossini showing some extrusion of liquefied sand.

Locality: S. Carlo



44.80455N 11.41810

**Photo 59.** Sand blows off the National Road 255. The thickness of the liquefied material is ~15 cm at this location.

Locality: S. Carlo



44.80637N 11.41472E

**Photo 60.** The main fracture in via Rossini locally shows ~20 cm of vertical offset.



44.80611N 11.41346E

**Photo 61.** Fracture with liquefaction in via Rossini.



44.80382N 11.41650E

**Photo 62.** Open fracture, 30 m-long, with massive ejection of dark grey sand in S. Carlo (photo Lino Ghidoni).



44.80565N 11.41590E

**Photo 63.** Area of fractures with massive liquefaction in the fields between via Rossini and the National Road 255 (photo Lino Ghidoni).

Locality: S. Carlo



44.80344N 11.41679E

**Photo 64.** Linear fracture with liquefaction (photo Lino Ghidoni).



44.80364N 11.41670E

**Photo 65.** Detail of a ~10 cm-wide open fracture. In this case the fracture is filled with grey sand that did not reach the surface (photo Lino Ghidoni).

Locality: S. Carlo



44.80381N 11.41661E

**Photo 66.** Fracture with massive liquefaction of hazel sand.

Locality: S. Carlo



44.80597N 11.41623E

**Photo 67.** In this ~20 cm-wide open fracture it is possible to observe several cm-wide, grey sand-filled cracks that represent the path to the surface of the liquefied material.



44.80388N 11.41687E

**Photo 68.** Light grey sand extruded from this 30 meters long fracture located East of the village.

Locality: S. Carlo



44.80556N 11.41586E

**Photo 69.** Fracture with few centimeters of vertical separation and small ejection of sand.



44.80458N 11.41810E

**Photo 70.** Vents aligned to form coalescent, up to 20 cm-thick sand volcanoes.

Locality: S. Carlo



44.80268N 11.40701E

**Photo 71.** Fracture with liquefaction in a backyard near the National Road 255.

Locality: S. Carlo



44.80462N 11.40907E

**Photo 72.** Extensive liquefaction affecting the basement of the church in S. Carlo.

Locality: S. Carlo



44.79859N 11.40301E

**Photo 73.** Liquefied sand filled this water well and poured out to cover a ~500 m<sup>2</sup> circular area.



44.79920N 11.40365E

**Photo 74.** The warehouse of a pottery sale in S. Carlo was covered by a ~15 cm-thick layer of liquefied sands and silts.

Locality: S. Carlo



44.79921N 11.40200E

**Photo 75.** Fenced field completely covered by dark grey sand southwest of the village.



44.80384N 11.41695E

**Photo 76.** Close up of sand blows (photo Lino Ghidoni).

Locality: S. Carlo



44.80385N 11.41740E

**Photo 77.** Close up of sand blows (photo Lino Ghidoni).



40.80388N 11.41687E

**Photo 78.** Small sinkhole within an area of liquefaction.

Locality: S. Carlo



44.80360N 11.40881E

**Photo 79.** View of via Risorgimento in S. Carlo soon after the May 20 mainshock (photo Lino Ghidoni).

Locality: S. Carlo



44.80462N 11.40907E

**Photo 80.** The basement of the church in S. Carlo uplifted of up to 70 centimeters.



44.80616N 11.41472

**Photo 81.** Liquefaction caused the rotation of this balcony.

Locality: S. Carlo



44.80412N 11.40830E

**Photo 82.** Uplift and rotation of the edge of a sidewalk.

Locality: S. Felice



44.83529N 11.14331E

**Photo 83.** Aerial view of the extensive liquefaction occurred in the stadium of the village.



44.83550N 11.14309E

**Photo 84.** Detail of the liquefaction in the soccer field.

Locality: S. Felice



44.83571N 11.14359E

**Photo 85.** Vents locally aligned to form coalescent, up to 20-30 cm-thick sand volcanoes.

Locality: S. Felice



44.83567N 11.14311E

**Photo 86.** The sand extruded from the vents is generally fine and mixed with silt.



44.83756N 11.14312E

**Photo 87.** Area of liquefaction 20 m-wide nearby the primary school.

Locality: S. Felice



44.83538N 11.14271E

**Photo 88.** Manholes and wells were often a preferential way of ejection of liquefied material.

Locality: S. Felice



44.83435N 11.14063E

**Photo 89.** A disused well near the railway station reactivated by the first mainshock with emission of clear water, and then reactivated again by the May 29 shock with emission of reddish water and gas bubbles.

Locality: S. Martino Spino



44.91839N 11.23726E

**Photo 90.** Liquefactions on both sides of an irrigation ditch.



44.92221N 11.22818E

**Photo 91.** Aerial view of liquefaction effects 1.5 km south of the village.

Locality: Scortichino



44.88918N 11.34389E

**Photo 92.** Widespread liquefaction in the ploughed fields NE of the village.



44.86940N 11.34160E

**Photo 93.** Fractures and diffuse extrusion of liquefied sands located 1.5 km ESE of Scortichino.

Locality: Scortichino



44.88825N 11.29282E

**Photo 94.** Fractures with liquefaction 3 km NW of the village.



44.89006N 11.28971E

**Photo 95.** Close up of the fracture at the centre of photo 94. A 15-20 cm-thickness of liquefied sand covered the cultivations.

Locality: Scortichino



44.85840N 11.34710E

**Photo 96.** Set of 30 m-long fractures with liquefaction between Scortichino and Casumaro.



44.88930N 11.30750E

**Photo 97.** N50°- and N175°-trending fractures with liquefaction 2 km NW of Scortichino.

Locality: Scortichino



44.88888N 11.28086E

**Photo 98.** Fractures with liquefaction, 30 m-long, between Scortichino and Forna.



44.88580N 11.30465E

**Photo 99.** Fractures with liquefaction near the County Road n. 45.

## Acknowledgements

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## References

- Emergeo Working Group (2012a). *Coseismic geological effects associated with the Emilia earthquake sequence of May-June 2012 (Northern Italy)*. In press on Natural Hazards and Earth Science Systems.
- Emergeo Working Group (2012b). *Technologies and new approaches used by the INGV EMERGEO Working Group for real time data sourcing and processing during the Emilia Romagna (Northern Italy) 2012 earthquake sequence*. *Annals of Geophysics*, 55, 4, 689-695, doi: 10.4401/ag-6117.

## Suggested Readings on earthquake-induced liquefactions

- Aydan, Ö., Kumsar, H., Toprak, S. & Barla, G., (2009). *Characteristics of 2009 L'Aquila earthquake with an emphasis on earthquake prediction and geotechnical damage*. *Journal of the School of Marine Sciences and Technology, Tokai University*, 7, 3, 23-51.
- De Martini, P.M., Cinti, F.R., Cucci, L., Smedile, A., Pinzi, S., Brunori, C.A., and Molisso, F., (2012). *Sand volcanoes induced by the April 6th 2009 Mw 6.3 L'Aquila earthquake: a case study from the Fossa area*. In press on *Italian Journal of Geosciences*.
- Galli, P., (2000). *New empirical relationships between magnitude and distance for liquefaction*. *Tectonophysics*, 324, 169-187.
- Monaco, P., Santucci de Magistris, F., Grasso, S., Marchetti, S., Maugeri, M., and Totani, G., (2011). *Analysis of the liquefaction phenomena in the village of Vittorito (L'Aquila)*. *Bull. Earthquake Eng.*, 9, 231261. doi 10.1007/s10518-010-9228-0.
- Obermeier, S.F., (1996). *Use of liquefaction-induced features for paleoseismic analysis An overview of how seismic liquefaction features can be distinguished from other features and how their regional distribution and properties of source sediment can be used to infer the location and strength of Holocene paleo-earthquakes*. *Engineering Geology*, 44, 1-76.

## Suggested Readings on the Emilia seismic sequence

Further information on the geological, geophysical and geochemical phenomena, and on the media communication related to the 2012 Emilia sequence are printed in the Special Issue "The Emilia (northern Italy) seismic sequence of May-June, 2012: preliminary data and results", *Annals of Geophysics*, 55, 4, 2012 (freely available on line at <http://www.annalsofgeophysics.eu/>).

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